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An Improved Principal Line-Based Alignment Refinement for Palm print Recognition

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ABSTRACT—Biometric identification based on palmprint has emerged as a powerful means for recognizing a person's identity, being used in commercial and forensic applications. Image alignment is an essential step for palmprint recognition. Most of the existing palmprint alignment algorithms make use of competitive valley detection algorithm to find some key points between fingers to establish the local coordinate system for region of interest (ROI) extraction. The ROI is subsequently used for feature extraction and matching. Currently key points based palmprint pre-processing methods provide coarse alignment only. The rotation and translation of extracted ROI image often causes the failure of genuine matching. In this paper, the palmprint verification accuracy improved by proposing an iterative closest point (ICP) algorithm to the palmprint principal lines. This compromises a more accurate alignment of palmprints by correcting efficiently the shifting, rotation and scaling variations introduced in data acquisition process. In Feature Extraction, Gabor filter is used for extracting orientation information from palmlines. The estimated parameters are then used to refine the alignment of palmprint features maps for more authentic palmprint matching. This method improves the accuracy of palmprint recognition efficiently and performs in real time environment.

KEYWORDS—Image alignment, Principal line extraction, ICP, palmprint recognition.

and stable biometric identifier because of non-genetically deterministic and complex patterns. As a physiological biometric characteristic, palmprint was first used for personal identification about ten years ago, and it has been extensively studied due to its merits such as distinctiveness, high accuracy,cost-effectiveness, user friendliness, and so on. Various palmprint recognition systems have been implemented and many palmprint recognition algorithms have been proposed [1].

According to the resolution of palmprint images, the palmprint recognition techniques can be classified as high-resolution (at least 400 dpi) and low-resolution (less than 150 dpi) approaches. High-resolution palmprint recognition is basically used in law enforcement applications[2], while low-resolution approach can be broadly used in civil and commercial applications. Most of the current researches focus on low-resolution palmprint recognition, which has two main branches. The first one is coding-based methods, such as PalmCode[3], CompetitiveCode (CompCode)[4], OrdinalCode (OrdCode)[5], Fusion Code[6], Robust Line Orientation Code (RLOC)[7], etc. These methods use a group of filters to enhance and extract the phase or directional features of the palmprint and then encode these features into binary codes for fast and accurate matching. These extract only the local features from ROI, which are more influential to discriminate the palmprints. The other branch is line-based methods. These methods use some line or edge detectors to explicitly extract the line information from the palmprint and then use them for matching. The representative methods include derivative of Gaussian-based line extraction method [9], Modified Finite Radon Transform (MFRAT) based line extraction method [6], etc. However, the extracted line features reflect the global transformation among palmprint images.

The palmprint verification process consists of data collection, region of interest (ROI) extraction, feature extraction, matching and decision making. ROI extraction is a very crucial step that prominently affects the following steps. It aligns the palmprint images and normalizes the region for feature extraction and matching.

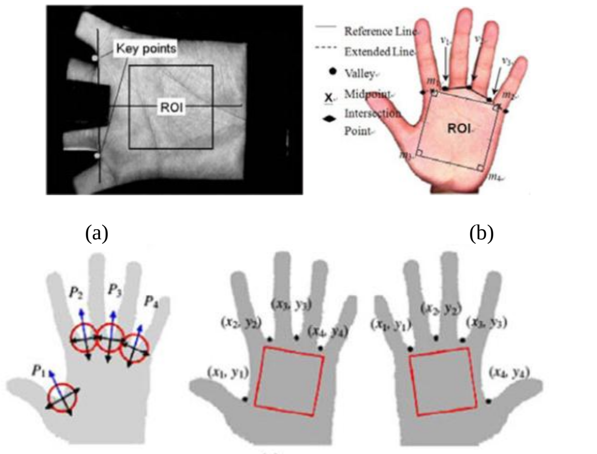
The rest of this paper is organized as follows. Section II describes the proposed ICP alignment method. Section III discusses about various ROI extraction methods. Section IV explained the principal line extraction procedure. Section V describes the ICP alignment, feature extraction method .Section VI presents the results, and discussion. Section VII gives the conclusion.

