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Image alignment based on invariant features for palmprint identification

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Abstract

Palmprint identification provides a new technique for personal authentication. Previous research on palmprint identification mainly focuses on feature extraction and representation (Pattern Recognition 33(4) (1999) 691). But a crucial issue, palmprint alignment, is not addressed. Palmprint alignment involves moving and rotating the palmprints to locate at their correct position with the same direction. By this alignment operation, a certain palmprint sub-area can be easily obtained so that the corresponding palmprint feature matching will be carried out satisfactorily. In order to align palmprints, two invariant features, outer boundary direction and end point of heart line, are introduced. The key point in this paper is to propose a new automatic invariant-feature-based palmprint alignment method, which is able to deal with various image distortions such as image rotation and shift. This method provides a foundation for further feature extraction and matching. The experimental results demonstrate the effectiveness and accuracy of the proposed method.

Keywords: Biometric computing; Palmprint alignment; Invariant feature extraction; Image segmentation; Palmprint verification

1. Introduction

Biometrics, which is concerned with the unique, reliable and stable personal physiological characteristics such as fingerprints, facial features, iris pattern, retina and hand geometry, or some aspects of behavior, such as speech and handwriting, is emerging as the most foolproof means of automated personal identification [1–4]. Research on fingerprint identification [5] and speech recognition [6] has drawn considerable attention over the last 25 years. Issues on face recognition [7] and iris-based verification [8] also have been extensively studied. However, little has been done on palmprint recognition though it could provide even more personal information than fingerprints [9]. It is quite natural for us to think of using palmprints to identify a person.

The palm is the inner surface of a hand between the wrist and the fingers. 'Palmprint' refers to the various lines on a palm (see Fig. 1). Generally,

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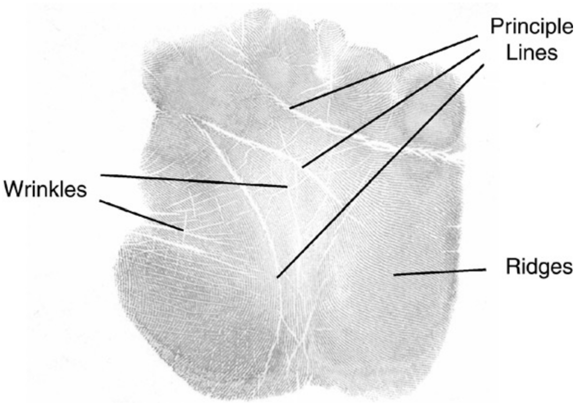


Fig. 1. Layout of palmprint image with principle lines, wrinkles and ridges.

lines on a palmprint fall into three categories: principle lines, wrinkles and ridges. The process of palmprint-based identification is similar to fingerprint identification: First, a palmprint is captured to obtain a digital image; then features on the image are extracted to match others in the database; and a decision is finally given according to a given matching score. Before feature extractions, all palmprints should be aligned under a right angle coordinate system.

Image alignment (also known as registration or positioning) refers to establishing a common frame of reference for a set of images: it has been widely investigated in various contexts [10]. A framework for aligning images without explicit feature correspondences was proposed in [11]. Two contour-based methods, which use region boundaries and other strong edges as matching primitives, were also presented in [12]. Refs. [13,14] developed sequential transforms to align two images. However, most proposed methods are focused on applications in multisensor imaging area and aim at solving problems such as how to align one object captured from more than one sensor. Usually objects in different images have similar contour shapes. For palmprint identification, the problem is somewhat different because palmprints not only have different qualities, but also different contour shapes. So it seems that existing alignment approaches are not suitable to solve our problem. As a result, a sound and reasonable palmprint coordinate system should be defined and an effective palmprint alignment algorithm should be developed. Since the captured palmprints may have different locations with various directions, the first step of alignment will be to detect the invariant features on palmprints. Then, palmprints are rotated in the same direction and shifted into the correct location according to these invariant features.

The rest of this paper is organized as follows: Section 2 introduces the basic concepts and disciplines of palmprint identification and illustrates the importance of palmprint alignment in the whole process. The proposed palmprint alignment method is defined in Section 3 in detail. Section 4 summarizes our experimental results and Section 5 highlights the conclusions.

