An excellent system in palmprint recognition

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Abstract. According to Federal Bureau of Investigation (FBI) of United States, more than 30% of record of evidence in criminal cases are derived from the palmprint, instead of fingerprint. For that reason, the research on palmprint biometric continues to be developed. One of the effort to improve the system is to implement the right algorithms for all stages of biometric research. An excellent system in this paper consists of four powerful algorithms to identify and verify a person through palm of the hand particularly increasing the ROI display image with wavelet, the selection of Gabor parameters, the use of appropriate dimension reduction, and the choice of proper matching method. According to research findings, the method is considered reliable to estimate the error rate with value 0.273% and success level of verification 99.727%.

1. Introduction

Palmprint recognition is a human identification system that is carried out through palm of either right or left hand that works exactly the same as using the fingerprint. Since the size of the palms is much larger than the fingerprint, the researchers in the biometric field are interested in obtaining the important information easily, fast, inexpensive, and flexible in a way that is suitable to use at the airport of the hand in moving state by simply waving a palm of the hand. Despite the palmprint recognition is relatively new compared to face recognition or fingerprint, but the system has its own advantages compared to any other method particularly due to the process of data matching that can be carried out by using a low-resolution image [1]. On the other hand, the system has several weaknesses such as position of hands is different from one another and hand grips tend to shrink when data input is being acquired.

As an identification medium, the principal lines, branch lines, and wrinkles of the palms is employed to match feature information. This is possible because no human has the same line pattern, even for twins, where the outline of palms began to form in the embryo since week 13 and reached the perfect shape in week 18 [2]. In the medical field, the palm pattern recognition are used to diagnose genetic disorders such as down syndrome, Aarskog syndrome, Cohen syndrome, and fetal alcohol syndrome [3]. Researchers aim at obtaining the best algorithms that meet three main objectives, namely lower EER rate, higher verification, and faster processing time. Some researchers [5, 6, 28] classify the palmprint recognition in several stages, specifically data acquisition, pre-processing, dimension reduction, and the matching process. Besides, the general review declares that the best way to increase the performance of system is to improve the algorithms at each stage.

Badrinath in [6] states that the data images from the acquisition process do not have the same level of brightness so need to be filtered to enhance the image clarity, Kang [7] strongly recommends that the filtering is necessary to overcome the grayscale imperfections as well as
the shear angle. After all the images have the same contrast level, then it is necessary to normalize the image positions as a point reference. Sung in [8] employs the Gabor method to normalize the position and scale for all the data. Furthermore, Wang [9] also uses the Gabor method to strengthen the feature information that weakened due to the influence of the low local value. The impact of the method is the emergence of the huge data as much as multiplication between orientation variable and scale. To reduce the immense number, the researchers use the dimension reduction method - the algorithm that can decrease the number of feature information as much as possible without compromising the quality of the system. Generally, the method is divided into two groups according to the processed data namely linear and non-linear. Connie in [10] uses three types of dimension reduction to analyze the palmprint images: principal component analysis (PCA), fisher discriminant analysis (FDA) and independent component analysis (ICA). The dimension reduction method is also used for the 3D data such as the one conducted by Cui [11] using LDA method to obtain feature information of palms. Despite the low number for the input data, the dimension reduction method remains in use as practiced by Yang [12] by using an unsupervised discriminant projection (UDP). After the dimension reduction is completed, the process continued with the method of matching between the sample data and the overall data. According to Zheng [13] using different matching methods will gain distinct performance achievement in the biometric system. Therefore, Chen in [14] uses the hierarchical-based similarity or matching process to achieve a high degree of accuracy in the palmprint recognition. Furthermore, Jia in [15] combines two matching score of principal lines and locality preserving projections features.

