A Novel Method for Locating Region-Of-Interest in Palmprint Recognition Systems

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Abstract— **Palmprint recognition systems consist of four parts: image acquisition device, preprocessing, feature extraction, and matching (classification). The results of recognition systems are highly dependent on each of these parts. The second part locates the region of interest (ROI) in palmprint images. The methods that have been used for preprocessing affected the system results and speed. Also, they have specified the type of palmprint capturing device. However, to the best of our knowledge, a few researchers have concentrated on locating the ROI in the palmprint and the consequences of the applied methods in system results and speed. Here, we have proposed a novel method based on morphological operation for ROI extraction in palmprint recognition systems. More importantly, since our method uses morphological operators, it is robust to translation. Moreover, using circular structuring elements spreading uniformly in all directions, our method is robust to rotation. Encouraging obtained results makes this method effective in verification and identification algorithms and increases the system speed.**

Keywords-component; Palmprint, Recognition, Preprocessing, Region Of Interest, ROI, Morphological Operators.

I. INTRODUCTION

Recognition systems are divided into three categories: possessions-based (e.g., ID cards), knowledge-based (e.g., passwords), and characteristics-based (e.g., fingerprints). However, the first and second approaches have some drawbacks. In the possessions-based approach, possessions can be easily stolen or lost. In the knowledge-based approach, the knowledge might be forgotten or guessed. Among these approaches, the characteristics-based known as biometrics is the most reliable and stable personal recognition system known yet. Also, these biometric characteristics are classified into three categories: physical (e.g., fingerprints), behavioral (e.g., signature), and chemical (e.g., volatile). Behavioral and chemical features vary in different conditions, such as stressed mood. Among physical biometrics, fingerprint is the most widely used feature, while the most reliable one is the iris. However, fingerprint recognition systems need high-resolution images (at least 400 dpi), and iris recognition systems use expensive capturing devices. Recently, palmprint recognition systems have drawn more attention among these biometric characteristics because of some significant advantages between others. Low-resolution imaging (less than 100 dpi) and low-cost capturing devices are two main advantages of this robust, stable, and unique biometric feature [1].

Palmprint recognition systems are divided into four parts: capturing device, preprocessing, feature extraction, and matching (classification). Capturing devices are separated into four types: CCD, digital scanners, digital cameras, and video cameras [2]. Various methods have been proposed for selecting the region of interest (ROI) in palmprint images. The tangent-based method calculates the tangent lines of two convex curves obtained from the index and middle fingers gap and ring and little fingers gap. Their intersections are the key points for establishing a coordinate system [1]. The bisector-based approach constructs a line using two points (the gravity center of a finger boundary and the midpoint of finger roots). The intersection of this line and the finger boundary is considered a key point [3]. The finger-based method uses the wavelet to find the middle fingertips and roots. One of the coordinate system axes is constructed by a line that passes through the midpoint of finger roots and fingertip point [4]. In the elliptical-based method, the hand orientation is determined by the orientation of the greatest ellipse that fits inside the palm and the origin is specified by the morphological erosion operator [5]. These approaches use a square region inside the palm for feature extraction. However, in another approach, elliptical half-rings are used as ROI after the key points are specified from three finger gaps [6]. Various methods have been used in feature extraction, such as 2D Gabor circular filter [1], 2D Gabor elliptical filter bank [7], Haar wavelet [6], and modified finite Radon transform [8] [9]. Furthermore, Hamming distance has been widely applied for matching in identification systems [1] [7] [8] [9].

Here, we have concentrated on selecting the best coordinate system and locating the region of interest in palmprint images. In the second section, the details of our method for ROI extraction are described. In the third section, the 2D Gabor circular filter is explained. Afterward, in the fourth section, the Hamming distance is represented. The feature extraction and matching algorithm have been selected based on the fact that the tangent-based method in [1] has been widely used in papers as the preprocessing approach [7] [8] [9]. Also, reference [1] is one of the most cited papers in the palmprint identification/verification research field. Hence, we chose these methods to compare and evaluate our method's performance.

