Palm Vein Verification System based on Nonsubsampled Contourlet Transform

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***Abstract*—This document presents a new approach in verification system to verify the identity of person by his intrinsic characteristics "Palm vein" which is unique, universal and easy to captured. The first step in this system is to extract the region of interest (ROI) which represent the most informative region of palm, then coding step based on nonsubsampled contourlet transform (NSCT) is presented to produce a binary vector for each ROI, next a matching step of different representative vectors is given and finally a decision is made for both identification and verification mode. This approach is tested on CASIA multispectral database; the experimentations have proved the effectiveness of this coding system in verification modes to gives 0.19% of Equal Error Rate (EER).**

Keywords—Verification; palm-vein; nonsubsampled contourlet transform; region of interest; equal error rate

I. Introduction

Biometrics is referring to the recognition of individual using his intrinsic characteristics no longer limited to the fingerprint's modality, and many modalities are used for access control applications to premises or personal items. Many modalities can be mention like the face, the voice, the signature, the iris.

Those modalities represent some problems such as lack of individuality and sensitivity to attacks for example fingerprints can be reproduced using silicone so to overcome that limits a new modality which is the palm vein has been used. Human palm vein biometrics represents one of the ambitious numerically biometric systems, this is due to the special characteristic of palm-vein texture among different persons and its unique and measurable intrinsic characteristics used to identify a person.

Some stringent pre-processing steps have been used to extract a stable region of interest (ROI) that has a fixed-size to minimize some translational and rotational variations in the palm vein image. Then, the texture of the ROI has been analyzed by the Non-Subsampled Contourlet Transform (NSCT), which is a shift-invariant, multi-directional and multi-scale transform, to capture significant veins features along all directions of the ROI image. The remainder of this paper is organized as follows: In Section two, existing methods in literature are briefly reviewed. In Section three, palm vein texture description is presented, the proposed palm veins feature extraction method is presented in section four. In section five, experimental results of the proposed method are given. Finally, conclusion is drawn in section six.

II. Literature Review

An image represents a set of details which appear at different resolutions. For that, multi-resolution decomposition is significant to analyze different type of image's structure in each resolution.

Several techniques in literature based on multi-resolution decomposition are proposed like the method based on Gabor filter in the work of '[1]' who measured the similarity between two-bit string representations called VeinCodes using hamming distance, and the work of '[2]'who used a Fisher Discriminated Analysis (FDA) to reduce the dimension of the features vector and the nearest neighbor's method for matching. Those techniques have been shown a satisfying efficiency in terms of recognition rate and execution.

There are many works in literature based on Curvelet transform like the work of '[3]'which applied Principal Component Analysis (PCA) on curvelet-decomposed images for dimensionality reduction and a simple distance-based classifier like the nearest-neighbor (NN) for matching, and the work of '[4]' which have used the curvelet transform to extract curve-like features from vein patterns and provides excellent sparse representations of the patterns.

Recently, multi-resolution transform codes are deemed to be the most promising methods, since the multi-resolution transform feature contains more discriminative power than other features and is more robust for illumination changes.

Therefore, this paper has also presented recognition performance from multi-resolution approach based on Non-Subsampled Contourlet Transform (NSCT) and tested on CASIA Multispectral Palmprint database. (http://biometrics.idealtest.org/dbDetailForUser.do?id=6).

III. Palm Vein Texture Description

The palm vein map represents several particularities since it had a structured pattern, homogeneous, directional, fine, rich, linear details that are interconnected.

When the hand is illuminated with infrared light, the venous network appears in black. It is enrolled as an "identity card" in a database and can be used as a comparison during recognition.

There are two types of "photography"; the first method, which is the most effective, is the "reflective" method and the second is the method of transmission (capture of light passing through the hand). Indeed, when it is cold, the veins contract and the contrast is not visible by the method of transmission while the reflected light is not changed.

Two types of texture can be found; the first is Macro-textures (or structured textures) which is easy to extract visually the basic pattern and the laws of assembling the primitives together. The second is Micro-textures (or random textures) that have a more chaotic appearance and more disorganized, but whose visual impression remains globally homogeneous. Palm vein represent a macrotexture type.

IV. ROI Extraction

ROI extraction should be extremely efficiency due to its importance in the following steps, the performance of the following steps in palm-vein verification systems is highly dependent on the results of the ROI extraction algorithm. In our research there are four stages to get the region of interest:

1) Straighten the palm Vein image with misalignments of the hand '[5]'.

2) Separate the form from the bottom that is not useful to the verification: Binarizing the input image by apply Ost'u thresholding algorithm that gives perfect results faster, directly and simply and that complies with the texture nature of our image.