II.PROPOSED METHODOLOGY

The existing algorithms for palmprint recognition failed to correct rotation and translation variations, it cannot to give efficient alignment of palmprint images. The proposed methodology includes the ROI extraction from the palmprint image, which consists of the features such as principal lines, wrinkles, ridges, datum points, etc. Feature extraction is followed by iterative closest point alignment strategy which involves correct the shifting and rotation variations and even small variations in scaling between palmprint images. In the proposed algorithm, first we extracted principal lines from the ROI. When matching of two ROIs performed, we use realistic ICP to estimate the shifting *T*, rotation *R* and scaling *S* between them according to the extracted principal lines. Then use the evaluated parameters *T*, *R* and *S* to correct the ROIs in order to reduce the shifting, rotation and scale variations. The clarified alignment of ROIs can bring great betterment in the consequent palmprint verification. Then the ICP alignment is incorporate with the Competitive Coding Scheme further to improve the palmprint verification accuracy.

III.ROI EXTRACTION

Most of the existing methods can extract ROI according to some key points between fingers or in palm boundary .Fig.1(a) illustrates a two-key-points-based ROI extraction method used in [3]. It first searches two key points in the two gaps between the forefinger and the middle finger and another one is between the ring finger and the little finger. Then, a coordinate system can be established according to the two key points. Finally, the ROI can be extracted as a constant square in this coordinate system. Fig.1(b) shows a three-key-points-based ROI extraction method intended by Connie *et al* [10]. This method first applied to the salient-point detection algorithm for obtain three key points, i.e., v_1, v_2, and v_3. Then connected v_2 and v_1 ,v_2 and v_3 as two reference lines, after that extended the two reference lines to intersect with the boundary of the image which lead to find the two midpoints m_1 and m_2 ; finally, the ROI can be extracted by a geometrical square based coordinate system where four edges having equal length. Four-key-points-based ROI extraction method proposed by Michael*et al* [11] described in Fig.1(c).They first proposed a competitive valley detection algorithm to Find the four key points, i.e., P_1,P_2,P_3,and P_4,gave aruleto determine the right and left hands, and deal with the right and left hands, respectively. Similar ideas are followed in these methods. All of them need to locate some key points from the gaps between fingers which decide the position of ROI. However, the palm is not a rigid object and there is no sharp corner in it, which makes the accurate location of key points very hard. Thus, the ROI extraction methods can be used for a coarse alignment of palmprint images, and there can still be some shifting and rotation variations after ROI extraction. Although shifting the matching template or using one to many matching strategy [7] can deal with some small translation and rotation, they are time consuming and cannot really solve the rotation effects.



(a) (b) (c)

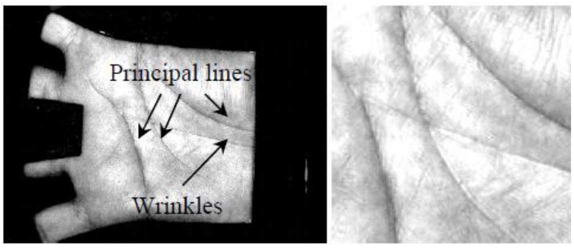
Fig. 1 Illustration of three typical ROI extraction methods by using (a) two key points (b) three key points and (c) four key points

Most of the recognition techniques assume that the palmprint images have been better aligned before feature extraction and matching but they are affected by residual translation and rotation variations. To more accurately and effectively correct the shifting, translation and rotation variations, and even small scale variations between palmprint images, we proposed a new alignment strategy by adapting iterative closest point (ICP) method to the palmprint principal lines. Principal lines are the most significant and stable features and thus they are very suitable for alignment refinement. The ICP algorithm is a classical method that originally designed for three dimensional (3D) shape registrations. It is also well suitable to align two dimensional (2D) curves. In the suggested algorithm, we first extracted the principal lines from ROI. When matching two ROIs, then we use ICP method to evaluate the shifting *T*, rotation *R* and scaling *S* between them according to the extracted principal lines. Then we use the appraised *T*, *R* and *S* to correct the ROIs so as to reduce the shifting, rotation and scale variations. The refined alignment of ROIs can bring in subsequent palmprint verification.

