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Combined Shape and Texture Information for Palmprint Biometrics

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Abstract: **Palmprint verification system is one of the most interesting biometrics approaches which offers significant advantages: it is non-intrusive, user-friendly, requires low spatial resolution imaging and has stable as well as unique features. In this paper we present our original methodology, in which texture feature extraction is merged with polygon-shape palm geometry features. Polygon shape detection is based on the detected characteristic hand geometry points. Such approach increased both detection and recognition efficiency of our palmprint biometrics system.**

I. Introduction and Motivation

Palmprint is a perfect biometric identifier because of its stability and uniqueness. The rich texture feature information of human palmprint places it as one of the powerful means in personal identification and authentication [1].
Palmprints are stable and show high accuracy in representing the identity of each individual [2]. Thus, they have been commonly used in law enforcement and forensic environments.
Palmprint feature extraction methods are mainly based on geometrical parameters, lines topology, texture features, Wavelets and Fourier transforms, PCA, Zernike Moments etc. [2][3][4][5][6][7][8][9]. Currently, much study is devoted to unsupervised, contactless palm images acquisition and pose invariance [10][11].
In general palmprint features can be divided into three different categories:

1. point features, which include minutiae features from ridges existing in the palm, and delta point features, from delta regions found in the finger-root region;

2. line features, which include the three relevant palmprint principal lines, due to flexing the hand and wrist in the palm, and other wrinkle lines and curves (thin and irregular);

3. texture features of the skin.

After detection, segmentation and normalization (size and orientation) steps, we calculate a set of palmprint texture features. Moreover, since we detect not only square-palm image, but also polygon-shape-palm images we calculate shape features of detected palm polygon.

In our biometrics system based on palmprint features we use the following features:

1. palmprint geometry features

2. the variance value calculated for each of the image blocks

3. Haar Wavelets

4. KLT/PCA (calculated on the variance and Haar wavelets feature vectors)

In Section II novel palmprint segmentation method is proposed. Developed palm shape descriptors enhancing our palmprint biometrics approach are presented in Section III. Texture feature extraction methods used in our system are presented in Section IV. Experimental results and conclusion are given thereafter.

II. Palmplrint segmentation and extraction

Captured palms images need to be pre-processed in order to perform successful palmprint extraction process. Firstly the skin color is detected. This procedure allows to reduce influence of unwanted elements (such as reflection) in the background on proper palmprint detection process. The skin detection is based on the following set of conditions: (R, G, B) is classified as skin if $R > 95$ and $G > 40$ and $B > 20$ and $max(R, G, B)min(R, G, B) > 15$ and $|R - G| > 15$ and $R > G$ and $R > B$.
After skin detection procedure the image is gently blurred to obtain softer extracted region's edges. Then the image is binarized to separate the palm from the background and to label palm as 1 and background as 0.
After preliminary processing the image is ready to apply the searching algorithm to find the most significant points of the palm. Sample result of palm significant points detection is presented in Figure 1. The P.0 point is the closest pixel of palm region to the top edge of the image. The next points marked as P.1, P.2, and P.3 are found by moving along palm edge, starting from the point P.0. The criteria deciding to mark these points significant was the local minimum of the analyzed pixels's distance to the bottom edge of the picture. The P.5, P.6, and P.7 points are found by detecting

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the first background pixel on line L3, L4, and L2 respectively. The line marked as L1 is simply created from points P.1 and P.4 and it is used as a reference to find the rest of lines (L2,L3,and L4). The line L2 and L3 are found by rotating the line L1 by 30 degrees and 60 degrees respectively using P.1 as a pivot point and the line L4 is found by rotating the line L1 by 60 degrees using P.4 as a pivot point.

