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EXCELLENT PERFORMANCE OF PALMPRINT RECOGNITION BY USING WAVELET FILTER

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Abstract. *The use of palmprint recognition as biometric system to identify person through their palms hand has been growing recently. The advantages of using this tool are its ability to recognize the important feature while the subject is moving by just waving to camera, and it can also work together with the other biometric types in fusion method. One procedure to improve the performance of the palmprint recognition is to enhance the appearance of input image by using wavelet method. In this paper, the four coefficients from wavelet decomposition were multiplied by Wiener filter and weighing method. Based on this research, the proposed method has a very promising system proven over the EER value generated.*
Keywords: Palmprint recognition, ROI image, EER rate, Curve performance, Wiener, Image enhancement, Weighing method

1. **Introduction.** Two functions of filter method in palmprint recognition are to improve or enhance the appearance of ROI image and to obtain the important feature. In general, the image processing filters are primarily used to conceal either the high frequency to get smoothing image or the low frequency to gain enhancing or detecting edges image. The filter also has additional function which is to enhance image display for various purposes as discussed in other studies. For example, researchers can use a filter to improve an appearance of palms images. Deepika et al. in [1] state that to obtain the expected features, it is necessary to firstly improve and enhance images of the palms ROI (region of interest) with the modified Legendre moments method. Cappelli et al. in [2] suggest that contextual filtering with a Gabor filter can gain the estimation of local orientation minutiae of palms. Moreover, researchers use a filter to extract information feature on palms image. Hennings-Yeomans et al. in [3] proposed a correlation filter method in each class of database that contains ROI of palms and then the result would be used to gain sharp peak in a score of an important feature. Zuo et al. in [4] used a steerable filter to retrieve an accurate orientation feature and then the results were used to process matching method. Evidently, the use of method from various filters still has some drawbacks. The Legendre moment had an insufficient native scale; thus in [1], the value of verification rate only reached 98%. Meanwhile, the contextual filter had disadvantage when operators cannot cover the corrupted areas; hence the EER rate (*error equal rate*) in [2] reached 0.01. The correlation filter in [3] was sensitive to noise; therefore, the addition of data would also increase the noise thus yielding the 0.2295 EER rate when used in 32 classes and

increased to reach 0.3831 when used in 128 classes. The steerable filter had a deficiency in its computation system, where the method had a long processing time and was also weak in identifying. It was proved by [4] that the EER rate was 0.412 with Casia database. Most researchers use enhanced palmprint images for verification and consider that the high image sharpness can still be improved. Zhang et al. in [16] found that the performance of palmprint recognition can be improved by using low sharpness images that is still within the range. In addition, the filter method can be used to improve the appearance of the histogram, so that the histogram bins have a more powerful capability discriminatory as has been done by El-Tarhouni et al. in [17]. Even Hong et al. in [18] used a series of different filters for texture coding procedure to obtain a binary scheme so that the similarity process can be implemented with the operator of 'or' and 'exclusive or'.

The results of previous research prove that the filter function to enhance image has good performance in palmprint verification. A wavelet filter in palmprint recognition system is more preferred to be used to improve image appearance than to obtain feature information. Zhang et al. in [5] state that the use of a modified complex wavelet of structural similarity index can change the look of original ROI palms that can generate a higher true acceptance rate and lower false acceptance rate simultaneously. Wang et al. in [6] recommend that fusion of 2D Gabor wavelet and pulse-coupled neural network yields a better performance in terms of correct classification and relatively high robustness to the variations such as orientation, position, and illumination. Wu and Zhao [7] concluded that the use of wavelet filter for palmprint application still can be developed. However, all of the research that has been done did not show the advantages of wavelet filter compared to other methods in terms of processing time, EER, and the percentage of verification according to Wang et al. [8].

For that reason, authors proposed a one-stage Haar wavelet decomposition to improve the palmprint recognition performance, unlike the three-stage decomposition used by Minaee and Abdolrashidi in [19]. The decomposition results were then multiplied with Wiener filter as conducted by Ercelebi and Koc [11]. Furthermore, the three detail of decomposition was multiplied by a weighting value as conducted by Kim et al. in [12]. Finally, extensive experiments were conducted on three palmprint databases to achieve palmprint recognition method with the most competitive performance value.

