SWT based Composite Method for Fingerprint Image Enhancement

K. V. Kale *Member, IEEE*, R. R. Manza, S. S. Gornale, P. D. Deshmukh[#] and Vikas Humbe
Department of Computer Science and Information Technology,
Dr. Babasaheb Ambedkar Marathwada University,
Aurangabad (MS) - 431 004 India
[#]MGM'S Dr.G.Y.Pathrikar College of Computer Science and IT, Aurangabad (MS) India
kvkale91@rediffmail.com

Abstract-

New technology for recognizing fingerprints for security purposes is proving as regards as reliable but efficient recognition is depending on the quality of input fingerprint image. Recognition of the fingerprint becomes a complex computer problem while dealing with noisy and low quality images. The proposed SWT based composite method is used for fingerprint image enhancement using SWT transform, morphological operation, quick mask and spatial filters. We have applied proposed method on FVC2002 fingerprint database and experimental results shows that this composite method is more effective and robust than the other existing method. Finally the result has compared using the texture descriptors.

Keywords- Stationary Wavelet Transform (SWT), Morphology, quick mask, texture analysis, ridge, valley etc.

I. INTRODUCTION

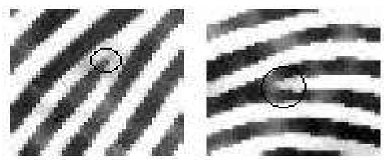
Biometric system is an imperative area of research in recent years. The biometric system having two important utility 1) authentication or verification and 2) Identification in which persons identity is verify by biometric sign. The biometric system consists different signs like fingerprint, face, iris, hand, pam etc. Out of these signs fingerprint is the oldest and more reliable sign used for identity [1] [2].

In a recent published World Biometric Market Outlook (2005-2008), analysts predict that while the average annual growth rate of the global biometric market is more than 28%, by 2007. The technologies that would be included are fingerprint technology by 60%, facial & iris by 13%, keystroke by 0.5% and digital signature scans by 2.5% [3]. The fingerprint recognition system basically divided into image acquisition, enhancement, feature extraction and matching. The enhancement stage is of great importance as it influences the performance of subsequent feature extraction and matching.

The most common method use to acquire the fingerprint image is to obtain the impression by rolling an inked finger on paper and then scan it using flat bed scanner. This method may result in highly distorted fingerprint images and thus it should be carried out by a trend professional. The live scan method provides better images and therefore it does not need expertise but highly distorted images are still possible because of dryness of skin, skin disease, sweat, dirt or humidity. The performance of fingerprint recognition system is depends on the quality of input fingerprint image. If the quality of input fingerprint is not good, automatic fingerprint identification or authentication is extremely difficult [4-8].

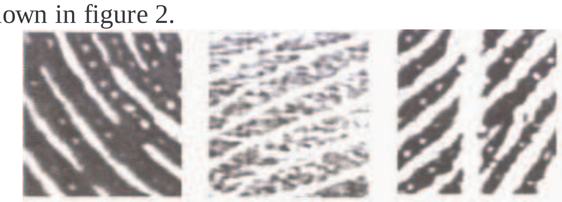
II. FINGERPRINT ENHANCEMENT

Enhancement is a process for improving the appearance or stability for particular image. In fingerprint recognition system the enhancement is an essential step, it provide a quality image, so that the feature extractor can obtain precise minutiae. Minutiae are local discontinuities in the fingerprint pattern. The most important ones are ridge ending and ridge bifurcation illustrated in figure 1.



(a) ridge ending (b) ridge bifurcation
Figure 1: Example of minutiae

The overall performance of the system is highly dependant on the fingerprint image quality i.e. a good quality input image gives a good performance whereas a poor quality image yields a poor performance. But in most of the cases a fingerprint image contains region of good, medium and poor quality, where in the ridge and valley pattern are very noisy and corrupted due to the various reasons as specified above, as shown in figure 2.



a) Wet Finger b) Dry Finger c) Wrinkle
Figure 2: effect of various sources of degradation on the gray scale image.