II. PREPROCESSING

The preprocessing method affects the system speed, results, and capturing device limitations, such as constraints to keep the hand steady. Therefore, we have proposed our morphological-based preprocessing method to cover some of these drawbacks. This method uses the gravity center of the palm and two key points to establish a coordinate system. These key points are obtained from the index finger and little finger roots. The following are the main steps in locating the ROI:

a) Noise removal: A low threshold is applied to attain a binary image, $B(i,j)$, that contains the noise of the capturing device, as shown in Fig. 1b. Then, a morphological opening is applied with a low radius circular structuring element (see Fig. 1c). The morphological opening operation is defined as:

$$B \circ SE = \bigcup \{ SE_Z \mid SE_Z \subseteq B \}, \quad (1)$$

where $\bigcup\{.\}$ denotes the union of all the sets inside the brackets, and SE_z indicates the structuring element with its reference point shifted by z pixels. Afterward, small non-hand parts are removed by using the connected component algorithm, as in Fig. 1d. Finally, the obtained image, $Hand(i,j)$, is multiplied by the original hand image, $IGray(i,j)$, as follows:

$$HandGray = IGray \times Hand \quad (2)$$

This leads to an enhanced hand image (see Fig. 1e).

b) Smoothed binary image of hand: A low pass filter like a Gaussian smoothing filter is applied to the enhanced image, and a higher value than the first step is used as the threshold to obtain a binary image, $S(i,j)$, (see Fig. 1f).

c) Binary Fingers image: A morphological erosion operator with a circular structuring element is executed on the smoothed binary image to reach the central part of the palm as in Fig. 1g. The center of this eroded image is calculated as the palm gravity center. The morphological erosion is defined as:

$$S \Theta SE = \{ z \mid SE_z \subseteq S \}, \quad (3)$$

where SE_z denotes the structuring element with its reference point shifted by z pixels. Then, a morphological dilation is performed on the eroded image, $E(i,j)$, with a bigger circular structuring element. As E and SE were defined, the morphological dilation is described as:

$$E \oplus SE = \left\{ z \mid (\hat{SE}_Z \cap E) \subseteq E \right\}, \quad (4)$$

where $\hat{SE}$ is the reflection of SE about its origin. This will lead to a binary image without fingers, $D(i,j)$, (Fig. 1h). Afterward, the smoothed binary image of the hand and the dilated image are combined as follows:

$$Fingers = S \cap (\sim D), \quad (5)$$

where symbols $\cap$ and ($\sim$) represent AND & NOT operators, respectively. Then, the connected components are specified, and the four nearest connected components to the palm gravity center are selected as fingers binary image (see Fig. 1i).

d) Specifying index and little fingers: The gravity centers of each finger from the fingers' image are calculated. Then, utilizing the cosine theorem in a triangle, all possible angles containing two fingers' gravity center and palm center, obtained from the eroded image, are computed. As illustrated in Fig.1j, the index and little fingers construct the biggest angle with the palm center, and the rest are the middle and ring fingers. The cosine theorem in a triangle is defined as:

$$a^2 = b^2 + c^2 - 2bc.\cos\theta, \quad (6)$$

where a, b, and c are the triangle sides, and θ is the angle between the b and c sides. Therefore, the θ will be:

$$\theta = \cos^{-1}\left(\frac{b^2 + c^2 - a^2}{2bc} \right) \quad (7)$$

e) Specifying key points: The nearest pixels of the middle and ring fingers to the gravity center of the palm are used to find the roots of the index and little fingers located in the gaps between the index-middle fingers and ring-little fingers, respectively. The nearest pixel of the index finger from the obtained middle finger point is considered one of the key points, and the same method is used to specify the other key point. Therefore, the line that crosses through these points is one of our coordinate system axes. Also, their midpoint is considered the origin of the coordinate system, as shown in Fig. 1k. Note that in palmprint databases that contain thumb finger, middle finger roots should be considered with some changes in the last two steps' procedure.

f) Subimage extraction: A fixed-size square image located at a certain area of the palmprint image is cropped for feature extraction based on the established coordinate system (see Fig. 1l).