2. **Research Method.**

Generally, filter method is used to overcome the interference attenuation of the signal. For example, in an image, the filter is used to modify pixels based on the system of local neighborhood. Then based on the function, the filter can use a mathematical operator to change the appearance of the image. One of the filters that is widely used in the field of engineering is a wavelet filter.

2.1. **Wavelet method.**

A wavelet is a mathematical expression used in digital signal and image processing that decomposes signals and images into component waves of varying durations. The wavelet is a waveform of effectively limited duration that has an average value of zero. In signal and image processing, the filter can be used to recover a weak signal from noise and to compress successively. In addition, the wavelet transform has characteristic of a multi-resolution system whereby a discontinuity signal will yield wavelet important coefficients around the local point and also the similarity benchmark of discontinuity in nonlinear approximation. The wavelet filter can minimize the very small coefficient and increase the rest by nonlinear mapping [9]. In addition, in the retinal system, the filter provides a visual representation of scales that progressively changes in geometrical patterns as difference occurs in the intensity scale modification in the image. Detecting the optimal size requires a different carrier (operator) and wavelet differential is suitable for this use [10]. To improve the performance of the palm print recognition

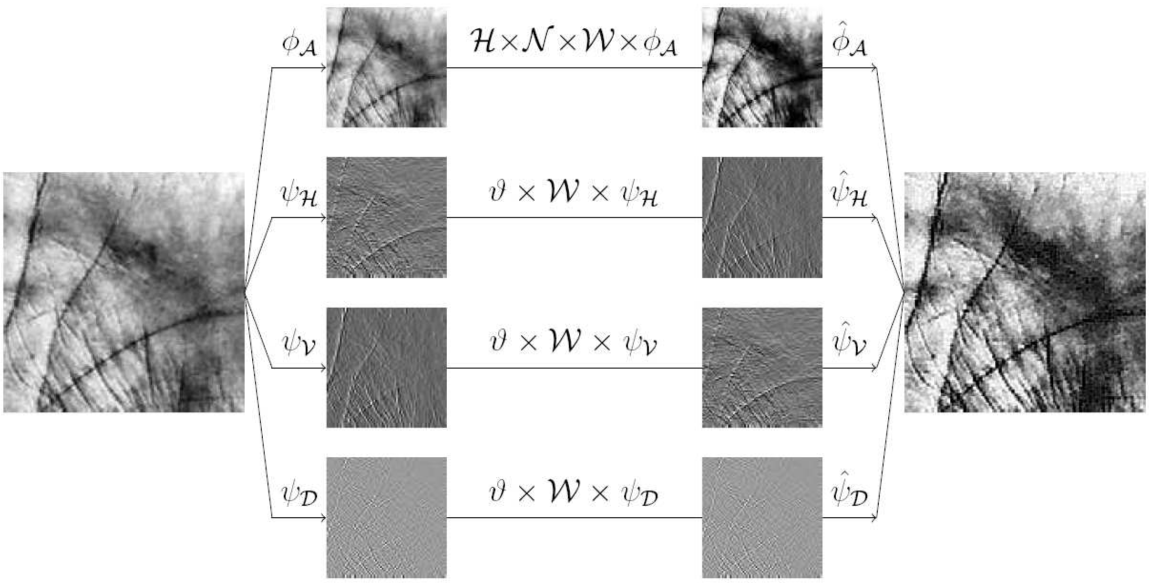

FIGURE 1. The wavelet filter process that involves the Wiener filter $\mathcal{W}$ and weighted value ϑ using an ROI of palmprint image

system by using the wavelet filter, an algorithm step was used to attain the research objectives as shown in Figure 1.