To solve these problems, several approaches have been used for fingerprint image enhancement, based on a wide variety of tool such as the Fourier transform [9], Wavelet transform [10-12], Gabor filters [6, 13-14] etc, and for minutiae filtering, applied to binary [15] or gray-scale images [16] but still the problem exists for noisy and low contrast images.
In this paper we have propose a new approach that combines the stationary wavelet transform (SWT) with morphological

operations, quick mask, spatial filtering for fingerprint image enhancement.

III OVERVIEW OF SWT

Wavelet transform is superior approach time-frequency analysis tools because its time scale width of the window can be stretched to match the original signal, especially in image processing analysis. Particularly it has a better performance when it is applied to non-stationary signal analysis such as noise removal and transient detection. Discrete wavelet transform (DWT) provides the useful information for texture analysis in the fingerprint image. DWT is multiresoluiton analysis, which is a non-redundant decomposition due to non-invariance in time [17]. The Stationary Wavelet Transform was proposed to make the decomposition time invariant [18] [19]. In order to preserve the invariance by translation, the down sampling operation must be suppressed and the decomposition obtained in redundant form, which is to be referred as Stationary Wavelet Transform, depicted in figure 3. The redundancy of this transform facilitates the identification of salient features in a signal, especially for recognizing the noises. This approach gives good result for images but not for signal analysis.

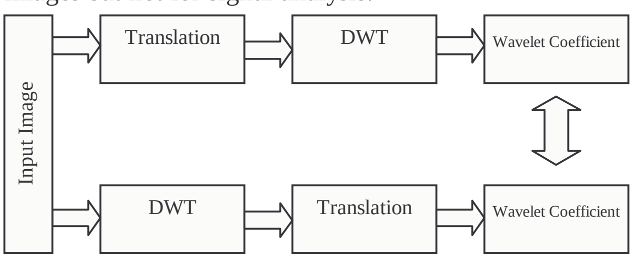


Figure 3: Stationary Wavelet Transform

SWT has similar tree structure implementation without any sub-sampling. This balance of Perfect Reconstruction (PR) is preserved through level dependent zero padding interpolation of respective low pass and high pass filters in the filter bank structure. In fingerprint image decomposition, separate the variables x, y of fingerprint image and have the following wavelets [20].

Vertical wavelet(LH): $\varphi^1(x,y) = \phi(x)\varphi(y)$ …(1)

Horizontal Wavelet(HL): $\varphi^2(x,y) = \varphi(x)\phi(y)$ …(2)

Diagonal Wavelet(HH) : $\varphi^3(x,y) = \varphi(x)\varphi(y)$ …(3)

Where, φ is the wavelet function and ϕ is the scaling function. The detailed signals contained in the three sub-images as follows:

$$w^1_{j+1}(k_x,k_y) = \sum_{lx=-\infty}^{+\infty}\sum_{ly=-\infty}^{+\infty} g(lx)h(ly)c_{j,k+2^j}(lx,ly) \quad \ldots(4)$$

$$w^2_{j+1}(k_x,k_y) = \sum_{lx=-\infty}^{+\infty}\sum_{ly=-\infty}^{+\infty} h(lx)g(ly)c_{j,k+2^j}(lx,ly) \quad \ldots(5)$$

$$w^3_{j+1}(k_x,k_y) = \sum_{lx=-\infty}^{+\infty}\sum_{ly=-\infty}^{+\infty} g(lx)g(ly)c_{j,k+2^j}(lx,ly) \quad \ldots(6)$$

IV. SWT BASED COMPOSITE METHOD

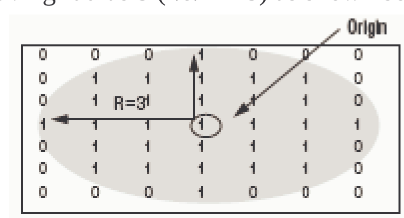
Here, the main purpose of applying this algorithm is to get more clarity of ridge and valley structure for preserving precise minutiae. The component of this method are categorized as follows:

A. Morphological Operation

Morphology is a biological term that deals with the structure and shapes that's why we found more suitable for the fingerprint image enhancement. When we perform the morphological operation like dilation and erosion, the *structuring element* plays an important role. Mathematical morphology is a comparing the objects contained in an image with known object called *structuring element (SE).* In fingerprint image enhancement the dilation (⊕) and erosion (Θ) are used most often in combination using the same or different structuring element. In this paper we have used the morphological opening, which is, defines as A o SE is simply erosion of A by SE followed by dilation of the result by SE [21].

$$(A \circ SE) = (A \Theta SE) \oplus SE \quad \ldots(7)$$

Here, we used the disk shaped structuring element (SE=disk) having radius 3 (i.e. R =3) as shown bellow:



This operation is useful for enhancing details in the presence of the ridge structure. Morphology offers a unified and powerful approach to numerous enhancement of fingerprint structure. The purpose of morphological operation is segmenting the foreground region from the background region and removes superfluous information.