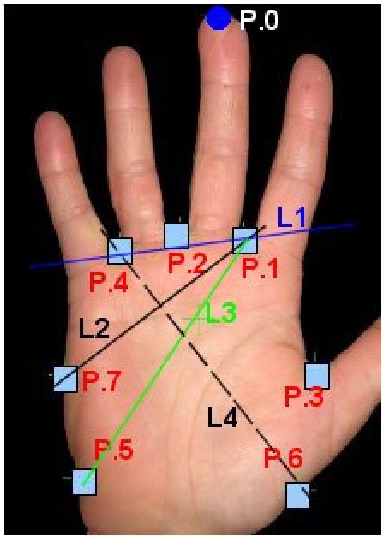

Figure. 1: Detection of palm fiducial points.

Detected significant points mark the area of palmprint (all point excluding P.0). To solve a problem of palm rotation, we implemented the procedure to find the angle of rotation and apply new rotation in the opposite direction. The result of rotation elimination procedure is shown in Figure 2.

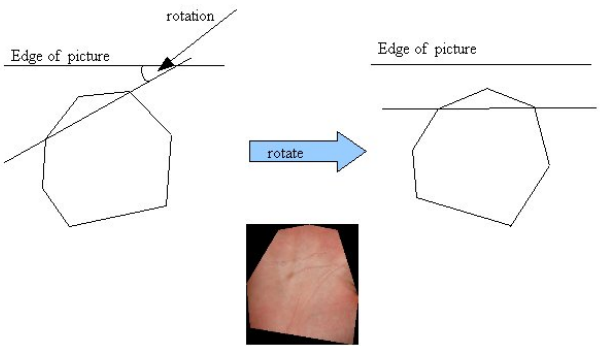

Figure. 2: Rotation elimination procedure

Such pre-processed image is the input of our palmprint extraction algorithm. Hereby we use our original methodology, in which square-shape palm detection is merged with polygon-shape palm detection. Marked points are used to extract the palmprint of the polygonal and rectangular shape. The results of our palmprint detection algorithm are presented in Figure 3. The rectangular palmprint extraction algorithm bases on information gained during the preliminary processing phase (palmprint rotation angle and position of point P.1 and P.4) and is presented in Figure 4.

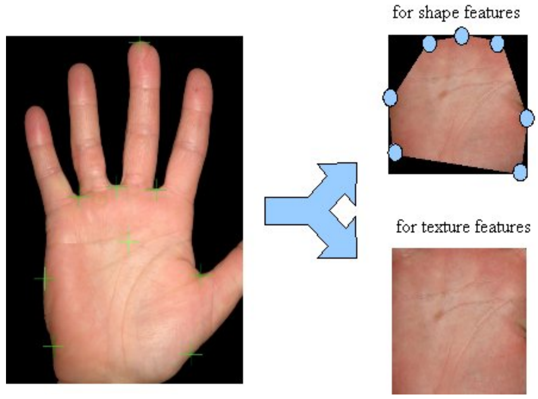

Figure. 3: Polygonal and rectangular palms.

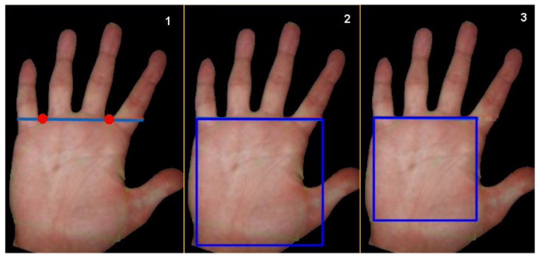

Figure. 4: Rectangular palmprint extraction approach.

III. Palmprint Shape Features

We developed several palm shape descriptors based on the detected characteristic hand geometry points. Each palmprint shape is encoded as a feature vector containing 15 elements. The calculated feature vector v is as follows:

$$v = (v_1, v_2, v_3, v_4, v_5, v_6, v_7, v_8, v_9, v_{10}, v_{11}, v_{12}, v_{13}, v_{14}, v_{15}) \quad (1)$$

where:

$$\begin{gathered} v_1 = p1.x; \quad v_2 = p2.x; \quad v_3 = p3.x; \quad v_4 = p4.x; \\ v_5 = p5.x; \quad v_6 = p6.x; \quad v_7 = p7.x; \quad v_8 = p1.y; \\ v_9 = p2.y; \quad v_{10} = p3.y; \quad v_{11} = p4.y; \quad v_{12} = p5.y; \\ v_{13} = p6.y; \quad v_{14} = p7.y; \quad v_{15} = ratio * 100 \end{gathered} \quad (2)$$

where:

$$ratio = \frac{d1}{d2} \quad (3)$$

and $p_1 \dots p_7$ are the detected significant points of the palmprint.
The points p are numerated according to the convention presented in Figure 5.
Although $ratio$ property is not directly connected with palmprint geometry it gives important information about palm rectangularity. If ratio is closer to 1.0 it has rather square shape. For thin and rectangular palms the ratio is closer to 0.5.