The wavelet equation is defined as follows [8]

$$f(n) = \frac{1}{\sqrt{M}}\sum_k W_\phi(j_0,k)\phi_{j_0,k}(n) + \frac{1}{\sqrt{M}}\sum_{j=j_0}^{\infty}\sum_k W_\psi(j,k)\psi_{j,k}(n), \tag{1}$$

with $f(n)$, $\phi_{j_0,k}(n)$, and $\psi_{j,k}(n)$ being discrete functions that are defined within the scope $n = [0, M-1]$. The wavelet coefficients were obtained from the inner product.

$$W_\phi(j_0,k) = \frac{1}{\sqrt{M}}\sum_n f(n)\phi_{j_0,k}(n), \tag{2}$$

$$W_\psi(j,k) = \frac{1}{\sqrt{M}}\sum_n f(n)\psi_{j,k}(n). \tag{3}$$

Equation (2) is called approximation coefficients while Equation (3) is detailed coefficients where $j \geq j_0$. Generally, $j_0 = 0$ and select M to be a power of 2 so that $M = 2^j$, while the summations were performed over $j = 0, 1, \ldots, J-1$ and $k = 0, 1, 2, \ldots, 2^{j-1}$.

Typically, the wavelet application on 2D was used for image encryption or to enhance the contrast that has the same principal with the Fourier transform. In the 2D of Fourier transform, the basis function of the transform is complex exponentials that can be modified into $\exp\left[j\left(\omega_1 t_1 + \omega_2 t_2\right)\right]$ instead of the form of $\exp(j\omega t)$. The transformed coefficient became two variable functions. Two variable functions for the 2D wavelet were the scaling function $\phi(x,y)$ and the translation function $\psi(x,y)$ which could be expressed in the following term.

$$\phi_{j,m,n}(x,y) = 2^{\frac{j}{2}}\phi\left[2^j x - m, 2^j y - n\right], \tag{4}$$

$$\psi^i_{j,m,n}(x,y) = 2^{\frac{j}{2}}\psi^i\left[2^j x - m, 2^j y - n\right], \quad i = \{\mathcal{H}, \mathcal{V}, \mathcal{D}\}. \tag{5}$$

In Equation (5), there were three different wavelet functions, $\psi_{\mathcal{H}}(x,y)$, $\psi_{\mathcal{V}}(x,y)$, and $\psi_{\mathcal{D}}(x,y)$. In theory, the scaling function was part of low frequency components; therefore, there was one 2D scaling function $\psi_{\mathcal{A}}(x,y)$. In the digital form, discrete wavelet usually used to get a representation of the timing and scale of a signal by using a digital filter technique and operation of sub-sampling. The signal was passed inside the high-pass and low-pass filters, and then half of each output was then taken as the superficial value or known as decomposition which consisted of four parts: approximation coefficients ($\phi_{\mathcal{A}}$), detail in horizontal ($\psi_{\mathcal{H}}$), detail in vertical ($\psi_{\mathcal{V}}$), and detail in diagonal ($\psi_{\mathcal{D}}$). As the wavelet function could be split from $f(x, y)$ to $f_1(x)f_2(y)$, then Equations (4) and (5) could be rewritten as

$$\begin{aligned} \phi_{\mathcal{A}} &\cong \phi_{\mathcal{A}}(x, y) = \phi(x)\phi(y), \\ \psi_{\mathcal{H}} &\cong \psi_{\mathcal{H}}(x, y) = \psi(x)\phi(y), \\ \psi_{\mathcal{V}} &\cong \psi_{\mathcal{V}}(x, y) = \phi(x)\psi(y), \\ \psi_{\mathcal{D}} &\cong \psi_{\mathcal{D}}(x, y) = \psi(x)\psi(y). \end{aligned} \tag{6}$$

Visually, the output $\phi_{\mathcal{A}}$ has the clearest display compared with the other three details. Some applications only take the approximation value and dispose the details such as in the compression process. Other cases only use the detail value to hide some information in the process of watermarking techniques. In this study, to get a stronger sharpness value, the decomposition wavelet value is multiplied by a Wiener filter.