IV.PRINCIPAL LINE EXTRACTION

As shown in Fig. 2(a), Principal lines are the most reliable and important features in palmprint images. Fig. 2 (b) is the two-key-pointsbased ROI extraction method illustrated in Fig. 1(a). Although the ROI extraction reduces the shift and rotation of palmprint images, there is still much method to further improve the palmprint alignment for higher verification accuracy. We proposed a principal line based ICP method for alignment refinement. Clearly, the first step is to extract the principal lines.

Generally line detection methods extract many wrinkles and incorrect line features from the palmprint. This will introduce much complexity to the following ICP correction. Line based methods exploit the global structural features in similarity measuring.Plain and clear line features will make the ICP algorithm converge perfectly and rapidly.



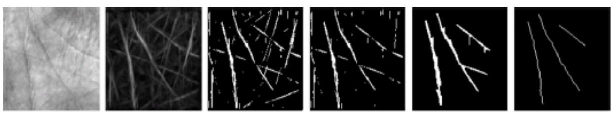
(a)Original palmprint sample (b) ROI

Fig 2.A Palmprint Image and the ROI of it.

Radon Transform (RT)based Huang's palmprint principal line extraction method was implemented and then a series of some post-processing operations is used to enhance the extraction results.

An MFRAT was proposed in[12] for principal line extraction:

$$r[L_k] = L_k*(g * H - H), \quad k = 1, 2,\dots ,N \qquad (1)$$



(a) (b) (c) (d) (e) (f)

Fig. 3.Extraction of principal lines. (a) Original ROI. (b) Energy image. (c) Binary image of (b) after thresholding. (d) Image after minor lines removal of (c). (e) Line map after morphological operation on (d). (f) Finally thinned principal lines.

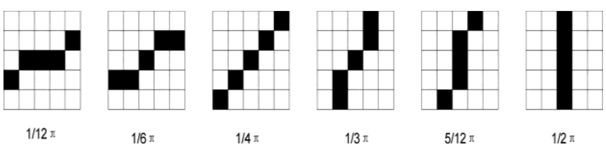


Fig. 4.Directional line structure templates used in the dilation operation

Where L_k denotes the square template of line structure, *H* represents an $m \times n$ image, *g* is a Gaussian filter,and*N* is the total number of templates. An energy image *E* and a direction image *D* are then calculated as follows.

$$E(i,j)=\max(|r_{i,j}[L_k]|),\ i=1,2,\dots,m,\ j=1,2,\dots,n \qquad (2)$$

$$D(i,j)=\arg\max(|r_{i,j}[L_k]|), \qquad (3)$$

$$i=1,2,\dots,m,\ j=1,2,\dots,n$$

where$|\cdot|$denotes the absolute value .Based on images *E* and *D* the principal lines are extracted. Using images *E* and *D* ,and with some post processing steps to remove small wrinkles and trivial structures ,finally a thinned principal line scan be obtained.Fig.3illustrates an example of line extraction process. Fig.3 (a)show original ROI. The associate denergy image *E* calculated by (2) and illustrated in Fig.3(b).After thresholding binarized image of energy image is calculated and shown in Fig.3(c). In this step,we preserve the top10% points with the highest energy in *E*.Fig.3(d) is obtained from(c) by removing the minor directional lines. In general ,the direction of principal lines in palmprint images is either within[0,π/2]or within[π/2,π]. Before extracting the principal lines, preprocessing on the obtained ROI image has to be performed to deal with illumination and broken principal lines followed by the binary image acquisition. The region properties of the binary image are calculated and then the area of the image is obtained for further removal of small trivial lines other than principal lines that may further complicate the linea lignmentre finement process.Wepartitionthepoints in(c)into two classes according to whether their directions are greater or less than π/2. Then ,the energy of each of the two classes is calculated as the summation of the energy of all points in that class .If the energy of class[0,π/2] is lower, then the minor direction of the map in(c)is defined as[0,π/2]or vice versa. Fig.3(e)shows the line map after some morphological operations on(d),including Dilation operations according to the direction image *D* to connect the broken lines. Several masks of different directions for dilation shown in Fig.4.Closeoperations perform by a 3x3 square mask to remove small holes on the lines, and Open operations by a circle mask to remove short lines and small blocks. Fig.3(f)illustrates the final line extraction result by thinning(e)and removing branches.

