APPLICATION OF FRACTIONAL WAVELET TRANSFORM FOR IMAGE AUTHENTICATION

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ABSTRACT

In this paper Fractional Wavelet Transform (FrWT) is chosen for fingerprint authentication. It is a new family of wavelet transform that is based on well defined scaling functions, the Fractional B-splines. Fractional wavelet transforms perform better than other wavelets due to their superiority of more energy compactation in approximation coefficients. This paper also presents simulation results of filter banks of FrWT and reveals the suitability and superiority of this transform for fingerprint authentication. Experimental results using Block Based Approach demonstrates the efficiency of the proposed algorithm in fingerprint authentication. Parameters like Energy, SSIM, UIQI, FAR and FRR are measured. It is observed that the proposed method outperforms some of the other existing algorithms with respect to above parameters.

Keywords: fractional wavelet transform, fingerprint image authentication, filter bank, energy, SSIM, UIQI, FAR, FRR parameters, biometrics.

1. INTRODUCTION

Fractional wavelet transforms has all the features of Wavelet Transform (WT) and it represents the signal in Fractional domain. It projects the data in time-fractional-frequency plane whereas the Wavelet Transform provides the data in time-frequency plane. This paper introduces the Block Based Approach (BBA) which is performed on images, it divides the latter into different sizes of blocks like 2x2, 4x4, 8x8 and so on and exploits statistical parameters of an image for each block of various sizes. It uses less overhead, reduces memory consumption and time consumption. Authentications of fingerprints are made through Block Based Approach using FrWT and fingerprint images are taken from DB1_B database. Some of the common challenges related to fingerprint authentication are low quality, low frequency and distorted images. The real wavelets used in image processing lack the shift invariant and the rotation invariant properties which are essential in image authentication. To overcome these disadvantages, I.W.Selesnick *et al.*, [1] formulated the Dual_Treeℂomplex Wavelet Transform (DT-ℂWT) which possesses different sets of PR filter banks at each stage with half sample delay condition. To avoid different sets of PR filter banks at each stage Thierry Blu and Micheal Unser [2] proposed Fractional Wavelet. Transform which have identical filter banks at all stages which ease the design aspect. However to avoid computational complexity further we propose to use BBA in association with FrWT. Fractional Wavelet transform introduced by Thierry Blu and Micheal Unser [3, 4] is a new family of scaling functions, the size and location of which are governed by the two parameters namely α (order) and τ (shift). It also involves binomial distribution, approximation theory and numerical analysis.

The rest of this paper is organized as follows: Section II describes the Fractional Wavelet Transform and in Section III emphasis is on its filter bank implementation. Section IV deals with feature extraction by determining the mean of each block as feature vector. Section V elaborates performance measures like energy, SSIM, UIQI of the Fractional Wavelet coefficients, FAR and FRR. To justify the usefulness of proposed algorithm for fingerprint image authentication, comparative study with other previous techniques is discussed. The results indicate that the proposed technique improves FAR and FRR.

2. FRACTIONAL WAVELET TRANSFORM (FrWT)

FrWT provides flexible time -fractional - frequency window which automatically shrinks with small scaling factor (high fractional frequency) and stretches with large scaling factor (low fractional frequency) and enables more degrees of freedom with varying orders and are highly suitable for image processing [5].

The FrWT of a 2Dfunction is given by

$$W^{\alpha_x \alpha_y}(s_1, \tau_1, s_2, \tau_2) = FrWT^{\alpha_y}_{t_{y\to v}}\left\{FrWT^{\alpha_x}_{t_{x\to u}}\{f(t_x, t_y)\}\right\} \qquad (2.1)$$

Where $s_1, s_2, and, \tau_1, \tau_2$ in equation (2.1) are dilation and translation parameters along x and y directions [6]. The Riesz basis criterion, Refinability, Partition of unity are some of the properties satisfied by this transform which are required for image authentication [7]. Table-1 shows the comparison of existing FrWT types, its scaling function (φ) and wavelet function (ψ) and their significant features which are simulation results obtained through ImageJ software and it is the pure Java image processing program [8]. The orthogonal, B and dual splines produce filters of ortho, B and symmetric filters, respectively.