2.2. **Wiener method.** Wiener filter was used to reduce the number of noise signals by comparing the received signal with the estimate of a desired signal noiseless. The process goal was to have a minimum mean square error, so that the difference between the origin signal and the new signal should be as few as possible. In palmprint recognition, the basic idea of image enhancement was based on research of Ercelebi and Koc in [11], where they state that the Wiener filter $\mathcal{W}$ is able to reduce image blur due to some movement of acquisition process in four parts of wavelet decomposition. By applying a Wiener filter in the research, then Equation (6) can be expressed as follows.

$$\begin{aligned} \phi_{\mathcal{A}2} &= \phi_{\mathcal{A}} \times \mathcal{W}, \\ \psi_{\mathcal{H}2} &= \psi_{\mathcal{H}} \times \mathcal{W}, \\ \psi_{\mathcal{V}2} &= \psi_{\mathcal{V}} \times \mathcal{W}, \\ \psi_{\mathcal{D}2} &= \psi_{\mathcal{D}} \times \mathcal{W}. \end{aligned} \tag{7}$$

The difference value between the approximation value ($\phi_{\mathcal{A}2}$) and the details value ($\psi_{\mathcal{H}2}, \psi_{\mathcal{V}2}, \psi_{\mathcal{D}2}$) was very large, so it was necessary to use a weighting value to reduce the gap.

2.3. **Weighting method.** A weighting method was generally used in study to compensate value for non-response and non-coverage value and to make estimates between selected sample and overall samples. In wavelet filter, the wavelet had limited method when cutting the excessive value of decomposition in high-frequency. Therefore, in order to overcome this problem, the authors used the results of research conducted by Kim et al. [12] where the use of the weight variable ϑ provides a stable value in the wavelet decomposition. By applying a weighting value in the research, then Equations (6) and (7) can be expressed as follows.

$$\begin{aligned} \hat{\psi}_{\mathcal{H}} &= \psi_{\mathcal{H}} \times \mathcal{W} \times \vartheta, \\ \hat{\psi}_{\mathcal{V}} &= \psi_{\mathcal{V}} \times \mathcal{W} \times \vartheta, \\ \hat{\psi}_{\mathcal{D}} &= \psi_{\mathcal{D}} \times \mathcal{W} \times \vartheta. \end{aligned} \tag{8}$$

In application, the weight value can be set according to the size of noise. With $\vartheta = 1.5$ for the value of detail and histogram-normalize for approximation value, the image enhancement provided performance improvements. The normalization ($\mathcal{N}$) of the image $I(x, y)$ could be written as follows.

$$\mathcal{N} = I(x, y) - \left[\frac{\min[I(x, y)] * I(\hat{x}, \hat{y})}{\max[I(x, y)] * I(\hat{x}, \hat{y})}\right] - \min[I(x, y)] * I(\hat{x}, \hat{y}), \tag{9}$$

with $(\hat{x}, \hat{y})$ being matrix of ones. The final result of image enhancement, $\hat{I}(x, y)$, obtained a new value of x and y from the wavelet inverse by combining Equations (6) and (9).

$$\hat{I}(x,y) = f\left[\hat{\phi}_{\mathcal{A}}, \hat{\psi}_{\mathcal{H}}, \hat{\psi}_{\mathcal{V}}, \hat{\psi}_{\mathcal{D}}, \text{`haar'}\right](x,y), \quad f \supseteq \begin{cases} \hat{\phi}_{\mathcal{A}} = \mathcal{H} \times \mathcal{N} \times \mathcal{W} \times \phi_{\mathcal{A}} \\ \hat{\psi}_{\mathcal{H}} = 1.5 \times \mathcal{W} \times \psi_{\mathcal{H}} \\ \hat{\psi}_{\mathcal{V}} = 1.5 \times \mathcal{W} \times \psi_{\mathcal{V}} \\ \hat{\psi}_{\mathcal{D}} = 1.5 \times \mathcal{W} \times \psi_{\mathcal{D}}, \end{cases} \tag{10}$$

with $f(x, y)$ being wavelet inverse and $\mathcal{H}$ being histogram equalization process. Figure 2 shows the influence of a variety of filters to the ROI image of palms.