V.ALIGNMENT REFINEMENT FOR PALMPRINT RECOGNITION

Once the principal lines are extracted, they can be used for palmprint alignment refinement by using the ICP alogrithm. A crucial issue of palmprint alignment is reported along with various image distortions such as image rotation and shift. The principal lines acquired from the ROI images are then aligned using ICP (Iterative Closest Point) configuration. In this section, the principal line-based ICP alignment algorithm is presented to correct the translation and rotation between the ROI images and, then, present an efficient way to incorporate the alignment result into the competitive coding method for palmprint recognition.

A. Principal Line-Based Iterative Closest Point Alignment

McKay was proposed the ICP algorithm [4] for registration of 3-D shapes. The significant step of ICP algorithm is to estimate the translation parameters T, rotation parameter R, and scaling parameter S between two point sets by minimizing the distance between the correspondence points. Palmprint images captured in the image acquisition stage may have different distortions including rotation, shift, and translation and also subject to noise.

In palmprint recognition, there is slight scaling variation in the palmprint sample images because the distance between the palm and the camera is fixed[3].

Therefore, we ignore the scaling factor *S* in the following development .This canal so improve the speed of ICP alignment process. Fig.5 illustrates the proposed alignment process.

The conventional ICP method is preferred to examine the transformation parameters between two palmprint images. According to their principal lines and, then, use the estimated *T* and *R* to correct the possible rotation and translation variations between them. The principal lines are first extracted from the two ROI images using the method described in Section IV, and then, the parameters *T* and *R* are estimated by applying ICP method to the extracted principal lines.

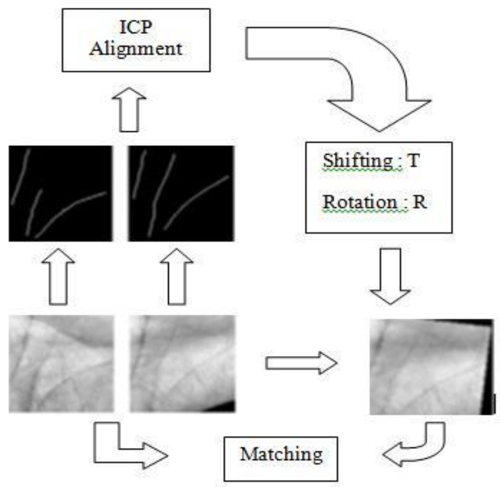


Fig. 5 Principal line-based ICP alignment refinement of two ROIs

TABLE I
ALGORITHM OF PRINCIPAL LINE BASED ICP ALIGNMENT

Input	Two principal line point sets: $P = \{\overrightarrow{p_i}\}$ and $Q = \{\overrightarrow{q_j}\}$, i = 1,2,…, *N, j =1,2,…, M* , suppose $N \leq M$.
Output	Translation and rotation parameters T and R.
Initialization	$T = \begin{bmatrix}0\\0\end{bmatrix}$ and $R = \begin{bmatrix}1 & 0\\0 & 1\end{bmatrix}$.
Loop	1) For every point $\overrightarrow{p_i}$ in P, find the closest point $\overrightarrow{q_i}$ in Q. $j \in \{1,2,\ldots M\}$ in Q to get the corresponding point pair $\{\overrightarrow{p_i}, \overrightarrow{q_i}\}$, $i = 1,2,\ldots,N$, where $\overrightarrow{q_i} = \overrightarrow{q_j}$. 2) Calculate the mean distance of corresponding pointpairs $\bar{E}_{PQ} = \frac{1}{N}\sum_{i=1}^{N} \lVert\overrightarrow{p_i} - \overrightarrow{q_i}'\rVert_2$ 3) Calculate translation T_c and rotation R_c using ICP method. 4) Update $P = R_c.\ P + Tc.\ T = Rc\ .\ T + T_c,\ R = R_c.\ R$
Stop Condition	$\bar{E}_{PQ}$ is less than a threshold E_r or the iterative number reaches the maximal number K.