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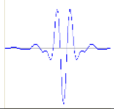
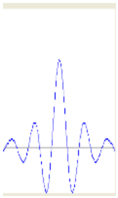
Table-1. The scaling functions and associated wavelet functions and their properties.

Type of splines and property	Scaling function	Wavelet function
O-Splines and Orthoganality		
B-splines and compact support, high degree of precision		
Dual splines and fully adjustable, mulyi-scale, non redundant decomposition		

3. FILTER BANK IMPLEMENTATION

The perfect filter banks are systems where there are no errors at the output i.e. output is a delayed version of the input [9]. The FrWT filters are FIR and are tuned to the length of the signal. To transform images using wavelets apply the one dimensional transform to the rows and columns of the image successively. In general two channel filter bank consists of two low pass filters $H(Z)$, two downsamplers, two high pass filters $G(Z)$ and two upsamplers. The downsamplers remove all the odd-numbered samples, and the upsamplers insert a zero between every pair of samples as shown in Figure-1. Each synthesis iteration costs the same as analysis iteration and produces reconstructed signal $\hat{x}(n)$

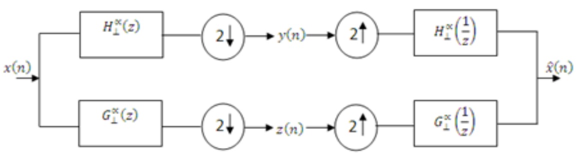


Figure-1. Analysis/synthesis filter banks with fractional splines.

$Y(n)$ and $Z(n)$ represents outputs of lowpass and highpass filters. The analysis and synthesis filter banks for Integer orders and Fractional orders are discussed.

3.1. Characteristics of fractional wavelet transform

3.1.1. Filter bank characteristics for integer orders

The impulse and frequency response of the filters describe the effect of the filter on signal input at different frequencies and z-plane characteristics state their stability.

Impulse response, frequency response of analysis and synthesis filters and roots in Z plane of a FrWT for integer orders are shown in Figures- 2 (a), (b), (c) and (d), respectively. The low pass filters produce low resolution signal approximation while high pass filter extracts wavelet components and the filters possess the linear phase property. The impulse responses obtained are asymmetric.

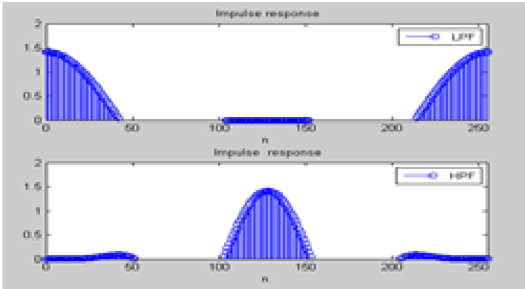


Figure-2(a). Impulse response of FrWT filters.

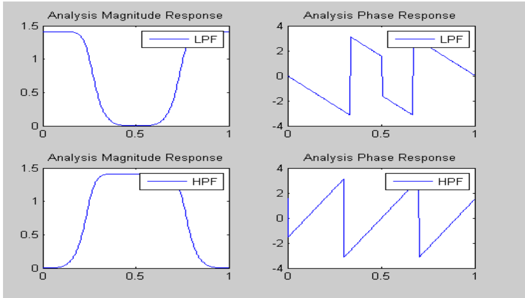


Figure-2(b). Magnitude and phase response for integer orders - Analysis filters.

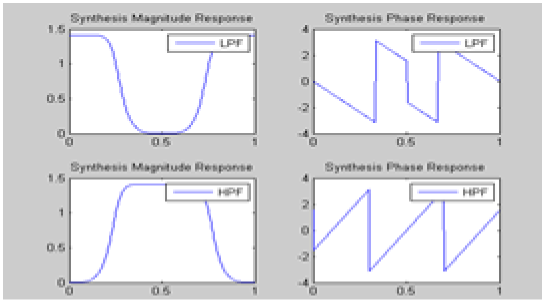


Figure-2(c). Magnitude and phase response of.