2. Palmprint identification

Two key points in palmprint identification are: (1) to develop an effective algorithm that extracts useful features and (2) to correctly measure the similarity of two feature sets. Successful palmprint alignment can provide the foundation for both feature extraction and matching.

2.1. Palmprint features

There are different features existed on a palm. The main types can be defined as

- *Geometric features*: Width, length and area in accordance with a palm's shape.
- *Principle line feature*: Both the location and form of principle lines (such as heart line, head line and life line [9]) in a palmprint, which are very important physiological characteristics in identifying individuals because of their stability and uniqueness.
- *Texture feature*: Wrinkles on a palm, which are different from the principle lines in that they are thinner and more irregular.
- *Delta point feature*: The center of a delta-like region in a palmprint, which is normally located in the finger-root region and outside the palmprint region.

2.2. Feature extraction

Until now, line features are regarded as the most effective ones in palmprint identification. The following lists the main steps of the line feature extraction algorithm:

- Determine vertical line segments using the five vertical edge detectors given in [9].
- Adopt a post-processing algorithm to thin the detected line segments and remove short and non-vertical segments.
- Apply a similar procedure to detect the line segments at three other orientations—horizontal, 45° and −45°.
- Combine all of the line segments in four directions.
- Use the post-processing algorithm to eliminate the overlapping line segments.

2.3. Feature matching

In general, line features are described by end-points: $(X_1(i), Y_1(i)), (X_2(i), Y_2(i)), i = 1, \ldots, I$, where I is the number of line segments. Matching two palmprint line feature sets is to tell how many line segments are matched for the given palmprints. To decide whether two line segments are matched, the distances between the end points of two lines are calculated. If the distances are smaller than a threshold, T, the conclusion that two line segments are matched is drawn.

However, if two palmprints with different directions are located in different places, the comparison is meaningless. Therefore, palmprint alignment should be conducted before feature extraction and matching, so that the features are described under the same coordinate system.

3. Palmprint alignment

The objective of palmprint alignment is to put all the palmprints into the same location in their images. In our alignment method, there are four main steps performed by (1) defining a coordinate system, (2) determining the Y-axis, (3) determining the origin, and (4) rotating and shifting the original image.

3.1. Coordinate system definition

In fact, the outside boundary of a palmprint is usually clear and stable and can be described by a straight line. This means that the outside boundary can be defined as the Y-axis, and the intersect point between the outer boundary and principle line given in [9] as the origin. Therefore, such a two-dimensional right angle coordinate system can be setup, as shown in Fig. 2. Using this coordinate system, we may move all the palmprints to a certain position with the same direction in their images, therefore different palmprints can be compared with each other.

3.2. Y-axis determination

The Y-axis in the original image is denoted as

$$y = ax + b, \tag{1}$$

where

$$a = \bar{y} - b\bar{x} \quad \text{and} \quad b = \frac{l_{xy}}{l_{xx}}. \tag{2}$$

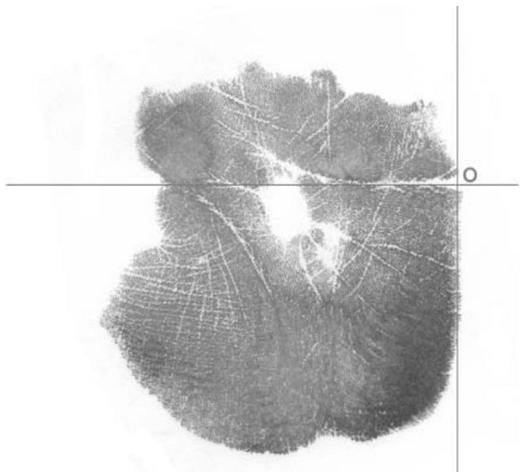


Fig. 2. A two-dimensional right angle palmprint coordinate system using two invariant features—outer boundary direction and end point of principle line.