The broken principal lines result inaccurate recognition as a result. We have to implement ICP correction. It is necessary to make sure that the extracted principal lines are continuous and well bond with the image to be compared or matched. Finally, ROI of one image can be corrected by *T* and *R* parameters to match with another one .The procedure of a above mentioned principal line-based ICP configuration refinement algorithm of palmprint ROI images is summarized in Table I.

B. Feature Extraction and Matching

The CompCode [4] is an effective algorithm for palmprint feature extraction and recognition. This scheme uses six Gabor filters with different orientations and estimates the direction of each point of a palmprint image ,then codes the estimated directions as a palmprint features for matching process .In this paper, the Competitive Code is used in joint with the enhanced ICP alignment refinement scheme for palmprint recognition. The following Gabor filter is used for orientation and directional feature extraction. In addition to that, the palm lines are negative; the negative real part of the 2D Gabor function is used.

$$\psi\,(x, y, \omega, \theta) = \frac{\omega}{\sqrt{2\pi}\kappa}\, e^{-(\omega^2/8\kappa^2)(4x^2+y^2)}\, e^{i\omega x'} - e^{\kappa^2/2} \quad (4)$$

Where x' = (x – x_o) cosθ + (y – y_o) sinθ and y'= -(x – x_o) sinθ + (y – y_o) cosθ;(x_o,y_o) is the center of the function, ω is the radial frequency in radians per unit length,θis the orientation of the Gabor functions in radians, and *k* is a coefficient defined by

$$k = \sqrt{2\ln 2}\left(\frac{2^{\delta}+1}{2^{\delta}-1}\right)(5)$$

Here δ is the half – amplitude bandwidth of the frequency response. When σ and δ are fixed, ω can be derived from $\omega = k/\sigma$.In general, it is enough to use six orientations in the Gabor-filter-based directional feature extraction. Because using more orientations cannot improve the accuracy considerably but increase the computational cost. Therefore, we make use of six orientations in the directional feature extraction and set different values of $\theta \epsilon \Theta = \{0, \pi/6, 2\pi/6, 3\pi/6, 4\pi/6, 5\pi/6\}$. After convolvingt he palmprint image with the six gabor filters of different orientations, at each position, the orientation which leads to the highest response is selected as the directional feature at that position.

$$D(x,y) = \arg\max_{\theta\epsilon\Theta}(\psi(x,y,\omega,\theta) * H) \quad (6)$$

Here *H* represents the input of palmprint ROI image. Where ∗denotes the convolution operator. After feature extraction, encoded each winning index into 3 bits for efficient palmprint representation. Kong *et al* presented an angular distance measure based on Boolean operators in the matching stage. The distance between two palmprints is then defined as the summation of the angular distance of all sampling points. With the bitwise feature representation and angular distance, the distance (dissimilarity) between two competitive codes can be efficiently computed by employing Boolean operators.

In verification (i.e., 1:1 matching) application, after computing the T and R parametersby the ICP algorithm, we can apply the correction to one of the two ROI images. Then, the Gabor-filtering based directional feature extraction, coding, and matching procedures can be performed for recognition. The complete verification time is less than 0.5 s, compared to other methods, which is fast enough for real-time applications. However, for identification (i.e., 1:N matching) application, correcting ROI images with the examined$T$ and R parameters and then performing feature extraction again is not a good tactic because Gabor-filter-based directional feature extraction spends much longer time than matching.

Actually, identification is doneby extraction of feature for each template sample. Then orientation feature maps are analyzed directly, instead of correcting the image first and then extracting features from the corrected image. For each point in the feature map extracted by the aforementioned Gabor filters,
we donate θ the orientation, and (x,y) the location.

$$Let\ R = \begin{bmatrix} \cos\theta_R & -\sin\theta_R \\ \sin\theta_R & \cos\theta_R \end{bmatrix} \qquad (7)$$

be the rotation matrix and $T = [t_x t_y]$ be the translation vector computed by ICP.The corrected orientation $\theta^{'}$ and location ($x^{'}$,$y^{'}$) are calculated as follows:

$$\theta^{'} = \theta + \theta_R \quad (8)$$

$$\begin{bmatrix} x^{'} \\ y^{'} \end{bmatrix} = R.\begin{bmatrix} x \\ y \end{bmatrix} + T \qquad (9)$$

