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Multispectral Palm Image Fusion: A Critical Review

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Abstract— **Hand biometrics, including fingerprint, palmprint, hand geometry and hand vein pattern, have obtained extensive attention in recent years. Physiologically, skin is a complex multi-layered tissue consisting of various types of components. Different components appear when the skin is illuminated with light sources of different wavelengths. This motivates us to integrate the information from multispectral palm images to a composite representation that conveys richer and denser pattern for recognition. In this paper, comparative study of several pixel level multispectral palm image fusion approaches is conducted and several well-established criteria are utilized as objective fusion quality evaluation measure. Among others, Curvelet transform based image fusion is found to perform best in preserving discriminative patterns from multispectral palm images.**

Index Terms— **Biometrics, Image Fusion, Multispectral, Palmprint, Region of Interest, (ROI), Score level fusion**

I. INTRODUCTION

The term "biometrics" is derived from the Greek words bio (life) and metric (to measure). For our use, biometrics refers to technologies for measuring and analyzing a person's physiological or behavioral characteristics. These characteristics are unique to individuals hence can be used to verify or identify a person. Humans recognize each other according to their various characteristics for ages. We recognize others by their face when we meet them and by their voice as we speak to them. Identity verification (authentication) in computer systems has been traditionally based on something that *one has* (key, magnetic or chip card) or *one knows* (PIN, password). Things like keys or cards, however, tend to get stolen or lost and passwords are often forgotten or disclosed.

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To achieve more reliable verification or identification we should use something that really characterizes the given person. Biometrics offer automated methods of identity verification or identification on the principle of measurable physiological or behavioral characteristics such as a fingerprint or a voice sample. The characteristics are measurable and unique. These characteristics should not be duplicable, but it is unfortunately often possible to *biometrics* create a copy that is accepted by the biometric system as a true sample. This is a typical situation where the level of security provided is given as the amount of money the impostor needs to gain an unauthorized access.

Palm print is a physiological trait that can be acquired using a low cost camera or scanner. Many researchers have shown that the performance of palm print based biometric systems is comparable to those of face, fingerprint and hand geometry. The information in palmprint images is in the form of thick, regular and thin irregular curves called principal lines and wrinkles, respectively. The palmprint recognition system has many advantages over other biometric systems in respect of reliability, low cost and user friendly. Palmprint is one of the most reliable means in personal identification because of its stability user friendliness, acceptability and uniqueness. The parameters are as given below

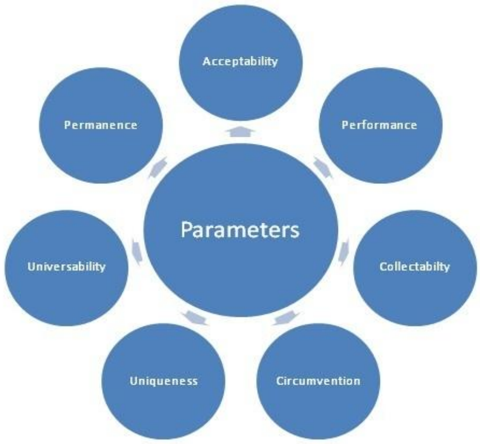

Fig1. Parameters of Biometrics

1. **Universality:** Each person should have the biometric characteristic.
2. **Distinctiveness:** Any two persons are not equal in terms of the characteristic.
3. **Permanence:** The characteristic remains the same over time or has not abrupt changes.

4. **Colectabillity:** The characteristic should be able to be measured quantitatively.

5. **Performance:** The achievable recognition accuracy and speed that the biometric system can achieve.

6. **Acceptability:** The acceptance of the end-users in using the biometric system in their daily lives.

7. **Circumvention:** The degree of security of the system given fraudulent attacks.

One potential solution to such improvement may be multispectral imaging.By multispectral imaging, a series of palmprint images at various spectral bands can be captured simultaneously. The spectral signature of the palm can not only provide more discriminative information to improve the accuracy [9], but also improve the anti-spoof capability of palmprint systems because it is very difficult to make a fake palm which can have the same spectral signatures with a real palm.