Although the biometric algorithms are promising, but invention and innovation is still an open issue [16]. In order to gain the reliable performance system - detection with low level EER and high percentage verification - then the authors offer four algorithms, starting from using a wavelet filter in pre-processing, selecting the Gabor’s parameters of orientation and scale, setting value of the KPCA-based in the dimension reduction method, and using cosine technique for matching process, abbreviated as warkac (Wavelet, Gabor, KPCA, and Cosine). First, the wavelet filter, the proposed improvements combine the Wiener method [17] and the weighting method [18] accompanied by searching normalization form and providing histogram equalization. To enable Gabor method determine the amount of orientation and scale variable, the four values of entropy, variance, energy, and the dissimilarity from the researcher [9] are used and then the power value $\sqrt{2}$ from the researcher [19] is applied. To improve dimension reduction method the midpoint equation from the researcher [20] is developed then amplified by the Wiener filter [17] and weighting method [18] as in the wavelet process earlier. A significant reduction of feature information is carried out by using the SVD method by simply taking the diagonal value. Finally, the last proposed method is to use the cosine similarity from the researcher [21] with modification in normalized value and covariance function.

2. Proposed Methods

With the amount of input data continues to grow from different databases then homogeneous illumination for all the palmprint image is required. A filter method is a general system to get an image enhancement through a series of pixel operations for the purposes of the next application process. in the biometric field, some researchers used filter, there are the Gaussian smoothing by Deepika [22], the two-dimensional (2-D) masking by Doi [23], and the sine method by Jain [24]. Huang in [25] states that the complex wavelet filter can be used to improve the appearance of ROI image which will generate low error rate and high acceptance verification. To attain contrast uniformity, the authors modify the wavelet algorithms belonging to Erecelebi [17] and Kim [18]. In the field of image and signal processing, the wavelet is a mathematical expression that decomposes the signal into the varying waveform. The method can be used to reinforce certain values and reduce the other value in addition to eliminating noise. The system principle is
similar to the Fourier transformation process. The wavelet function can be defined by multiplying operation between a function \( f(t) \) and a mother wavelet \( \psi(t) \) as follows [18].

\[
\Psi(\kappa, \tau) = \int_{-\infty}^{\infty} f(t)\psi(\kappa, \tau)(t)dt, \quad (1)
\]

with \( \Psi(\kappa, \tau) \) is wavelet function, \( \kappa \) for scale and \( \tau \) for duration of time. In general, the Haar 2D DWT (discrete wavelet transform) is widely used in the image processing application by using the lowpass and highpass filters where each the filter produces two outputs. The output is known as a decomposition value which comprises four coefficients: approximation \( \xi_A \), detail in horizontal \( \xi_H \), detail in vertical \( \xi_V \), and detail in diagonal \( \xi_D \). Equation 1 can be rewritten as follows.

\[
\Psi(\kappa, \tau) = \frac{1}{\sqrt{2}} \begin{bmatrix} 2 & 0 \\ 0 & -2 \end{bmatrix} \psi(\kappa, \tau)(t) = [\xi_A, \xi_H, \xi_V, \xi_D] \quad (2)
\]

Authors offer algorithms for ROI image enhancement by developing an Ercelebi algorithm [17] which is multiplied by the Wiener filter \( (W) \) for all wavelet coefficients and then with the weighing value \( (\delta) \) from Kim algorithms [18] which has the value of \( \delta = 1.5 \) for the three coefficients detail. The coefficient approximation value is multiplied by a normalization \( (N) \) in order to avoid an anomalous value which can be expressed as follows.

\[
\mathcal{N} = I(x, y) - \frac{A}{B} - \min [I(x, y)] \times I(\hat{x}, \hat{y}), \quad (3)
\]

with image \( I \) in pixel of \( (x, y) \), \( A = \min [I(x, y)] \times I(\hat{x}, \hat{y}) \) and \( B = \max [I(x, y)] \times I(\hat{x}, \hat{y}) \), whereas the notation of \( (\hat{x}, \hat{y}) \) is pixel with matrix of ones. The final output of the wavelet process \( I_W(x, y) \) from equation 1 until 3 is obtained by using inverse wavelet that can be expressed as follows.

\[
I_W = I[\xi, \text{haar}], \xi \subseteq \begin{cases} 
\hat{\xi}_A = \xi_A W \wedge \mathcal{N} \\
\hat{\xi}_H = 1.5W\xi_H \\
\hat{\xi}_V = 1.5W\xi_V \\
\hat{\xi}_D = 1.5W\xi_D 
\end{cases} \quad (4)
\]

with \( \xi \) is the four value of decomposition wavelet method and \( \wedge \) is process histogram equalization.