The corrected direction θ' is quantized into one of the six orientations, $\theta \epsilon \Theta = \{0, \pi/6, 2\pi/6, 3\pi/6, 4\pi/6, 5\pi/6\}$,and then, we code them with integer values 0, 1, 2, 3, 4, and 5, respectively.Instinctively define the distance between parallel directions as 0, the distance between perpendicular directions as 3, the distance as 1 when the angle of the two directions is $\pi/6$ or $5\pi/6$, and the distance as 2 when the angle of the two directions is $2\pi/6$ or $4\pi/6$. Let $D_d$and $D_t$be the two coded feature maps of two palmprint ROI images; the matching score between them can be defined as

$$S_D = \frac{\sum_{i=1}^{n}\sum_{j=1}^{m} F(D_d(i,j), D_t(i,j))}{nm} \qquad (10)$$

where$F(\alpha,\beta) = \min(|\alpha-\beta|, 6-|\alpha-\beta|)$,(11)
$\alpha,\beta \in \{0,1,2,3,4,5\}$

Here, $F(\alpha, \beta)$ represents the angle distance between α and β whose value can be 0, 1, 2, or 3 as described previously. Finally, if the distance S_D is less than a threshold, the two palmprint images are recognized to be from the same person. In this method, we first present the principal line-based ICP alignment algorithm to correct the translation and rotation between the ROI images and, then, a proficient way to incorporate the alignment result into the competitive coding method for palmprint recognition is proposed

VI.Results And Discussion

In this method, the principal line and ICP-based palmprint alignment and recognition method is based on Hong Kong Polytechnic University (PolyU) open palmprint database[21] and this PolyUdatabasecontains7752samplescollected from386different palms. Thus extracting the principal lines and performing the ICP alignment, feature extraction, and matching on those ROI images has been done.

To evaluate the verification accuracy of the proposed method, each palmprint image is matched with al the other palmprint images in the database .A successful matching is called intraclass matching or genuine if the two sample are from the same palm. Otherwise,the unsuccessful matching is called interclass matching or impostor. The matching accuracy is highly achieved in the recognition process .The proposed principal line and ICP based palmprint alignment is used in joint with Competitive Coding. Table II lists the equal error rate(EER),feature extraction time, and average matching time of the proposed method. Here the feature extraction process includes ROI extraction, principal line extraction, orientation feature extraction, and coding, while the matching process includes ICP alignment refinement and feature map matching.

TABLE II
EER Feature Extraction Time And Average Matching Time By Different Methods On Polyudatabase

Methods	**EER (%)**	**Feature Extraction Time**	**Matching Time**
Proposed ICP+CompCode	0.0201	255ms	0.62ms
CompCode	0.0389	97ms	0.11ms

Especially, the proposedICP+CompCodemethodachievesabout48.2%improvement over the original Comp Code method, and it has the highest accuracy in various codings chemes.

TABLE III
Matching Accuracy

Database	**Accuracy**
400 images	96 %
1000 images	84 %

Even though the speed of feature extraction and matching of the proposed methods is slower than the original methods because of the additional cost of ICP alignment, it is still fast enough for real-time implementation.

Therecognitionwasfirstperformedfor40subjects consistingof4 00imagesandamatchingaccuracyof96% wasachieved.Secondly,thematchingwasdonefor1000 imagesof1 0 0 subjects.Thematchingaccuracy of 84% inferred in the TableIII.

VII.CONCLUSION

The proposed novel alignment refinement strategy for palmprint recognition applied the ICP method to palmprint principal lines. For the two palmprint images to be aligned ,the principal lines were first extracted ,and then, the ICP algorithm was used to align the two line datasets .The proposed method can effectively reduce the translation and rotation variations in palmprint images, which are inevitably introduced in the palmprint data acquisition process .In couple with some existing palmprint feature extraction and matching method, such as CompCode. It can achieve much higher palmprint recognition accuracy .The results showed that the recognition accuracy of ICP method is higher when compared with Competitive Coding scheme. The proposed method is very effectual for correct in the rotation variations in palmprint images, which is one of the hardest problems to othe algorithms. Finally, the proposed method is very fast, and it can be implemented in realtime for verification, as well as identification of mediums iz database.

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