Each variable is defined as follows:

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i, \quad \bar{y} = \frac{1}{n}\sum_{i=1}^{n} y_i, \tag{3}$$

$$l_{xx} = \sum_{i=1}^{n}(x_i - \bar{x})^2, \quad l_{xy} = \sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y}), \tag{4}$$

where $(x_i, y_i)(i = 1, \ldots, n)$ are points on the edge of palmprint outer boundary. Fig. 3 illustrates the Y-axis determined by the given method. Fig. 3(a) is the original image and Fig. 3(b) is the binary image of Fig. 3(a) on which boundary tracing is performed. Fig. 3(c) shows the outer boundary and a straight line, which describes its direction. Such a straight line thereafter is defined as the palmprint's Y-axis.

3.3. Origin determination

Origin determination involves the detection of the end points of principle lines on a palm, which is based on the original gray-level images. After the palmprint direction is defined, a projection is conducted to the Y-axis and the position of end point gets the largest energy. Such a process of finding origins is shown in Fig. 4. Note that Fig. 4(a) is the rotated palmprint image and the rectangle on upper right corner is used to extract a sub-image on which the origin of the palmprint coordinate system is determined. The sub-image extracted from Fig. 4(a) is enlarged in Fig. 4(b). As a horizontal projection map of Fig. 4(b), we can get the largest energy on the intersect between the heart line and the outer boundary in Fig. 4(c).

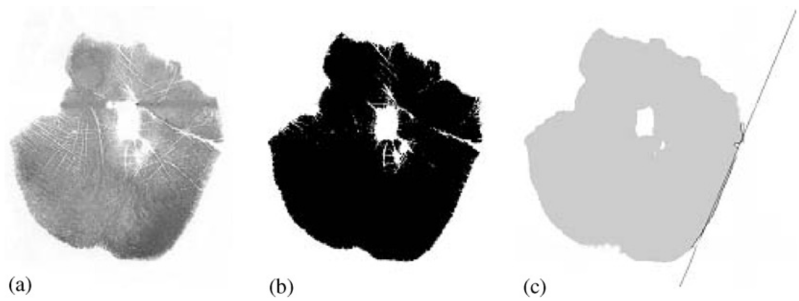


Fig. 3. Main process for Y-axis determination.

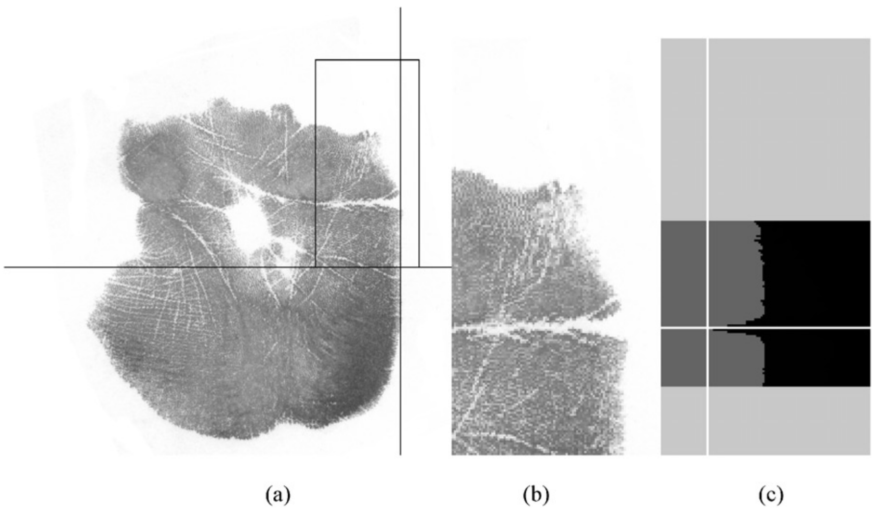


Fig. 4. Illustration of palmprint origin determination.

3.4. Image rotation and shifting

The image rotation and shifting formula is

$$x' = x\cos\theta + y\sin\theta + d_1, \quad (5)$$

$$y' = -x\sin\theta + y\cos\theta + d_2. \quad (6)$$

4. Experimental result

The palmprint images for the testing are based on the resolution of 125 dpi (432×432 pixels and 256 grayscales). A total of 200 images from 100 different individuals are stored in our palmprint image database. Experiments have been carried out to verify the performance of the proposed alignment method.