Although 3-D imaging could be used to address these issues, the expensive and bulky device makes it difficult to be applied for real applications. One solution to these problems can be multispectral imaging which captures an image in a variety of spectral bands[8].

Each spectral band highlights specific features of the palm, making it possible to collect more information to improve the accuracy and antispoofing capability of palmprint systems. A contact-free palmprint verification system has been presented using multispectral palm image by means of feature level registration and pixel level fusion strategies. Initially a sequence of multispectral hand images is obtained by illuminating the hand with multiple active lights. Coarse localization of ROI is performed through preprocessing on each image and it is then further refined through feature level registration. Finally, authors integrate the multiple image sources and the fusion is performed with multi-scale decomposition, activity measure and coefficient combining methods[6].

A multispectral palmprint recognition system using wavelet based image fusion is proposed. [5] It uses a multispectral capture device to sense the palm images under different illumination conditions, including red, blue, green and infrared. Further wavelet transform is used for combining the palmprint images obtained from different channels. During image acquisition the situation of hand movement is also considered. Finally, competitive coding scheme has been adopted for matching. It uses Wavelet based image fusion as data level. Again this system has been further extended where features extraction and matching have been made of red, green, blue and NIR bands of a multispectral palm image. Finally these matching scores obtained from matching against different bands are fused using simple sum rule.

Feature band selection based multispectral palmprint recognition has been proposed where the statistical features are extracted to compare each single band. Score level fusion is performed to determine the best combination from all candidates.

The most discriminative information of palmprint images can be obtained from two special bands. Region of Interest (ROI) is determined from hyperspectral palm cube using local coordinate system. [3]

Multispectral palmprint recognition has been presented where multiple information related to hand are used. Hand shape, fingerprints and palmprint modalities are used for recognition. This system shows good recognition accuracy on a medium size database while fusion is performed with multiple fingers and fusion of finger and palm. [9]

A comparative study of several multispectral palm image fusion techniques has been presented. Some well-studied criteria are used as objective fusion quality measure. However, the curvelet transform is found to be the best among others in preserving discriminative patterns from multispectral palm images. [10]

This paper presents a novel palmprint verification method in which palm images are fused at low level by wavelet transform. [5] Fused palm is then represented by Gabor wavelet transform [11-13] to capture the palm characteristics in terms of neighborhood pixel intensity changes.

Gabor palm responses contain high dimensionality features and due to this high dimensionality ant colony optimization (ACO) [14] is applied to select the optimal set of distinct features. Finally, support vector machines (SVMs) are used to train the reduced feature sets of different individuals and verify the identity. Proposed palmprint system is evaluated with CASIA palmprint database and the results are also compared with other existing methods to measure the effectiveness and robustness of the system.

Multi-resolution analysis [4] of images provides useful information for several computer vision and image analysis applications. The multi-resolution image is used to represent the signals where decomposition is per- formed for obtaining finer detail. Multi-resolution image decomposition gives an approximation image and three other images viz., horizontal, vertical and diagonal images of coarse detail. The Multi-resolution techniques are mostly used for image fusion using wavelet transform and de- composition.

In [6], Hao *et al.* extended their work to a larger database and proposed a new feature level registration method for image fusion. The results by various image fusion methods were also improved. Although image- and feature-level fusion can integrate the information provided by each spectral band, the required registration procedure is often too time consuming [7]. As to matching score fusion and decision level fusion, it has been found [11] that the former works better than the latter because match scores contain more information about the input pattern, and it is easy to access and combine the scores generated by different matchers. For these reasons, information fusion at score level is the most commonly used approach in multimodal biometric systems and multispectral palmprint systems.