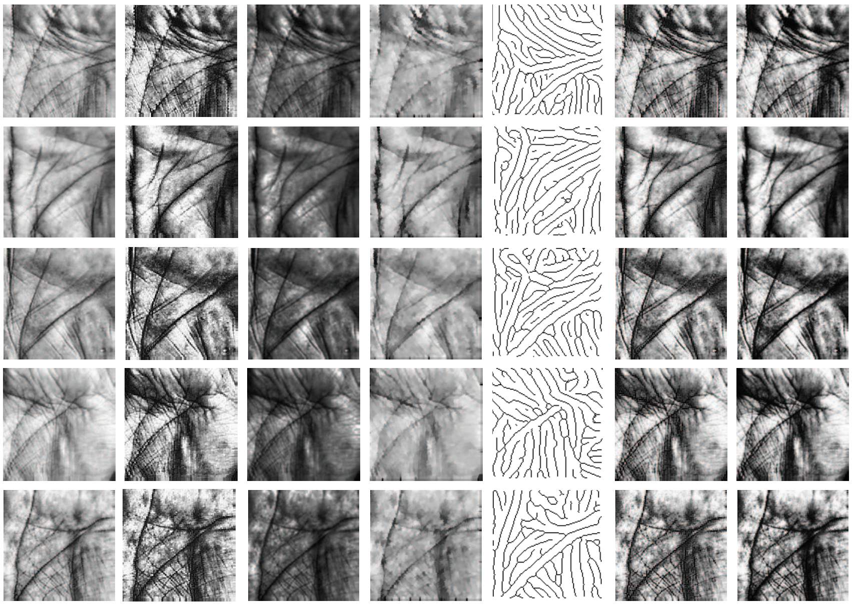

FIGURE 2. The impact of various filter methods to the ROI images of palms: (a) original, (b) wavelet, (c) multiple, (d) shock, (e) skeleton, (f) anisotropic and (g) histogram equalization

After the image enhancement of all input data by the wavelet method, then Gabor method was used to examine the same position and size of input. In the paper, selection of Gabor parameters was based on Zhang et al.'s algorithm [13]. The drawback of using the Gabor method is when the huge number of feature information was added as the result of multiplication between scale and orientation. To overcome this problem, researchers used the dimension reduction such as KPCA method (*the kernel principal component analysis*) as used by Štruc and Paveši in [14]. Finally, the matching process of cosine method was used for identification and verification process as conducted by Meraoumia et al. in [15].

3. **Result and Discussion.** In this paper, three open source-based databases that contain images of palms from Casia, IITD-India, and PolyU were used. The number of groups and details of each database were 6 images in 650 groups, 5 images in 450 groups, and 10 images in 550 groups for Casia, IITD-India, and PolyU in consecutive. The results of research are written in Table 1 and shown graphically in Figure 3.

Overall, the wavelet filter was leading in terms of EER value and verification percentage. However, KPCA-based (*the kernel principal component analysis*) had the best characteristic in processing time. In Casia database, wavelet filter was leading in KPCA and PCA (*the principal component analysis*) with the values of time process (T_C), EER (E_C), and

TABLE 1. The time duration of processing (T), error equal rate (E), and verification percentage (V) in three databases: Casia (C), IITD-India (δ), and PolyU (P)

$\mathcal{DR}$	Filter	T_C	E_C	V_C	T_δ	E_δ	V_δ	T_P	E_P	V_P
KPCA	Original	1.18026	0.02515	97.462	0.40384	0.01886	98.111	0.8769	0.00362	99.636
	Wavelet	1.20458	0.00998	99	0.35847	0.02001	98	0.68244	0.00272	99.727
	Multiple	1.1478	0.5	50.846	0.3722	0.01998	98	0.90415	0.00274	99.527
	Shock	1.18499	0.01088	98.923	0.37578	0.02327	97.667	0.71127	0.00729	99.273
	Skeleton	1.19819	0.04295	95.692	0.38855	0.04221	95.778	0.66315	0.00835	99.182
	Anisotropic	1.26801	0.02309	97.692	0.40838	0.39781	60.222	0.69574	0.00363	99.636
	Histogram	1.24321	0.01538	98.462	0.36596	0.01775	98.222	0.72881	0.00254	99.427
PCA	Original	3.31448	0.0338	96.615	1.56055	0.0224	97.778	2.14047	0.00792	99.182
	Wavelet	3.2997	0.01994	98	1.51611	0.02327	97.667	2.13797	0.00524	99.455
	Multiple	3.37865	0.03078	96.923	1.48397	0.02441	97.556	2.17399	0.00636	99.364
	Shock	3.42018	0.03238	96.769	1.52879	0.02558	97.444	2.15976	0.00908	99.091
	Skeleton	3.33632	0.09561	90.462	1.54714	0.06426	93.556	2.14357	0.0199	98
	Anisotropic	3.38774	0.02928	97.077	1.5026	0.02568	97.444	2.17839	0.00655	99.245
	Histogram	3.40127	0.02227	97.769	1.48864	0.02104	97.889	2.14939	0.0076	99.345