3) Trace along the outline of the hand to find the possible locations of the valley: Locate the boundary of the palm using an edge detection algorithm which is sobel filter.

4) Detect the key points using competitive hand valley detection algorithm (CHVD) with our new algorithm which Making the perpendicular line passed by each key point previously founded, the perpendicular line is indeed for each point "Pi" which verifies the three preceding conditions, the following pixel is immediately taking on the skin of the hand "Pi + 1" and trace an infinitesimal segment [m1, m2] which passes through the two points (Pi) and (Pi + 1) (m1 is the point Pi and m2 is the point Pi + 1), then the pixel (mj) is located according to the following two conditions:

- The distance between (m1, mj) = c, where c = 1 pixel.
- The angle (m1m2, m1mj) = 90°.

And we repeat its two conditions by increasing the distance m1mj by one pixel each time and keeping the same angle until reaching the edge of the image as illustrated in 'Fig.1'.

5) Extract the region of interest by Making a square around the region of interest (ROI) using the process describe in fig 2. the general process of our ROI extraction method.

The fifth step describes a new effective algorithm to determine a square that characterizes and delimits the region of interest (ROI):

1) 1. Align the second valley point V2 and the fourth valley point V4 (trace the segment [V2, V4]).

2) Calculate the average distance Dm between [V2, V4].

3) Locate points A1 and A2 that meet the following conditions:

- The distance V2A1 = V4A2 = Dm / 4.
- The point A1 is on the perpendicular which goes through V2 and which verifies that the angle (V2V4 ^ V2A1) = -π / 2.

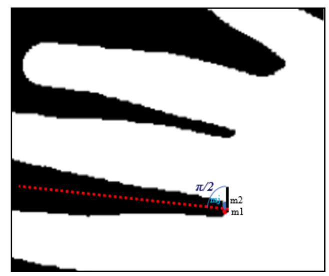

Fig. 1. Perpendicular Line Passed by a Valley.

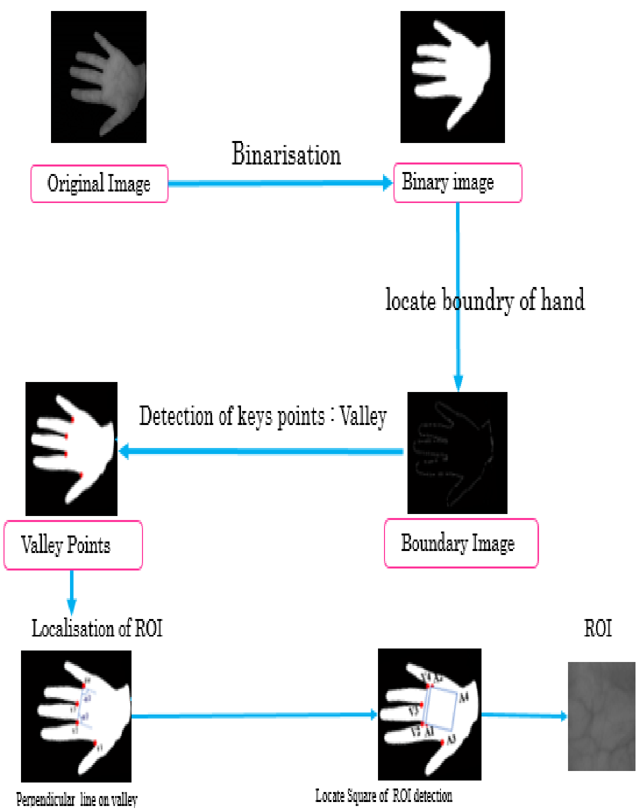

Fig. 2. General Process of ROI Extraction Model using Palm Veins Pattern.

Point A2 is on the perpendicular that goes through V4 and verifies that the angle (V4V2 ^ V4A2) = -π / 2

4) Finally, a side square A1A2 is located on the palm of the hand and the region of interest of the original image is obtained.

V. Palm Vein Feature Extraction

1) General Process: In order to extract the most discriminating information in palm vein texture, the following steps are used:

a) Filtering input images using NSCT on N levels and on L directional subbands.

b) Calculate the phase response information on the NSCT coefficients in each directional subbands.

c) Divide the resulting images into local regions

d) Calculate statistical descriptors for each region in different subbands and directions resulting from the phase response of the NSCT coefficient matrix.

e) From the statistical descriptors obtained, determine a binary code based on the descriptor signs in the resulting directional subbands.

NonSubsampled Contourlet Transform which provides an excellent representation of information in space and spatial frequency is applied.

The input image (ROI) undergoes the first NSCT undoped pyramidal filter and returns an image of single-scale high-pass subbands. It only allows the robust information to be transmitted at the directional NSCT filter. the NSCT coefficient phase response has been chosen since it is the most suitable for palm vein maps because it presents well the orientation of the vein line and has a linear relationship with the dominant orientation angle in a subband.