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I. MULTISPECTRAL PALM IMAGE PROCESSING

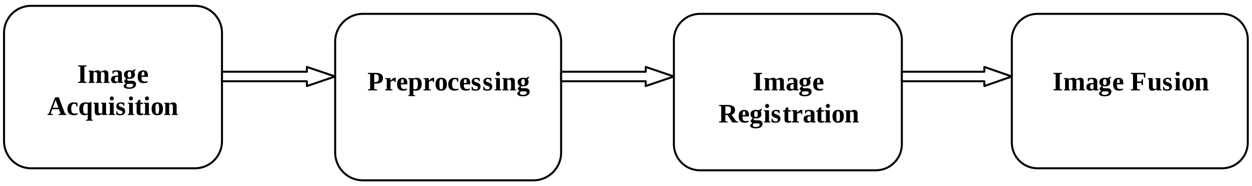


Fig2. Flow chart of proposed system

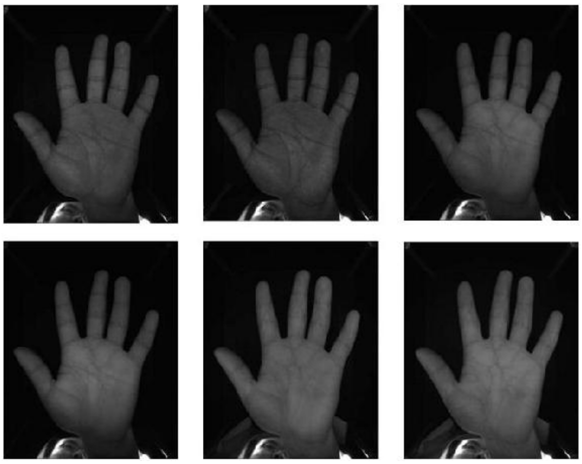
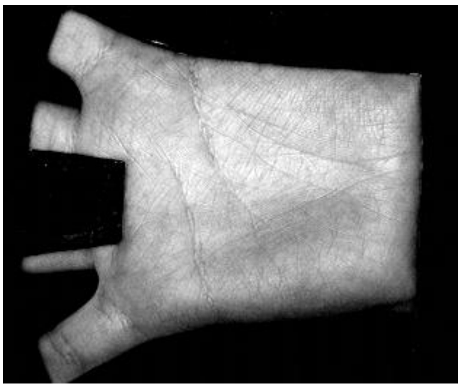
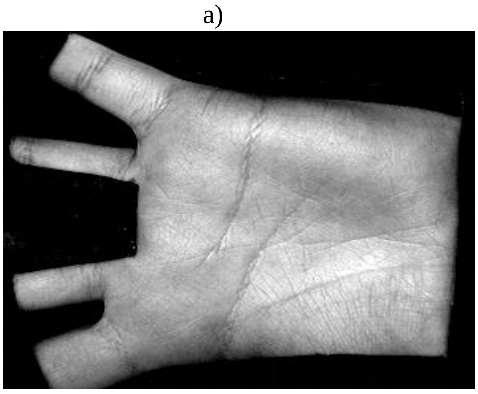


Fig3 : Six typical palmprint images in the CASIA database



a)



b)

Fig4: Two typical palmprint images in the POLYU database

II.Hardware Setup

For collecting the palm images here both with contact or without contact set up is to be considered. With contact is the more hygienic method for collecting the palm images.