The testing is conducted step by step as follows:

(1) Before the alignment, the origins and directions of all palmprints are manually determined. In Fig. 5, L' is a vertical line on a fixed location; o' is a fixed point on L'; L is the palmprint's Y-axis and o is the origin determined manually. Also, A is defined as the angle between L and L' and D as the distance between o and o'. We calculate the A's and D's in all palmprints to obtain their average A (which we call 'direction deviation') and average D (which we call 'origin deviation') before automatic alignment.

(2) Then we apply the proposed automatic alignment method to all palmprint images to recalculate the direction deviation and origin deviation after the alignment.

(3) Last, we make a comparison of both direction deviation and origin deviation before and after the alignment. Table 1 shows that before the alignment the direction deviation is 7.87° and the origin deviation is around 27.87 pixels, but after the alignment the direction deviation becomes 2.07° and the origin deviation is only about 3.17 pixels.

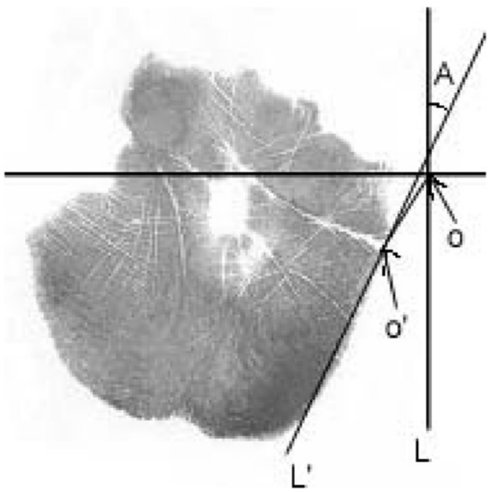


Fig. 5. Illustration of palmprint origin determination.

It is obvious that our alignment method can automatically put all the palmprints into their closed locations and directions, which are acceptable in palmprint identification. Some typical examples before and after the automatic alignment are shown in Fig. 6.

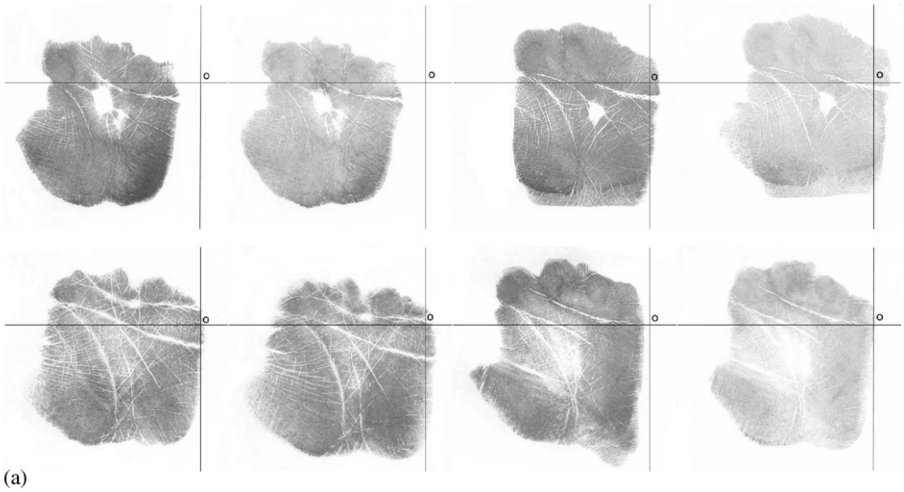
In addition, the palmprint identification approach described in Section 2 is performed. Based on 100 pairs of palmprint images in our database, the experiments show that 81 and 94 pairs can be correctly identified before and after using the alignment method, respectively.