IV. Palmprint texture features

In this Section our palmprint texture feature extraction methods based on the variance value calculated for each of the image blocks, Haar Wavelets and PCA are presented.

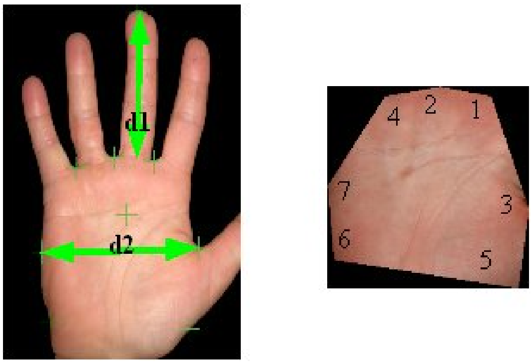

Figure. 5: Significant points of the palmprint geometry.

A. Variance value local features

Before palm texture feature extraction preprocessing is performed. In our case the histograms of extracted palmprints are stretched. Result of preprocessing based on histogram equalization is presented in Figure 6.
Such transformation is easy to perform by recalculating new brightness for each pixel by using equation 4:

$$C_{new} = \frac{255 \cdot (C_{old} - C_{min})}{C_{max} - C_{min}}, \quad (4)$$

where C_{new} is a new value of pixel brightness, C_{old} is the old value, C_{max} is the maximum brightness and C_{min} is the minimal brightness.

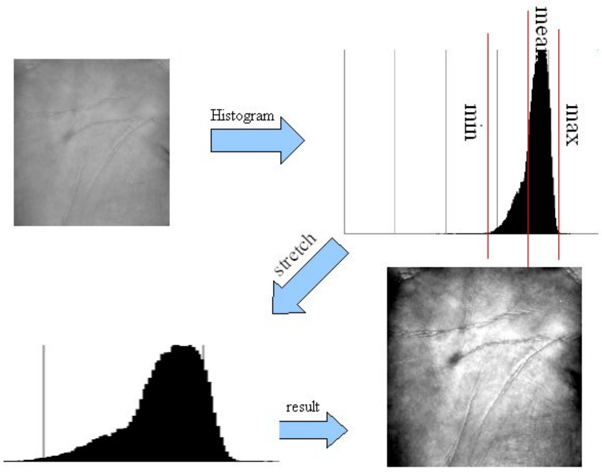

Figure. 6: Texture preprocessing based on histograms.

After presented preprocessing procedure the palmprint is divided into several blocks and the variation value is calculated in each of the blocks. This algorithm is graphically presented in Figure 7.
Variation values computed in each block are stored in a feature vector. Its dimension depends on the number of blocks.

B. Wavelet-based features

Hereby we propose to use wavelet distribution of image to calculate palmprint features and to achieve better features separation.
Our main goal is to separate high and low frequency image information to decide which kind of features (wrinkles or big spots) are more distinctive for human identification.

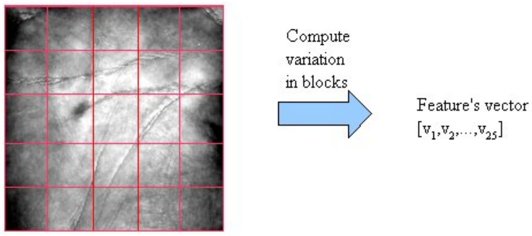

Figure. 7: Texture feature extraction.

We use the Mallat algorithm to perform the wavelet transformation of the original palm images. The result of wavelet transformation is shown in Figure 9.