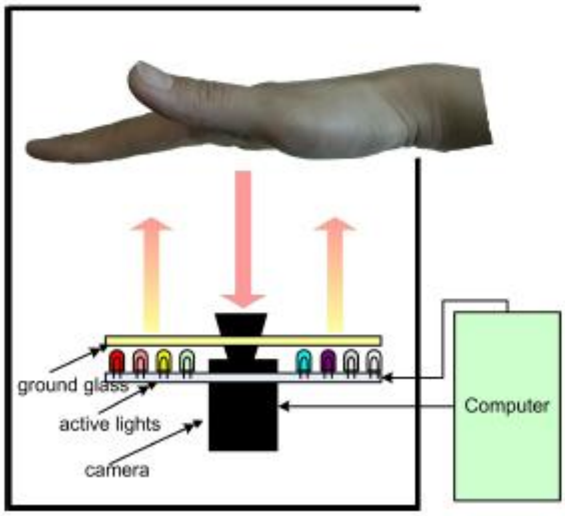


Fig.5 Set up for Multispectral palm image capture device

Fig. 5 shows the hardware design to capture images in both visible and near infrared spectra. The device works under a sheltered environment and the light sources are carefully arranged so that the palm region is evenly illuminated. An infrared sensitive CCD camera is fixed at the bottom of the inner encloser and connected to a computer via USB interface. An integrated circuit plate is mounted near the camera for illumination and different combinations of light wavelengths can be accomplished by replacing the circuit plate. By default, the two sets of lights are turned on in turn so that only expected layer of hand appears to camera. When illuminated with visible light, image of hand skin surface, namely, the

palmprint is stored. while when NIR light is on, deeper structure as well as parts of dominant surface features, for example the principal lines, are captured.

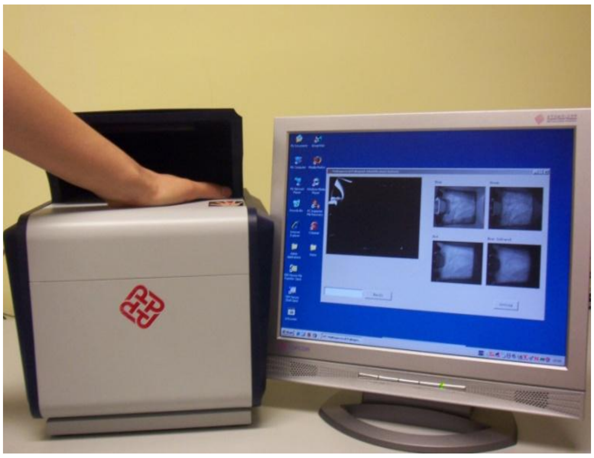


Fig.6 set up for Multispectral palm image capture device (POLYU data base of D. Zhang)

Fig 5 shows the with contact set-up. It gives more accuracy than contactless images. Multispectral palmprint images were collected from 250 volunteers, including 195 males and 55 females. The age distribution is from 20 to 60 years old. We collected samples in two separate sessions. In each session, the subject was asked to provide 6 images for each palm. Therefore, 24 images of each illumination from 2 palms were collected from each subject. In total, the database contains 6,000 images from 500 different palms for one illumination. The average time interval between the first and the second sessions was about 9 days. Hence the database of polyu and CASIA tabulated as follows-

Database	**polyU**	**CASIA**
Palms	**500**	**200**
Samples	**12**	**6**
Total MSIs	**6000**	**1200**
Bands	**4**	**6**
Central(nm) Wavelength	**470,525,660,880**	**460,630,700,850,940, While**

Table1.Multispectral palm images are available on CASIA and POLYU database.

A. ROI Extraction:

To extract the ROI of palm image, it is necessary to define a coordinate system based on which different palm images are aligned for matching and verification. Gaps between fingers have been used in as reference points for determining the coordinate system. This paper also applies this technique to determine the ROI of the multispectral palm image. The following algorithm is followed to extract the central part of the palmprint image as ROI and further this ROI is used for multispectral fusion of palm images.

I. Algorithm of ROI extraction:

1.Convert the multispectral palm image to a binary image. Gaussian smoothing can be used to enhance the image.

2. Apply boundary-tracking algorithm to obtain the boundaries of the gaps between the fingers. Since the ring and the middle fingers are not useful for processing.
3. Determine palmprint coordinate system by computing the tangent of the two gaps with any two points on these gaps.
4. The *y*-axis is considered as the line which joining these two points. To determine the origin of the coordinate system, midpoint of these two points are taken through which a line is passing and the line is perpendicular to the *y*-axis.
5. Finally, extract ROI for feature extraction which is the central part of the palmprint.