5. Conclusion

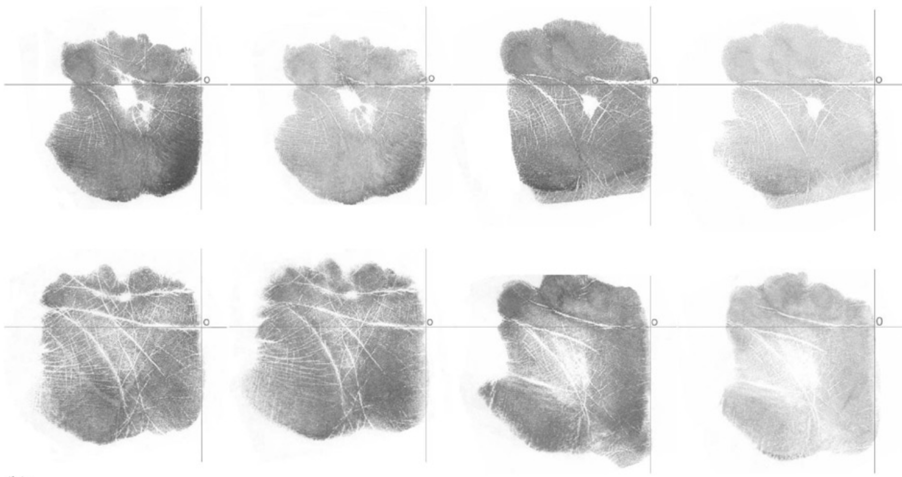
Palmprint is regarded as one of the most unique, reliable and stable personal characteristics; palmprint verification provides a powerful means to authenticate individuals for many security systems.

Table 1
Average distance comparison between palmprints before and after alignment

	Origin deviation (pixel)	Direction deviation (deg.)
Before alignment	27.87	7.87
After alignment	3.17	2.07



(a)



(b)

Fig. 6. Experimental results by a group of palmprints before and after alignment.

In palmprint identification, the first and crucial step is palmprint segmentation and distortion correction. This paper introduces a new palmprint alignment method for dealing with image rotation and shifting. Our method uses two invariant characteristics of a palmprint, i.e., key point and outer boundary, to automatically put all the palmprints into the closed location and direction. Based on our proposed alignment method, up to 13% correct identification rate can be improved. The experiments illustrate the effectiveness of the proposed method.

Acknowledgements

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References

[1] A. Jain, R. Bolle, S. Pankanti (Eds.), Biometrics: Personal Identification in Networked Society, Kluwer Academic Publishers, Dordrecht, 1999.

[2] D. Zhang, Automated Biometrics—Technologies and Systems, Kluwer Academic Publishers, Dordrecht, Hingham, MA, 2000.
[3] G. Lawton, Biometrics: a new era in security, Ind. Trends Comput. IEEE 31 (8) (1998) 16–19.
[4] B. Miller, Vital signs of identity, IEEE Spectrum 32 (2) (1994) 22–30.
[5] A. Jain, L. Hong, R. Bolle, On-line fingerprint verification, IEEE Trans. Pattern Anal. Mach. Intell. 19 (4) (1997) 302–313.
[6] J.P. Campbell, Speaker recognition: a tutorial, Special issue on automated biometrics, Proc. IEEE 85 (9) (1997) 1437–1463.
[7] J. Zhang, Y. Yan, M. Lades, Face recognition: eigenface, elastic matching, and neural nets, Special issue on automated biometrics, Proc. IEEE 85 (9) (1997) 1423–1436.
[8] R.P. Wildes, Iris recognition: an emerging biometric technology, Special issue on automated biometrics, Proc. IEEE 85 (9) (1997) 1348–1364.
[9] D. Zhang, W. Shu, Two novel characteristics in palmprint verification: datum point invariance and line feature matching, Pattern Recognition 33 (4) (1999) 691–702.
[10] L.G. Brown, A survey of image registration techniques, ACM Comput. Surveys 24 (4) (1992) 325–376.
[11] V. Govindu, C. Shekhar, Alignment using distribution of local geometric properties, IEEE Trans. Pattern Anal. Mach. Intell. 21 (10) (1999) 1031–1043.
[12] H. Li, B.S. Manjunath, S.K. Mitra, Acontour-based approach to multisensor image registration, IEEE Trans. Image Process. 4 (3) (1995) 320–334.
[13] H.S. Sawhney, R. Kumar, True multi-image alignment and its application to mosaicing and lens distortion correction, IEEE Trans. Pattern Anal. Mach. Intell. 21 (3) (1999) 235–243.
[14] C. Shekhar, V. Govindu, R. Chellappa, Multisensor image registration by feature consensus, Pattern Recognition 32 (1) (1999) 39–52.