III. FEATURE EXTRACTION

We used the proposed method in [1] for feature extraction, where a 2D Gabor phase coding scheme has been used as the feature extraction technique. The general form of a 2D circular Gabor filter is defined as follows [1]:

$$G(x,y,\theta,u,\sigma) = \frac{1}{2\pi\sigma^2}\exp\left\{ -\frac{x^2+y^2}{2\sigma^2} \right\}\exp\left\{ 2\pi i\,(ux\cos\theta + uy\sin\theta) \right\}, \quad (8)$$

where u is the frequency of the sinusoidal wave, θ controls the direction of the function, and σ is the standard deviation of the Gaussian envelope. For making the system robust from brightness, a zero DC discrete Gabor filter is used, which has the following formula [1]:

$$\tilde{G}[s,y,\theta,u,\sigma] = G[x,y,\theta,u,\sigma] - \frac{\sum_{i=-n}^{n}\sum_{j=-n}^{n} G[i,j,\theta,u,\sigma]}{(2n+1)^2}, \quad (9)$$

where $(2n+1)^2$ is the filter size. Note that the imaginary part is zero DC because of odd symmetry. The performance of the Gabor filter depends on the Gabor parameters which are u, θ, and σ.

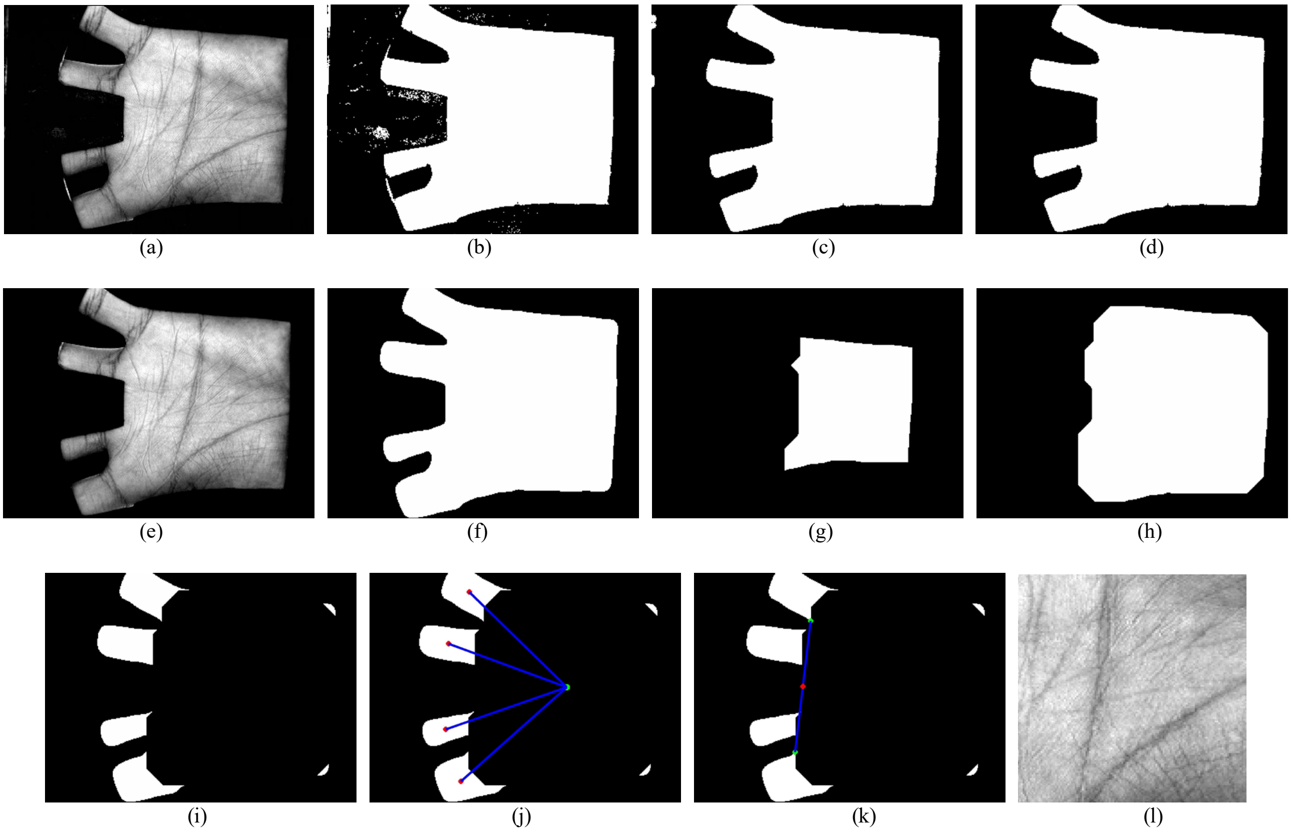


Figure 1. Main steps of proposed preprocessing method: (a) Original image (b) Obtained binary image with a low threshold (c) Results of opening operation (d) Hand area without noise (e) Hand image without noise (f) Smoothed binary image of hand (g) Eroded image (h) Dilated image (i) Combined images (j) Fingers and eroded image gravity centers and also all possible angles (k) Key points, one axes of constructed coordinate system and its origin (l) Extracted ROI.

IV. MATCHING

The similarity between two feature vectors is measured by normalized hamming distance, which has been proposed in [1] and used in [7] [8] [9]. The feature vectors consist of real and imaginary parts. Also, it includes a mask denoting the non-palmprint pixels by zero. Assume that P and Q are two feature vectors. The normalized hamming distance is defined as follows:

$$D=\frac{\sum_{i=1}^{N}\sum_{j=1}^{N}P_M(i,j)\cap Q_M(i,j)\cap\left(P_R(i,j)\otimes Q_R(i,j)+P_I(i,j)\otimes Q_I(i,j)\right)}{2\sum_{i=1}^{N}\sum_{j=1}^{N}P_M(i,j)\cap Q_M(i,j)}, \tag{10}$$