B. Decomposition with SWT

When we get the segmented image we can decompose the segmented image into a multiresoluiton representation using Stationary Wavelet Transform (SWT). Here, we select the Daubechies wavelet at level 1 and 2, result as shown in figure 4 and figure 5. Generally, we can select any levels to decompose the image. Here, we select one and two level to decompose fingerprint image because more level decomposition can vanish the orientation characteristic of ridge structure. The benefit of this selection is to preserve the ridge structure. Second level gives better result than first. Here we applied the quick mask on the diagonal sub-image.

The quick mask is applied with spatial filtering as described in section C and E respectively.

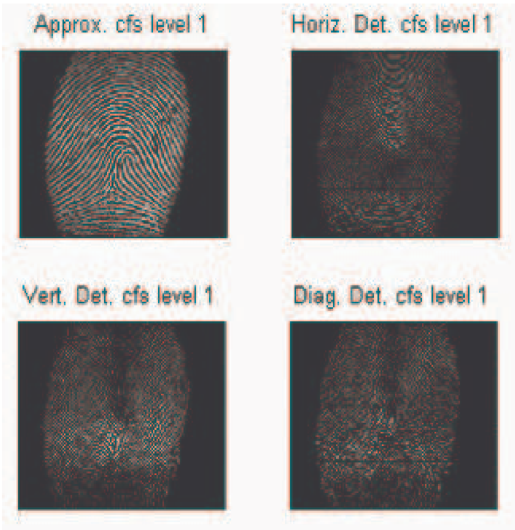


Figure 4: SWT Decomposition at level 1.

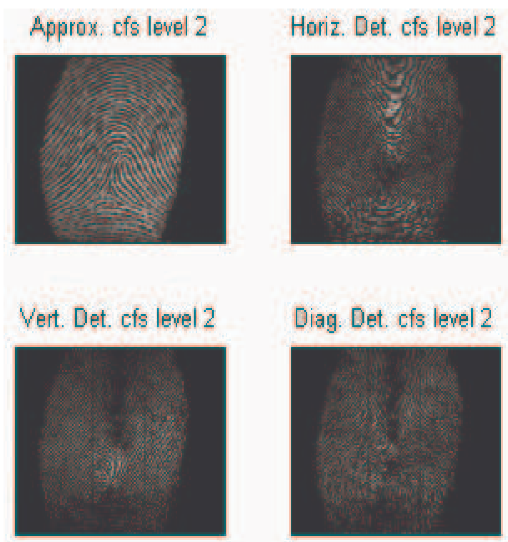


Figure 5. SWT Decomposition at level 2.

C. Quick Mask

One of the principal approaches for edge detection is based on the use of mask also called as filter, kernels, templates, or windows. There are two basic principles for each edge detector mask. The first is that the numbers in the mask sum to zero. The second basic principal is that the mask should approximate differentiation or amplify the slope of the edge. Researcher's have used different techniques to derive mask and then experimented with them to discover more masks. The few famous and more applicable masks for edge detection are Kirsch, Prewitt, Sobel, Canny, Roberts, Laplacian etc. Another most important mask is *quick mask* created by Dwayne Philips [22]. Except quick mask above all masks are compass gradient or directional edge detectors. This means that to detect all eight directional connectivity neighbors we have to apply eight different masks. If, you want to detect all of the edges, you would need to perform convolution over an image eight times using the eight different masks. The quick mask is so named because it can detect edges in all eight directions in one convolution this as obvious speed advantages when you want to detect all the edges. Here we applied the quick mask by using the spatial filtering on diagonal sub-image the results as show in figure 6.

D. Reconstruction

After modifying the diagonal coefficients sub image with quick mask, we can reconstruct the image. The image is reconstructed by using the inverse SWT on the processed data. This resultant image is passed for spatial (smoothing) filter for further processing.