After getting the uniformity of brightness the next process is finding a reference point for the beginning of the process. The Gabor method is a means to get the reference point that some researchers [8,9,22] have been using in the palmprint recognition.

The Gabor method is a linear filter that is commonly used for the edge detection process. The result is obtained through convolution operation between a sine wave and a Gaussian function. In addition to obtaining a reference point, another advantage of using the Gabor method is the ability to obtain important information in different time spans. Although other methods such as the windowed short-time Fourier transform method or WSTFT can do the same thing, but it is difficult to obtain the desired information for different periods of time, while in many applications, researchers need the important information of frequency at different duration time. To address weaknesses the WSTFT, the Gabor method is used. The working principle of Gabor filter is similar to the wavelet function mainly the Morlet-wavelet with the intention of reducing the impact of standard deviation values that accompany it within the time and frequency.
General expression of the Gabor function \( G(\phi, \kappa) \) is the multiplication between a sinusoidal wave \( (S) \) and an exponential Gaussian function \( (\Gamma) \) that can be expressed as follows [19],

\[
G(\phi, \kappa) = ST = \frac{|\xi_{\phi,\kappa}|^2}{\sigma^2}e^{-\frac{\xi_{\phi,\kappa}^2 + \kappa^2}{2\sigma^2}}e^{i(2\pi \xi + \delta)},
\]

with \( \phi \) for an orientation, \( \kappa \) for scale, \( S \) for frequency, \( \lambda \) for a wavelength, \( \sigma \) for a phase, and \( \delta \) for standard deviation. Of all the variables that exist in the Gabor function, only two important variables that are always considered, there are orientation and scale. From equation 5 with the image of wavelet process is as follows.

\[
I_G(x, y) = I_w(x, y)G(\phi, \kappa),
\]

where \( I_G(x, y) \) is image result of Gabor method, \( I_w(x, y) \) is wavelet image, and \( G(\phi, \kappa) \) is Gabor process. Figure 2. Shows the image selection 40 variations Gabor with the value of orientation is 8 and the scale is 5.

The authors modify Wang’s algorithms [9]: entropy, variance, energy, and dissimilarity and then replaced by variable of : \( f_{\max} = 0.25 \), \( n_i = \sqrt{2} \), \( \gamma = \sqrt{2} \), \( \Delta = \sqrt{2} \) successively. Next, the authors also adopt Perez’s algorithm [19] in scale series with the number of \( \sqrt{2} \). The scale with seven value in series order can be presented as \( \kappa = 2, 2\sqrt{2}, 4, 4\sqrt{2}, 8, 8\sqrt{2}, 16 \) meanwhile the eight series value in the orientation can be presented as \( \phi = 0, 1, 2, 3, 4, 5, 6, 7 \). If the \( \phi = 8 \) and \( \kappa = 7 \) then the image is increased into 56 of a new image. With the large number of images and ever growing input data, the dimension reduction method (\( \mathcal{DR} \)) is required to eliminate most of the insignificant information data.

The main purpose using the \( \mathcal{DR} \) method is to get the output system with the same result both in untouched and touched the input image data. The analogy is similar to image compression process as in the JPG image. Three advantages of using this \( \mathcal{DR} \) method are reduction of process time thus speeding up the computation time, reduction of complex data space thereby reducing the parameters used, and saving the observation of feature information hence making it more rigorous in supervision. There are two type data for the dimension reduction, linear and non-linear. Using linear type has drawback in process when involving big data and also hard to to represent the object data visually in chart. Researchers believe manifold method is the best solution to change linear form to non-linear either in the form of 2D or in 3D. Several authors [13, 24, 25] have been using the linear dimension reduction method for their research in the palmprint recognition. Generally, the linear type of the PCA is the most used in biometric. However, according to Jaswal [26] the PCA method has a drawback in recognition process when the data input continues to grow. Instead of using the method, the other researchers use the KPCA (kernel principle component analysis) method. A kernel is a technique that maps the distribution of data in multiple arrangements of axes (dimensional manifold).