Let ROI decomposed by the pyramidal and directional filters of the NSCT with J scales and K orientations by scale, and let $S_{jk}(i,j)$ be the coefficient of the subband at position (i, j) at the scale j and the orientation k, where j = 1, 2, ..., J and k = 1, 2, ..., K. as shown in 'Fig. 3' when J = 3 and K = 8, the process is presented in fig. 4.

Phase information (P) at a sub-band at (i, j) is defined as the difference between the coefficient phase at this point and at the next coefficient. Specifically, the P at the spatial location (i, j) of a subband is given by:

$$Pjk(i,j) = \begin{cases} \angle S_{jk}(i,j) - \angle S_{jk}(i,j+1) si 1 \leq k \leq \frac{K}{2} \\ \angle S_{jk}(i,j) - \angle S_{jk}(i+1,j) si \frac{K}{2} \leq k \leq K \end{cases} \quad (1)$$

Where ∠ denotes the phase.

Then a binary signature which represent the palm vein texture description would be extracted. A size of 64*64 ROI is considered so the size of the characteristic vector obtained is 32768 bits. What is considered very important and will increase the overall computation time for recognition system. To reduce the size of the characteristic vector, we proposed to subdivide the phase response image into blocks of (8*8), then a statistical descriptor such as the standard deviation STD, the mean or the mean absolute deviation AAD is calculated in each block. Then, a coding of the characteristic vector is necessary to generate a binary signature. Inspired by the work of '[6]', the matrix of statistical characteristics is linearized and then compared the values of the blocks, each value is compared with the previous one and coded by 1 if it is greater or 0 otherwise. In this way, a binary Vector is obtained with 512 bits of size.

2) Similarity comparison: The verification and identification processes require the comparison between two images by quantifying the similarity rate between their signatures using hamming distance '[7]'seen that a binary vector is obtained as a result of the previous step, this distance is calculated by:

$$HD = \frac{1}{XY} \sum_{x=1,y=1}^{XY} V^1(x,y) \oplus V^2(x,y) \quad (2)$$

With $V^1$and V^2 represent the binary vector of two different images and (x, y) represents the coordinates of the pixel in the X × Y subband image.

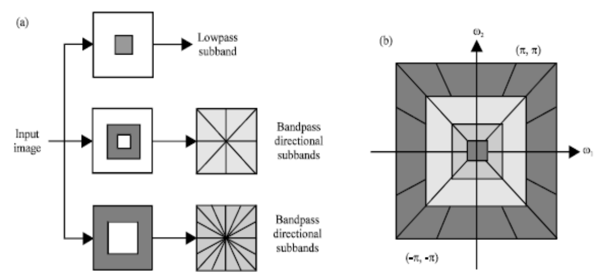

Fig. 3. Nonsubsampled Contourlet Transform: (a) NSCT Structure and its Decomposition Process, (b) Idealized Schematic Diagram of Frequency Resolutions.

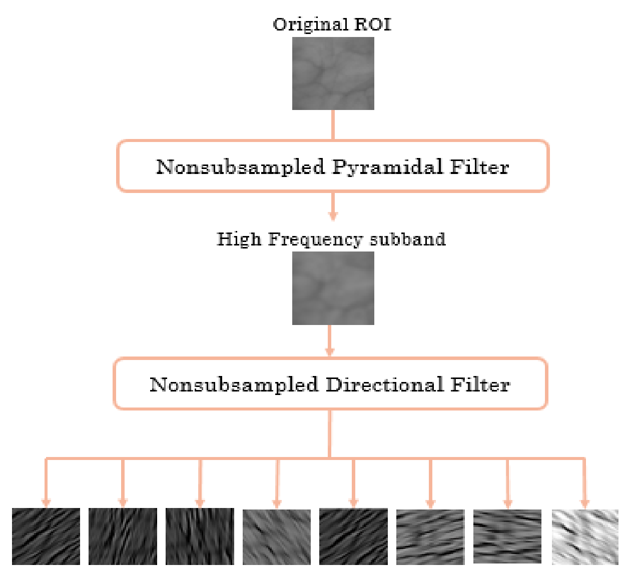

Fig. 4. Palm Vein Decomposition using NSCT.

VI. Experimental Results

In verification mode: When checking, all images are considered in comparison. The performance of this approach is measured through: intra-class and inter-class curves, Detection error tradeoff (DET curve), equal error rate (EER), decidability and degree of freedom.

During the experiments, Hamming distances is calculated and characterize "one to one" comparisons and determine the distribution of similar (genuines) vectors represented by the intra-class curve and the distribution of non-similar vectors (impostors) represented by the inter-class curves as shown in 'Fig 5'.