(a) (b)

Figure 6: (a) Original Image (b) Reconstructed

E. Spatial Filtering

Fingerprint requires the enhancement of small areas and details. A possible way of processing the image is by considering not only the pixel itself, but also the neighborhood of it at every location in the image. Linear filtering of image *f* of size m-by-n with the filter kernel *w* of size s-by-t can define as follows [21-23]:

$$g(x,y) = \sum_{s=-(m-1)/2}^{(m-1)/2} \sum_{t=-(n-1)/2}^{(n-1)/2} w(s,t)\, f(x+s, y+t) \qquad \ldots(8)$$

Where, x=0,1,2,…….m-1, and y=0,1,2,…….n-1. In the experimental work we have used the average filter mask (w) of size 5-by-5. This spatial linear filter is applied on the reconstructed image and the final resultant image is shown in figure 7.

V. EXPERIMENTAL RESULTS AND ANALYSIS

In the experimental work the proposed SWT based composite method is applied on FVC2002 fingerprint Database.

(a) (b)

(c) (d)

Figure 7: (a) (c) Original Image (b) (d) Resultant

We compare the result with some texture descriptor based on the intensity histogram viz.; 1. Mean (M): It measures the average intensity of given image 2. Standard Deviation (σ): It measures the average contrast of the image. 3. Smoothness (S): It measures the relative smoothness of the intensity in a region. S is 0 for a region of constant intensity and approaches 1 for regions with large excursions in the values of its intensity levels. The variance used in this measure is normalized to the range 0 to 1. 4. Uniformity (U): It measures uniformity. It is maximum when all gray levels are equal (maximally uniform) and 5. Entropy (E): It measures the randomness. All these texture descriptors are defined respectively as follows:

$$M = \sum_{i=0}^{l-1} x_i \, p(x_i) \qquad \ldots(9)$$

$$\sigma = \sqrt{\mu_2(x)} = \sqrt{\sigma^2} \qquad \ldots(10)$$

$$S = 1 - 1/(1+\sigma^2) \qquad \ldots(11)$$

$$U = \sum_{i=0}^{l-1} p^2(x_i) \qquad \ldots(12)$$

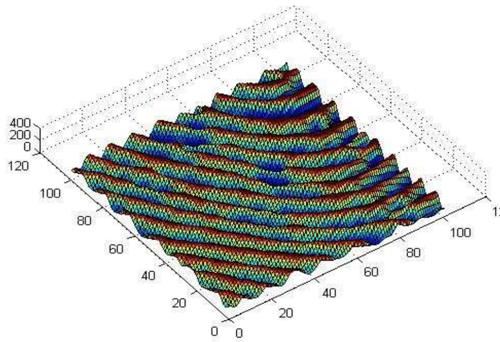
$$E = \sum_{i=0}^{l-1} p(x_i) \log_2 p(x_i) \qquad \ldots(13)$$

Where the x_i is the random variable indicating intensity value, $p(x)$ is the histogram of the intensity levels in a region, l is the number of possible intensity levels.

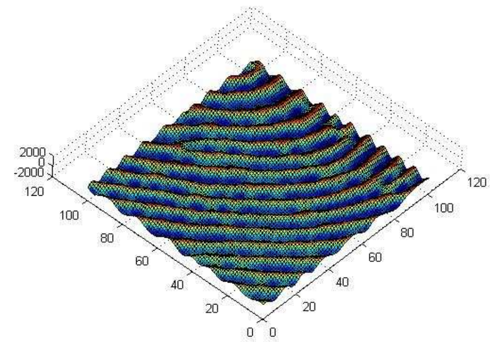
These descriptors are tested on several images and some of the comparative result of before and after enhancement is predicted in table 1. From this table, it is observed that there is variation in between before and after enhancement, it also indicate that after enhancement, all the values obtained in the same range specified in all texture descriptors. We illustrated the 3-Dimensional view of cropped fingerprint image sample 1, before and after enhancement in figure 8. The graphical representation of effect of SWT based composite method on various types of fingerprint images in terms of (a) standard deviation and (b) smoothness as before and after enhancement shown in figure 9.