A. *B*. Location Of ROI:

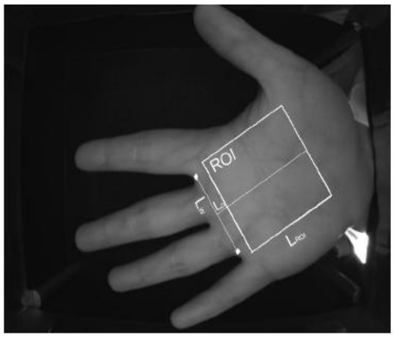


Fig7: ROI Localization

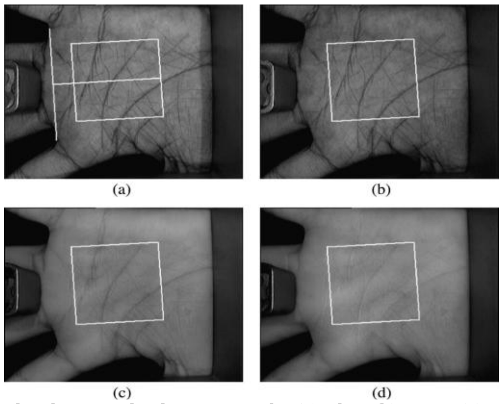


Fig8: Typical multispectral palmprint sample. (a) Blue. (b) Green.(c) Red. (d) NIR. The white square is the ROI of the image.

I. Palm Image Fusion

The image fusion is a mechanism to improve the quality of information from a set of image. It means that Image fusion is a process of combining the relevant information from a set of images, into a single image wherein the resultant fused image will be more informative and complete than any of the input images.

A. Image Fusion Methods:

1. Wavelet Transform
2. Curvelet Transform
3. Principle Component Analysis (PCA)
4. Intensity-hue-saturation (IHS)
5. Laplacian Pyramid
6. Brovey Transform
7. Gradient Pyramid
8. Filter-Subtract-Decimation (FSD)

9. Contrast Pyramid
10. Linear Superposition

1.Wavelet Transform-

The most recent and advanced methods used for image fusion are wavelet-based. In these methods, the discrete wavelet transform (DWT) is performed on each of input images. The corresponding approximation and detail coefficients are fused based on some optimization criteria.
Finally, the inverse DWT is utilized to produce the fused image.

The DWT multiresolution representation, or wavelet pyramid, has a number of advantages over the other predominantly Gaussian pyramid based multiresolution techniques. One of the most fundamental issues is that wavelet functions used in this type of multiresolution image analysis form an orthonormal basis that results in a nonredundant signal representation. In other words, the size of the multiresolution pyramid is exactly the same as that of the original image.

To enhance the performance of palmprint identification, two or more spectrum of palmprint images are fused as shown in Fig. 3 (for *Blue*, *Green* and *Red*). Single level *DWT* is applied on these images to obtain the detail and approximation wavelet bands for these images. Let *LLb*, *LHb*, *HLb* and *HHb* be the four bands from all the spectrum palmprint images (*b ´ Blue*, *Green* or *Red*). To preserve the information from all the images, coefficients from approximation band and the three detailed bands of all images are averaged, as follow:

$$Bf = mean(B\text{blue};B\text{green};B\text{red}) \quad (1)$$

Fig.4: Where *B* represent one of the four band (*B´ LL*, *LH*, *HL* or *HH*), and *Bf* represent the averaged band. Inverse *DWT* is then applied on the four fused bands to generate the fused image. The result image is used for identification.

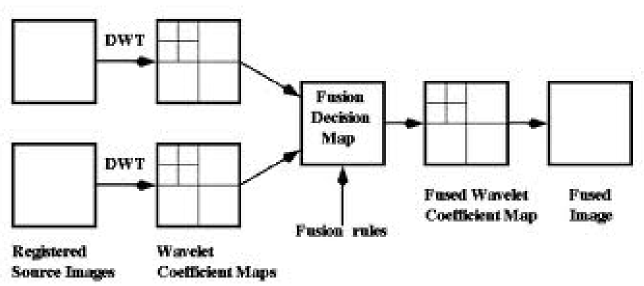


Fig9: Block diagram of Discrete Wavelet transform

2.Curvelet Transform-

Curvelet Transform is a new multi-scale representation most suitable for objects with curves. The Curvelet Transform includes four stages-a)Sub-band decomposition b)Smooth partitioning c)Renormalization d)Ridgelet analysis. The basic limitation of wavelet fusion algorithm is in fusion of curved shapes and this can be rectified by application of curvelet transform would result in the better fusion effiency.