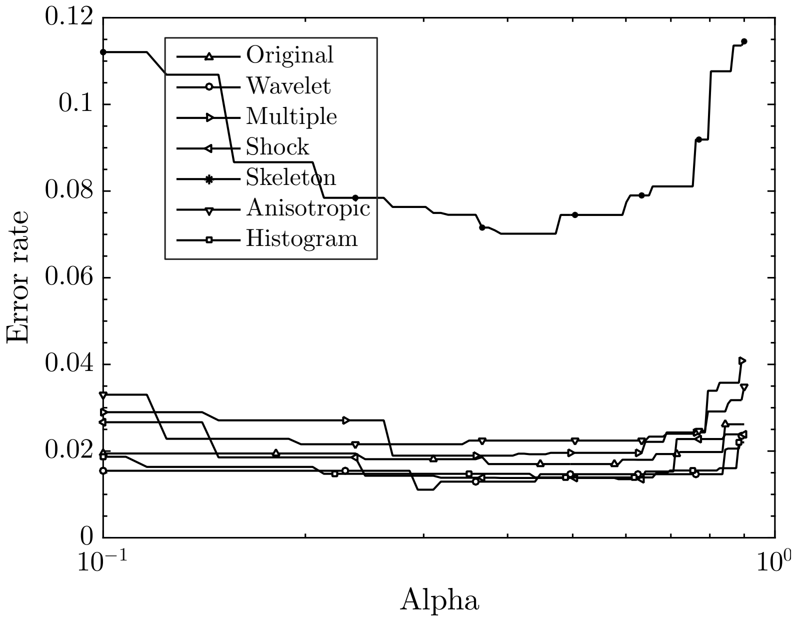

FIGURE 3. The EPC curve showing wavelet filter method in little circle black marker representation had the lowest error rate value compared to other methods

verification (V_C) in KPCA being 1.20458 seconds, 0.9%, 99%, respectively. Meanwhile, the respective values of time process (T_C), EER (E_C), and verification (V_C) in PCA were 3.2997 seconds, 1.994%, and 98%. However, in IITD-India database, the wavelet filter was not significantly better than other methods. Finally, in PolyU database, the wavelet filter was also the method with the highest performance, although with only a slight difference value across a wide range of filters used in the study. The best value achieved through the use of wavelet filter in KPCA-based was 0.68244 seconds for time processing, 0.00272 for error rate value, and 99.727% for success in identifying.

The EPC curve in Figure 3 clearly shows that the method of the wavelet filter represented by black lines has the lowest curve graph. Thus, it can be concluded that the wavelet method had the optimum system with the lowest error rate value compared with other methods of original, multiple, shock, skeleton, anisotropic, and histogram equalization.

4. **Conclusion.** In the palmprint recognition, the wavelet filter was the best choice for image enhancement compared with other methods such as original, multiple, shock, skeleton, anisotropic, and histogram equalization as the wavelet filter had the fastest processing time, the lowest error rates, and the highest value in verification. Meanwhile, the KPCA-based was able to bring the system to reach optimum value with the respective value of EER, the verification, and duration of processing time being 0.00272, 99.727%, and 0.68244 seconds on PolyU database. Excellent palmprint recognition using wavelet filter presents a challenging yet promising direction for future research. Unfortunately, big data and dimension reduction method require long computation process; thus, it is not suitable to be used in system with only Intel processor i5 series. In the future, author(s) plan to use more dimension reduction method and matching method and continue to apply the wavelet method to improving the performance of the biometric system.

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