Table 1: Represents the description of 1) Mean (M) 2) Standard Deviation (σ) 3) Smoothness (S) 4) Uniformity (U) and 5) Entropy (E)

Images	**Mean (M)**		**Standard Deviation (σ)**		**Smoothness (S)**		**Uniformity (U)**		**Entropy (E)**	
	Before	After	Before	After	Before	After	Before	After	Before	After
1	152.1482	146.7871	73.5592	125.9815	0.0768	0.1962	0.0125	0.5100	7.5691	1.0023
2	167.0315	152.4241	78.0520	125.0227	0.0587	0.1938	0.0425	0.5186	7.0201	0.9790
3	191.3521	157.8404	28.1111	123.7944	0.0120	0.1907	0.0106	0.5273	6.6782	0.9722
4	185.5375	156.6282	69.5205	124.0936	0.0692	0.1915	0.0838	0.5254	6.3850	0.9715
5	143.3708	118.3064	81.8752	127.0611	0.0935	0.1989	0.0395	0.4983	6.7990	1.0502
6	120.7261	137.6370	60.0727	127.0581	0.0526	0.1989	0.0069	0.5021	7.4947	1.0090
7	149.0006	144.3407	73.9294	126.3679	0.0775	0.1972	0.0238	0.5083	7.2337	0.9926
8	177.5506	149.4709	62.0524	125.5651	0.0556	0.1952	0.0437	0.5142	6.7261	0.9866
9	163.4251	152.8823	71.8757	124.9118	0.0736	0.1935	0.0233	0.5190	7.3283	0.9832
10	178.9457	151.4860	74.6373	125.1577	0.0789	0.1941	0.0694	0.5159	6.6098	0.9992

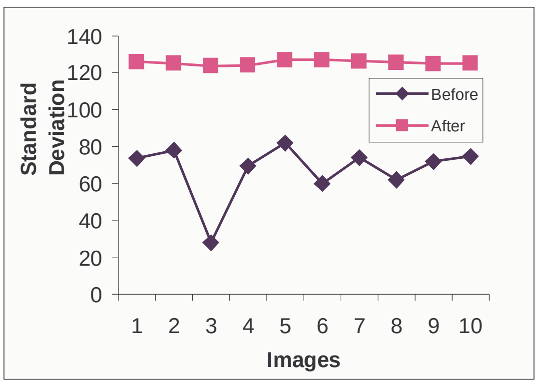


(a)

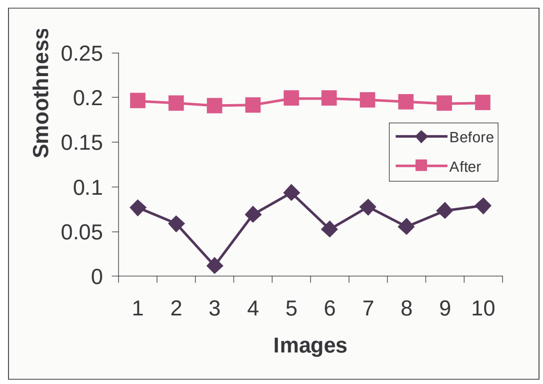


(b)

Figure 8: 3D view of (a) before and (b) after enhancement.



(a)



(b)

Figure 9: show the graphical representation of effect of SWT based composite method on various types of fingerprint images in terms of (a) standard deviation and (b) smoothness as before and after enhancement.

VI. CONCLUSION

In this paper, we present a novel SWT based Composite method to deal with fingerprint image enhancement. The new approach adopts the denoising by SWT.

The SWT based composite method provided better results on low contrast and noisy fingerprint images. Morphological operations eliminate superfluous details, smaller than the structuring element, without affecting its universal features of fingerprint. Further the quick mask is applied on processed data and found more useful to connect broken ridges of all eight direction within one convolution operation, hence its saves computational efforts and finally the some obtained result has compared using texture descriptor, before and after enhancement.

This approach has an obvious advantage, in time invariance and useful in recognizing the noises in fingerprint images and also useful for improving the recognition performance.

ACKNOWLEDGEMENT

This research work is supported by University Grant commission, New Delhi, India (F. 14-14/2003(SR)).

REFERENCES

[1] Davide Maltoni, Dario Maio, Anil K. Jain and Salil Prabhakar, "Handbook of fingerprint recognition" Springer-Verlag, 2003.