where P_R (Q_R), P_I (Q_I), and P_M (Q_M) are the real part, the imaginary part, and the mask of P (Q), respectively. The output of the XOR Boolean operator $\otimes$ is equal to zero if and only if the two bits $P_{R(I)}(i,j)$ and $Q_{R(I)}(i,j)$ are equal. The symbol $\cap$ represents the AND operator. The normalized hamming distance is between zero and one. Better matching results for the same palms are achieved through lower scores, and the best matching score belongs to zero. As a result of the imperfect preprocessing, one of the images has been transferred vertically and horizontally from -2 to 2 pixels and matched with the other image. Then, the minimum matching score has been considered as the final matching score for these two palms [1] [7] [8] [9].

V. EXPERIMENTAL RESULTS

A. Database

Here, we have used the PolyU Palmprint Database [10] to test the efficiency of our method and for better comparison with related works that have used this database. This database contains 7752 images corresponding to 386 different palms from 192 people, and each palm has around 20 samples. The average captured intervals of the same-person palm images are two months. In our experiment, three samples from 100 different palms have been considered the learning data, and the rest of the database has been dedicated to the testing data.

B. Identification

For efficiency comparison, the proposed method has been compared with [1], which has been implemented accurately. For both methods, ROI images with the size of 128×128 have been extracted for feature extraction. 900 dimensions feature vectors have been used for matching, and the best-obtained results of each method have been represented. The Receiver Operating Characteristic (ROC) curve depicts that our results are better than the tangent-based algorithm (Fig. 2). Table I shows the comparison of these two approaches by Equal Error Rate (EER) where False Acceptance Rate (FAR) equals False Rejection Rate (FRR) and the corresponding thresholds.