The total number of operations is 35,9400, distributed as follows: 3,000 authentic and 716,400 imposters.

The overlap corresponding to a zone of doubt means that false acceptances and false rejected whose rates depend on the separation threshold from which any candidate is considered as impostor.

The value of the threshold is varied between 0 and 1 by looking at the overlap area delimited by a range of Hamming distances between 0.13 and 0.14 and each time, the corresponding FAR and FRR in calculated. This work has been repeated for several illuminator wavelength values and their curves have grouped in , which finally allowed to obtain the DET curve shown in 'Fig.6' which shows that the performance of the system clearly depends on the value of the illuminator wavelength that is an optimal ERR equal to 0.19% for 940 nm.

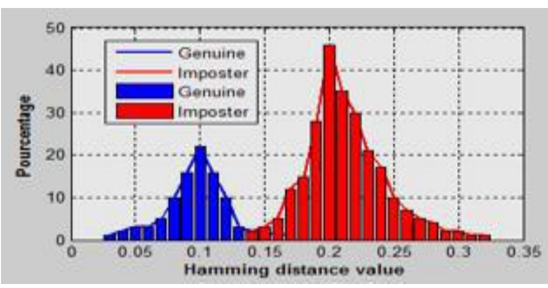

Fig. 5. Illustration of Intra-Class and Inter-Class Distributions.

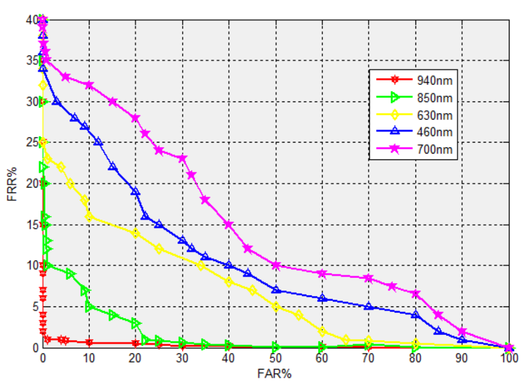

Fig. 6. DET Curves: Illustration of the Evolution of the FAR According to the FRR.

VII. Comparison and Discussion

In order to validate the performance of the presented approach in verification mode, results are compared with others obtained by the methods of: Derived from the Gaussian filter of '[8]', Wavelets of '[9]' and Gabor Wavelet Filter of '[10]' on the same database "CASIA multispectral Database". The DET curves in 'Fig.7' illustrating the evolution of the FAR according to the FRR, allow us to perform a graphical comparison in verification mode between the different methods. In fact, the red curve relating to our method coincides with the ordinate axis, which is not the case for the representative curves of the Wavelet and Gabor wavelet filter methods.

Table 1 summarizes the analytical results of the EERs obtained from the DET curves for the different methods studied. The proposed approach minimized the error of 2.69% compared to the Gaussian filter derivative method, 0.67% compared to the Gabor Wavelet Filter method and 0.3% compared to the method of wavelets.

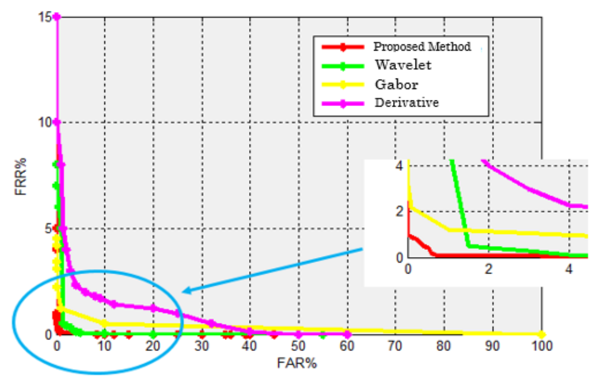

Fig. 7. DET Curves: Comparison of different Methods.

TABLE. I. EER Comparison of Different Approaches

Method	EER %
NSCT	0,19
Derivative of Gaussian Filter	2.88
Gabor	0.86
Wavelet Filter	0.49

VIII. Conclusion

A palm vein characterization approach is proposed, in which invariant, multi-scale and multidirectional NSCT coefficients are used as effective characteristics of the venous card. The region of interest of the palmar vein image is used as the input of the NSCT and the phase response information of the NSCT coefficients in each directional subband is used to extract the characteristics. An encoding technique is provided to generate 512 bytes of binary signature.

Finally, the similarity between the models is estimated by the calculation of the Hamming distance. The NSCT transformation is a truly two-dimensional transformation that captures the intrinsic geometric structures of the image.

In this paper results in verification mode are presented, in a future work the performance of biometric system on identification mode will be studied.

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