Curvelet transform involves the segmentation of the whole image into small overlapping tiles and then the ridgelet transform is applied to each tile. The purpose of segmentation process is to approximate curved lines by small straight lines. The overlapping of tiles aims at avoiding edge effects.

3.Principle Component Analysis (PCA)-

PCA fusion method converts the original bands into a new set of uncorrelated bands called principal components. The optimal weighting by a PCA of all input intensities. By performing a PCA of the covariance matrix of input intensities, the weightings for each input image are obtained from a eigenvector corresponding to largest eigenvalue.Hence we can say that PCA is a space vector transform often used to reduce multidimentional data sets to lower dimensions for analysis.

4.Intensity-hue-saturation(IHS)-

IHS transformation separates spatial (I) and spectral (H,S) in information from a standard RGB image. Next the intensity component is replaced by the PAN, and doing the reverse HIS transform ,we get the RGB fused image.

5.Laplacian Pyramid-

Laplacian pyramid of an image is a set of bandpass images, in which each is a bandpass filtered copy of its predecessors. A strength measure is used to decide from which source what pixels contribute at each specific sample location.In this approach, the Laplacian Pyramids for each image component (IR & Visible) are used.

6.Brovey Transform-

Brovey transform is a simple image fusion method that injects the overall brightness of the PAN image into each pixel of the normalized MS bands according to an algebraic expression. Hence Brovey methods obtain the missing spatial detail information from intensity image calculated between the lower spatial resolution SAR image.

7.Gradient Pyramid –

Agradient pyramid is obtained by applying a set of four directional gradient filters (horizontal, vertical & two digonal) to the Gaussian pyramid at each level. At each level, these four directional gradient pyramids are combined together to obtain a combined gradient pyramid that is similar to a Laplacian pyramid. Hence the gradient pyramid fusion is therefore the same as the fusion using laplacian pyramid except replacing the laplacian pyramid with the combined gradient.

8.Filter-Subtract-Decimation (FSD)-

FSD pyramid fusion method is computationally more efficient than the laplacian pyramid method by skipping an unsampling step.

9.Contrast Pyramid-

The contrast itself is defined as the ratio of the difference between luminance at a certain location in the image plane and local background luminance to the total background luminance**.** The construction of the contrast pyramid is similar to the construction of the popular laplacian pyramid.

In this case the fusion rule is to select at each pixel location i,j at the pyramid level L the pixel value from the largest deviation from unity from unit source A or B.

10.Linear Superposition-

The probably most straightforward way to build a fused image of several input frames is performing the fusion as a weighted superposition of all input frames.The optimal weighting coefficients, with respect to information content and redundancy removal, can be determined by a principal component analysis (PCA) of all input intensities. By performing a PCA of the covariance matrix of input intensities, the weightings for each input frame are obtained from the eigenvector corresponding to the largest eigen value.

II. Conclusion

A novel palmprint feature extraction approach is used. The novelty lies in extracting two intramodal discriminative features; lines like principal lines and dominant wrinkles and energy features using the same wavelet decomposition of the palmprint ROI.

The recent trend of intelligent human computer interface has motivated to tackle the problem of contact free hand based biometrics. Integrating information deep inside skin with appearance in the context of hand biometrics is considered. The advantages of pixel-level fusion are appearance as well as inner information of hand is combined to form one solo representation, enforcing the security of the whole system. Multispectral palmprint capture device was designed to offer illuminations of Red, Green, Blue and Infrared channels. The verification results on different illumination are irradiative for choosing the best spectrum for palmprint recognition. By using image fusion in multispectral palm images we get more discriminative features which finally improve accuracy of recognition.

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