TABLE I. Comparison of EER and the corresponding threshold between Morphological based and Tangent based methods

Method	Threshold	EER
Tangent Based	0.3098	0.01645
Morphological Based (Original database)	0.3087	0.01645
Morphological Based (Rotated database)	0.3147	0.01821

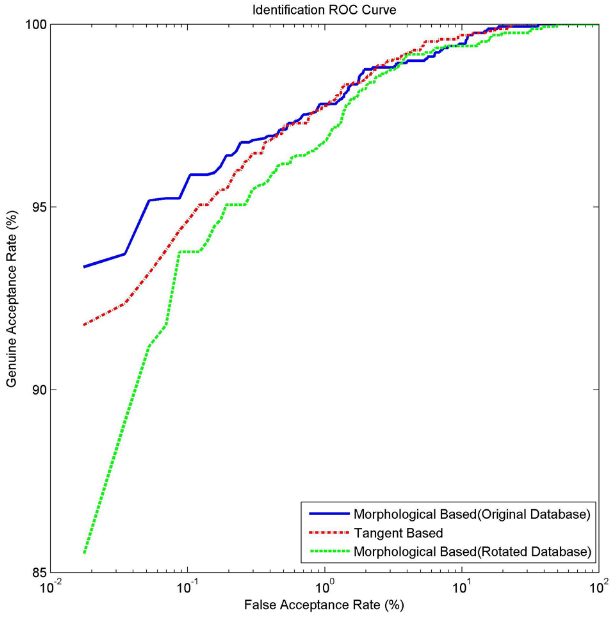


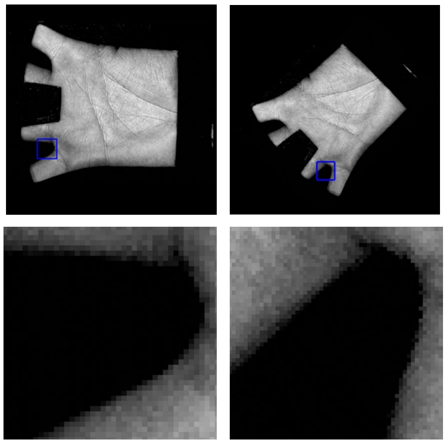
Figure 2. Receiver Operating Characteristic (ROI) Curves for Identification

C. *Rotation Robustness*

A new database has been constructed to evaluate the robustness of our proposed method against rotation. For this purpose, we assumed the worst condition, i.e., all images were rotated with random angles from zero to 360 degrees and rounded to two decimal digits. Fig. 2 and Table I show the results of the rotated database utilizing the morphological method versus both methods using the original database. Despite well-obtained results on the new database, a tiny downfall can be seen in the ROC curve and EER parameter. This reduction is a consequence of rotation distortion shown in Fig. 3. Edge distortion can be seen from this figure, which affects the location of key points in the rotated image. Therefore, if there were an original database that covers our assumption for rotation, the results could be as good as our genuine results for the PolyU palmprint original database.

D. *Speed*

As mentioned before, preprocessing affects the system speed. Therefore, we have considered speed improvement as one of our goals. Both algorithms were executed with an HP laptop PC, embedded 2.0 GHz Intel Core2Duo Processor (P7350), 4 GB RAM, and MATLAB software version 7.8. The runtime for the tangent-based method was 0.24 seconds, and for the morphological-based method was 0.17 seconds. It can be seen that our proposed method is considerably faster than the tangent-based method.



a b

Figure 3. Distortion that made by rotation (a) Original (b) rotated

VI. CONCLUSION

We proposed a novel preprocessing method for the palmprint recognition systems that utilizes the morphological operator with circular structuring elements on the binary images to specify the fingers' area, index finger, and little finger in the PolyU palmprint database. A coordinate system has been established using two key points from these fingers' roots. As a result of circular structuring elements usage, the proposed method is highly robust to rotation and translation. The obtained results show that we have presented a new preprocessing procedure that can achieve good performance in terms of speed and accuracy. At last, we concluded that our preprocessing method is suitable for online palmprint identification (verification) and comparable with other preprocessing methods.

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