The KPCA process is the development and expansion of the PCA method by using the kernel support. In order to map the data point of \( x_i \) in advance in the space \( \phi(x_i) \) of the feature information. According to Jaswal [26] to get a kernel can be obtained from multiplication matrix with its transpose that can be expressed as follows.

\[
\mathcal{K}(x_i, x_j) = \phi(x_i)^T\phi(x_j),
\]

with \( \mathcal{K}(x_i, x_j) \) for the KPCA process and \( T \) for transpose operation.

In equation (7), the value of \( \phi(x_i) \) is too big, thus solving this problem can be carried out by making a midpoint of centered features \( \tilde{\phi}(x_i) \). Then, Equation (7) can be changed in the following form.

\[
\mathcal{K}(x_i, x_j) = \tilde{\phi}(x_i)^T\tilde{\phi}(x_j)
\]
Translation and simplification Equation (8) can be defined in another form as follows.
\[ K_c = K - 2\ell K + \ell K\ell, \]  
with \( \ell \) is a \([N \times N]\) matrix with the value of 1/N for all elements. Varon [20] states that the determination of midpoint in Equation (8) is critical value in KPCA system. In this paper, authors novelty research is modifying Jaswal’s method [26] by adding several point value that can be defined as follows.
\[ K(x_i, x_j) = \left[ \hat{\phi}(x_i) \hat{\phi}(x_j) \right] \sqrt{2}, \]  
and also the new form of center kernel in Equation (9) is can be defined as a follows.
\[ K_c = K - \ell K - K\ell + \ell K\ell. \]  

Last process in dimension reduction is reducing the amount data of \( K \) significantly without sacrificing the important feature then the process should be resumed with the diagonal value of SVD (singular value decomposition).

After DR process is finish then the next step is matching method. Matching or similarity method is a technique of intentionally inserting some test images into the palmprint system to recognize it. Generally, to recognize how good or bad the system performance in biometric is by using indicator value of FAR and FRR. The false accepted rate is the ratio system to recognize the test images as part of a reference database. Whereas, in fact, it does not belong to the reference. The false rejection rate is the ratio system to recognize database, while in fact, they do not to the reference. Whereas in fact, it does belong to the reference. A critical point of intersection line between FAR and FRR known as a EER value. The error equal rate is the easy way how to look at the system performance. The smaller value of EER, means the better the system. According to Senoussaoui [21], the matching method for uncertain condition with forecast noise in big volume of data can be resolved by using a cosine method. In general, the cosine method can be expressed as follows.
\[ d(x, y) = \frac{x^T y}{|x| \cdot |y|}, \]  
with \( x = \left( \sum_{i=1}^{n} x_i^2 \right)^{1/2} \) and \( y = \left( \sum_{i=1}^{n} y_i^2 \right)^{1/2} \). In this paper, author propose to use a normalization \( [x_N, y_N] \) and covariance Cov value to anticipate the random changing that may occur in all value data then, the cosine method can be changed as follows.
\[ d(x, y) = \frac{x^T \cdot \text{Cov}(y)}{x_N \cdot y_N}. \]

Finally, this paper uses four curves for performance identification: ROC (receiver operating characteristic), CMC (cumulative match curve), EPC (expected performance curve), and DET (detection error trade-off), in addition to the table showing the value of the research results.

3. Results and Discussion
The study aims to determining the reliability of the system by using the PolyU image database of ROI palm hand. The number of ROI is 550 subjects with 10 data variations for each subjects, so total data input is 5500 images with the size of \([128 \times 128]\). Especially for the testing of dimension reduction methods, input research is added with database the Casia and the IITD-India with the number of 650 and 450. Each has a variety of images as much as 5 and 6. To
Table 1. Various methods of image enhancement filter to select the most reliable in palmprint recognition

| Filter      | Time  | EER   | Ver.  |
|-------------|-------|-------|-------|
| Original    | 0.8769| 0.00362| 99.636 |
| Wavelet     | 0.68244| 0.00272| 99.727 |
| Multiple    | 0.90415| 0.00274| 99.727 |
| Shock       | 0.71127| 0.00729| 99.273 |
| Skeleton    | 0.66315| 0.00835| 99.182 |
| Anisotropic | 0.69574| 0.00363| 99.636 |
| Histogram   | 0.72881| 0.00254| 99.727 |

show the reliability filter options, seven different method is used. This research employs PolyU database which the results is shown in Table 1.