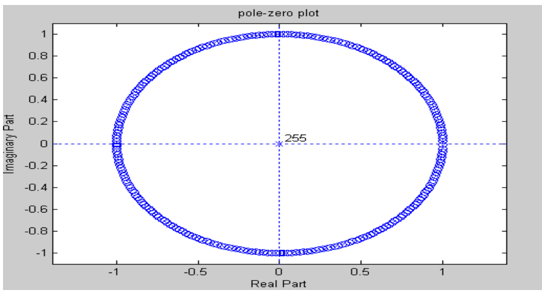


Figure-2(d). Z-plane characteristics-synthesis filters.

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The scaling and wavelet function of FrWT for integer orders are depicted in Figures 3(a) and 3(b), respectively. These functions are piecewise functions and smoothness is not observed in case of integer orders and it does not coincide with the signal for perfect reconstruction and hence fractional orders are preferred.

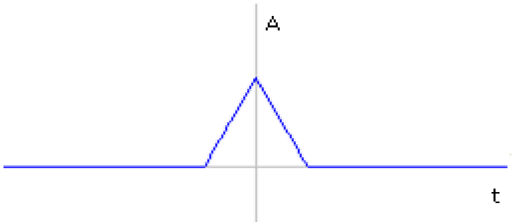

Figure-3(a). Scaling function (Integer order).

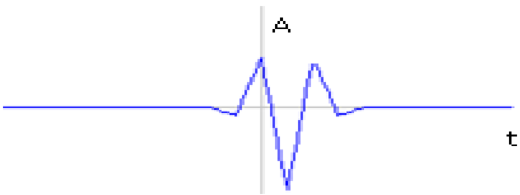

Figure-3(b). Wavelet function (Integer order) for α (order) = 1.

3.1.2. Filter bank characteristics for fractional orders

Impulse response, frequency response of analysis and synthesis filters and roots in Z-plane characteristics of FrWT filters with fractional order and are shown in Figures 4(a), (b), (c), (d), respectively. The filters possess the linear phase property, which is required for the image authentication purpose. The impulse responses obtained are symmetric.

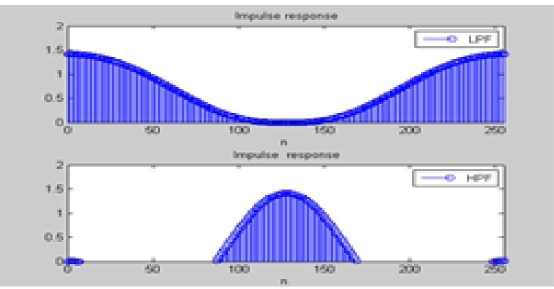

Figure-4(a). Impulse response of FrWT filters.

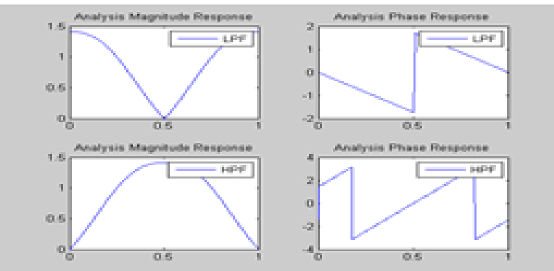

Figure-4(b). Magnitude response and phase response for fractional order - Analysis filters.

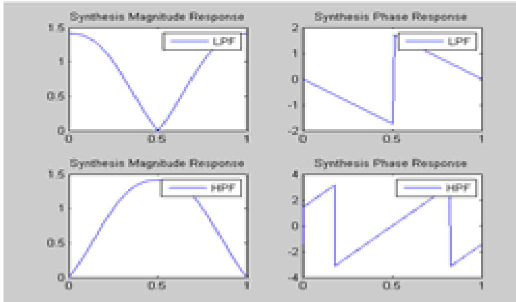

Figure-4(c). Magnitude and phase response of filters.