Figure. 8: Output of palmprint wavelet distribution.

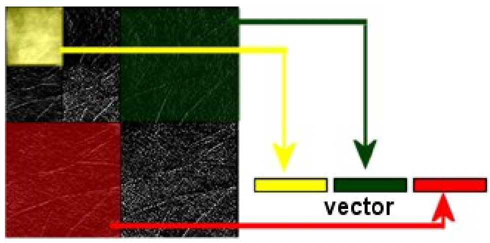

Figure. 9: Output of wavelet distribution with marked areas qualified to feature extraction algorithm.

In our case we used the Haar wavelet, which gives good results for edge detection.

C. Feature calculation based on KLT/PCA transform

Due to the fact that the feature vectors created on the basis of the methods presented in sections IV-A and IV-B may have large dimensionality we decided to use Karhunen-Loeve Transform (KLT).
The algorithm of applying KLT to the task of palmprint feature extraction is presented below:

1. Suppose we have a set of observations of M variables. We arrange that data as a set of N data vectors $x_1 \dots x_N$.

2. We write $x_1 \dots x_N$ as column vectors, each of M dimensionality.

3. Such column vectors are placed into a single matrix X of dimensions $M \times N$.

4. Mean value $u[m]$ along each dimension is calculated, such that:
$$u[m] = \frac{1}{N}\sum_{n=1}^{N} X[m,n]. \quad (5)$$

5. The standard deviation is calculated:
$$B = X - u \cdot h \quad (6)$$
$$nonumber h[n] = 1 \quad (7)$$
for $n = 1 \ldots N$.

6. Then we find the covariance matrix C, such that:
$$C = \frac{1}{N} B \cdot B^{r}. \quad (8)$$

7. The eigenvectors and eigenvalues of the covariance matrix are defined
$$V^{-1}CV = D \quad (9)$$
where D is the diagonal matrix of eigenvalues of C.

8. Columns of the eigenvector matrix V and eigenvalue matrix D are sorted in the decreasing eigenvalues order.

9. Cumulative energy g is calculated:
$$g[m] = \sum_{q=1}^{m} D[p,q] \quad (10)$$
for $p = q$ and $m = 1 \ldots M$.

10. We use the vector g to choose an appropriate value for L (new dimension of observation vectors). We use the following criteria: $g[m = L] \geq 0.9 \cdot g$. Then the rows length of eigenvector's matrix is trounced: $W[p,q] = v[p,q]$ for $p = 1 \ldots M$ $q = 1 \ldots L$.

11. We create $M \times 1$ empirical standard deviation vector s from the square root of each element along the main diagonal of the covariance matrix C
$$s = s[m] = \sqrt{C[p,q]} \quad (11)$$
for $p = q = m = 1 \ldots M$.

12. The Z matrix of the data is projected into the new basis:
$$Y = W^{T} \cdot Z = KLT\{X\}. \quad (12)$$

V. Experiments

A. Image acquisition

To test our system we created our own image database. To capture palms a special tripod was made. Its shape and proportion are supposed to minimize errors caused by camera movements and rotation. The created tripod is shown in Figure 10.

Our palmprint image database contains 252 pictures (three pictures for each of 84 individuals). These pictures were taken from different subjects in different age (from 20 to 55 yo.).

Figure. 10: Picture of the designed tripod.

B. Experimental scenario and system parameters

In our experiments we tested all the captured images from our database. We took 20% of dataset for impostors (16 individuals). All the other images were divided into genuine set (23 individuals) and training set (45 individuals). All the experiments were performed on our own application written in Java environment.

In our experiments we calculated standard biometrics recognition parameters, namely False Rejection Rate (FRR) and False Acceptance Rate (FAR).