The value in Table 1 involves the use of filters wavelet, multiple, shock, skeleton, anisotropic, and histogram equalization. It shows that the wavelet method has a value of 0.00272 which is the lowest EER value. The value is equivalent to 99.727% rate of success in verification. The wavelet filter method reliability can be proved with a curve of DET and CMC in Fig. 1 and 2.

![Figure 1. The DET curve in selection filter method](image-url)

After completing the filter process then continuing with the selection Gabor parameters, the results is shown in Table 2. The option parameters of $8 \times 7$ is the best choice compared others with the process time of 1.92639 seconds. In addition, the EER is only 5.233% and verification accuracy degree is 94.769%. Although in terms of process time, another selection of $8 \times 5$ is better with the value of 1.69758 seconds. To support the research with evidence, Fig. 3 presents ROC curve which clearly shows that with $\phi = 8$ and $\kappa = 7$ has an image display with the best performance.

After Gabor process is completed, dimension reduction method is started. However, this
Table 2. The results of examination of seven pairs of Gabor parameters for different of orientation and scale

| $\phi \times \kappa$ | Time  | EER   | Ver.  |
|---------------------|-------|-------|-------|
| 5 $\times$ 8        | 1.93044 | 0.40207 | 0.59846 |
| 8 $\times$ 7        | 1.92639 | 0.05233 | 0.94769 |
| 8 $\times$ 4        | 1.71137 | 0.35799 | 0.64231 |
| 8 $\times$ 5        | 1.69758 | 0.42606 | 0.57462 |
| 8 $\times$ 6        | 1.80697 | 0.31604 | 0.68385 |
| 5 $\times$ 8        | 1.77491 | 0.40207 | 0.59846 |
| 15 $\times$ 8       | 2.44745 | 0.29442 | 0.70538 |

The paper puts the matching process earlier than dimension reduction. The reason is to emphasize the importance of selecting dimension reduction appropriately. Table 3 shows the results of 7 different matching methods on palmprint. As seen from the Table, there are similarities in terms of the processing time of 2.5 seconds for all the methods. But in terms of EER value, the cosine algorithm is superior compared with another method with the value of 0.543%. That value is equivalent 99.455% in system verification. Evidence of cosine method superiority can be seen in the EPC curve in Fig. 4. In the curve, the green curve line represents cosine method that is displayed in the lowest position axis of error rate.

Finally, to find the best method in reduction dimension, four algorithms: KFA, KPCA, LDA, and PCA and three database: Casia, IITD-India, and PolyU are used in this research with the results displayed in Table 4 and curve in Figure 8.

The best EER value occurs in the database PolyU using KPCA method to the value of 0.00273 for the EER, 0.84399 seconds for processing time, and 99.727% for successful verification. With other databases, LDA method is sometimes better than KPCA, but LDA has drawback in processing time is longer than KPCA.
4. Conclusion
From a series of trials that have been conducted in order to obtain the optimum palmprint recognition system, the wavelet filter is a good option for image enhancement, the value of $[8 \times 7]$ is the best selection of the Gabor method, the use of KPCA is the superior for the dimension reduction, and the cosine algorithm is the right choice for similarity method. When all of these methods are combined, or we believe that warkac would be a powerful system for verification and identification of palmprint, which is proven by attainment of EER value $0.272\%$, processing time of $0.84399$ seconds, and success verification of $99.727\%$.

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Figure 4. View of the EPC curve showing the use of cosine similarity for the matching method has the best performance characteristics showing the smallest value of error rate with green curve line.

Table 4. The results of the research to find the reliability of the four method of dimension reduction in palmprint recognition

| Database | KFA | KPCA | LDA | PCA | KFA | KPCA | LDA | PCA |
|----------|-----|------|-----|-----|-----|------|-----|-----|
| Casia    | 2.24663 | 1.48114 | 5.89667 | 4.59728 | 1.38616 | 0.45817 | 2.99767 | 2.23623 |
| IITD     | 1.41342 | 0.84399 | 4.32426 | 3.04235 | 1.41342 | 0.84399 | 4.32426 | 3.04235 |

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