[2] L.C. Jain, U. Halici, I.Hayashi, S.B. Lee, S. Tsutsui, "Intelligent Biometric Techniques in Fingerprint and Face Recognition", by CRC Press LLC, 1999.

[3] RNCOS's Market Research Report "World Biometric Market Outlook (2005-2008)", 22nd March 2006 (IT Market Research)

[4] K. V. Kale, R R Manza, V. T. Humbe and Prapti Deshmukh, "Fingerprint image enhancement using Composite Method", GSPx-2005 Pervasive Signal Processing Conference, California USA, 24-27 Oct, 2005.

[5] Ling Hong, Yifei Wan, A.K. Jain, "Fingerprint Image Enhancement: Algorithm and Performance Evaluation", IEEE, Tran. On Pattern Analysis and Machine Intelligence, vol. 20. pp. 777-789, Aug-1998.

[6] Lin Hong, A. K. Jain, Sharth Pankanti, Ruud Bolle, " Fingerprint enhancement", IEEE in proc. WACA, PP.202-207, sarasota, FL, 1996.
[7] Louis Coetzee and Elizabeth C. Botha, "Fingerprint Recognition in Low Quality Images", Pattern Recognition, vol. 26. No. 10, PP.1441-1460, 1993.
[8] A. K. Hrechak and J. A. McHugh, "Automatic Fingerprint Recognition using Structural Matching", Pattern Recognition vol. 23, PP. 893-904, 1990.
[9] B. G. Sherlock, D. M. Monro, and K. Millard. "Fingerprint enhancement by directional fourier filtering" IEEE Proceedings in Visual Image Signal Processing, Vol.141(2),PP87–94, April 1994.
[10] C. Hsieh, E. Lai, and Y. Wang. "An effective algorithm for fingerprint image enhancement based on wavelet transform", Pattern Recognition, Volume 36:303–312, 2003.
[11] Wei peng Zhang et al, "A wavelet based method for fingerprint image enhancement", Proceedings of the first international conference on Machine learning and Cybernetics, PP. 1973-1977, November 2002
[12] Keita Torii and et al, "An effective Algorithm for Detecting valley of fingerprint based on wavelet transform" IEEE Canadian Conference on Electrical & Computer Engineering, PP. 1223-1226, May 2003
[13] Greenberg, M. Aladjem, and D. Kogan, "Fingerprint image enhancement using filtering techniques", Real Time Imaging, Vol.8, PP. 227–236, 2002.
[14] J. Yang, L. Liu, T. Jiang, and Y. Fan. "A modified gabor filter design method for fingerprint image enhancement", Pattern Recognition Letters, Vol. 24 PP.1805–1817, 2003.
[15] D. Hung. "Enhancement and feature purification of fingerprint images", Pattern Recognition, Vol. 26(11) PP.1661–1671, 1993.
[16] Maio.D. maltioni D, "Direct grayscale minutiae detection in fingerprints" IEEE Tran. On Pattern analysis & Machine Intelligence Vol. 19(1), pp-27-40, 1997.
[17] S. Mallat, "A Theory of Multiresolution Signal Decomposition: The Wavelet Representation," IEEE Trans. Pattern Analysis and Machine Intelligence, vol. 11, pp. 674-693, 1989.
[18] J. C. Pesquet, H. Krim, and H. Carfantan, "Time-invariant orthonormal wavelet representations," IEEE Trans. Signal Processing, vol. 44, pp. 1964–1970, Aug. 1996.
[19] Warin Chumsamrong and et al, "Using Stationary Wavelet Transform in the classification of SAR Images", 19^{th} Asian Conf. on Remote Sensing, 16-20 Nov, 1998
[20] X. H. Wang, Robert S. H. Istepanian, and Yong Hua Song, "Microarray Image Enhancement by Denoising Using Stationary Wavelet Transform" IEEE Tran. on Nanobioscience, Vol. 2, No. 4, 2003
[21] Rafael C. Gonzalez, Richard E Woods, "Digital Image Processing", Second Edition, Pearson Education, 2003
[22] Dwayne Phillips, "Image Processing in C", BPB Publications, Ist Indian edition, 1995.
[23] John C. Russ, "The Image Processing Handbook", 3^{rd} edition CRC Press 1999.