Number of blocks	Parameters	Texture	Texture +Haar wavelet trasform	PCA+ Texture	PCA+Texture+Haar wavelet transform
4x4	FRR	0,051	0,121	0,052	0,155
	FAR	0,039	0,117	0,058	0,117
	Vector length	16	36	13	15
9x9	FRR	0,017	0,086	0,017	0,068
	FAR	0,019	0,078	0,000	0,078
	Vector length	81	178	44	51
11x11	FRR	0,017	0,051	0,017	0,051
	FAR	0,019	0,058	0,019	0,058
	Vector length	121	267	56	64

Figure. 11: Results of our experiments for Texture, Haar Wavelets and PCA methods **without** palmprint shape and geometry information.

Number of blocks	Parameters	Texture	Texture +Haar wavelet trasform	PCA+ Texture	PCA+Texture+Haar wavelet transform
4x4	FRR	0,051	0,086	0,052	0,155
	FAR	0,039	0,078	0,058	0,117
	Vector length	31	51	13	15
9x9	FRR	0,017	0,068	0,017	0,06
	FAR	0,019	0,058	0,000	0,07
	Vector length	96	193	44	51
11x11	FRR	0,017	0,051	0,017	0,051
	FAR	0,019	0,039	0,019	0,058
	Vector length	136	282	56	64

Figure. 12: Results of our experiments for Texture, Haar Wavelets and PCA methods **with** palmprint shape and geometry information.

FAR is a measure of the likelihood that the accessed system will wrongly accept an access attempt; that is, will allow the access attempt from an unauthorized user. For many systems, the threshold can be adjusted to ensure that virtually no impostors will be accepted. Unfortunately, this often means that an unreasonably high number of authorized users will be rejected, which can be measured by FRR (the rate that a given system will falsely reject an authorized user).

Both rates, FAR and FRR should be as low as possible for the biometric system to work effectively.

C. Results and evaluation of the palm shape features

In our experiments we wanted to evaluate our methods and discover if shape vector combined with texture vector increases system reliability. By comparing results presented in Figures 11 and 12 it can be proved that adding palmprint geometry information to the feature vectors increased system effectiveness for wavelet based method.
Furthermore, we noticed that applying the PCA to the calculated feature vectors allow to trounce their dimensionality without decreasing system reliability.
The results of our experiments are presented in Figures 11-12. In Figure 11 experiments for Texture, Haar Wavelets and PCA methods **without** palmprint shape and geometry information are shown. In Figure 12 results for Texture, Haar Wavelets and PCA methods **with** added information about palmprint shape and geometry are given.

VI. Future Work

So far, we have experimented with hand-palm biometric features in order to build multimodal biometrics system [**?**][14]. Our next goal is to enhance hand-palm information with knuckle-biometrics, to create 3-Type-feature biometric system.
We are aware of the strong trend to search for perspective and novel biometrics methods that can enable to improve identification rates and can overcome limitations of single biometrics systems.
Therefore, we believe that one-sensor (camera) multimodal hand-palm-knuckle biometrics based on shape-texture information is a promising direction of biometrics research.
Knuckles have not been considered as biometrics so far, apart from the work by Morales et. al [16].
We decided to examine if knuckles texture information may improve the effectiveness and reliability of our hand-palm system.
So far we have developed an algorithm to detect and segment knuckles from the hand image (Figure 13).

Figure. 13: Sample results of knuckles detection.

Now, we perform intense research to select best features for knuckles recognition. We mainly focus on texture features and Zernike moments features.
Another trend in a biometrics community is to use mobile-phones and handhelds camera images in biometrics systems and applications [17].
Therefore, now we create 3-Type (hand+palmprint+knuckles) image database acquired by mobile-phones. We plan to use such images in our further research in order to create mobile identification application.

VII. Conclusion

In the article our developments in palmprint segmentation and feature extraction for human identification in biometrics system are presented.
We showed that palmprint features may be considered as very promising biometrics modality which can be used in high-security human identification systems.
The major contributions of this paper are: a new approach to palmprint segmentation, calculation of polygon-shaped palmprint geometric features and texture feature extraction methods based on variance and Haar Wavelets. Moreover we applied KLT/PCA on the calculated feature vectors to reduce feature dimensionality.
We tested and evaluated the presented features and showed that experimental results proved the effectiveness of our method. We also proved that adding palmprint geometry (shape) information increased system efficiency.

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