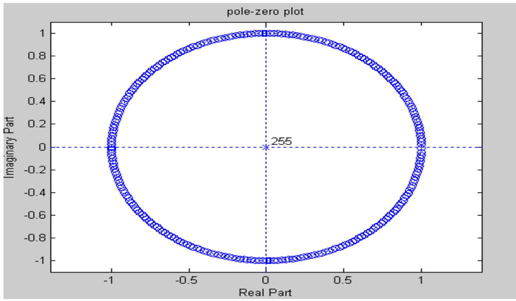

Figure-4(d). Z-plane characteristics-synthesis.

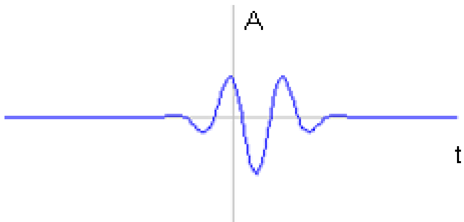

Figure-5(a). The scaling function (Fractional order).

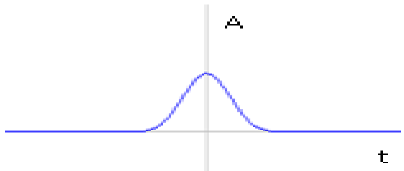

Figure-5(b). The wavelet function for α = 2.5.

The scaling and wavelet function of FrWT for fractional orders are depicted in Figure-5 (a) and 5(b), respectively. These functions are spline functions and smoothness is observed in case of fractional orders and more degrees of freedom can be used for processing the image signal for better results.

The Figure-6(a) shows the original image of fingerprint and Figures 6 (b, c, d) shows decomposition of the image at varying levels 1, 2, 3, respectively and the block at the upper left corner of each image gives the coarse approximation of the original image and other sub bands giving the details of image and the energy concentrated in these bands are less. It is very clearly evident that most of the signal energy is concentrated at the approximation level. In this paper, first level

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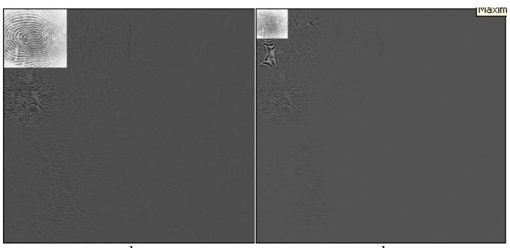
decomposition for image authentication is preferred as the energy compactation is more and subsequently decreases for second and third level of decomposition. The energy parameters are shown in Table-2 where C_A, C_H, C_V *and* C_D represents approximation, horizontal, vertical and diagonal components, respectively of FrWT decomposition.

(a) Original image **(b)** 1st level



(c) 2nd level **(d)** 3rd level

Figure-6. FrWT decomposition of the image.

Table-2. Energy compaction of a FrWT of images of varying levels.

Levels of decomposition of FrWT	Energy in C_A (%)	Energy in C_H (%)	Energy in C_V (%)	Energy in C_D (%)
First	98.33	1.24	0.3	0.1158
Second	94.01	3.1	1.05	0.4071
Third	89.23	7.59	1.78	1.201

Table-3. Comparison of time taken to authenticate fingerprint image.

Type of comparison	Time in seconds
Direct one to one matching	256 sec
Block based approach (2 x 2) size	64.235 sec

In this work, for image authentication two approaches are possible, they are direct one to one mapping and block based approach. Time consumption for fingerprint authentication using one to one approach and BBA are shown in Table-3. It is observed that Block Based Approach is consuming less time and hence this approach is preferred in this paper.

4. A B-SPLINE WAVELETS APPROACH TO IMAGE AUTHENTICATION

The objective of this application is to explore the capability of B-spline wavelets and to improve fingerprint image authentication. Our idea is based on the fact that these functions act like fractional differentiators. The proposed algorithm of fingerprint authentication using block based approach provides an inductive method which is given below. The idea of the block based approach is to divide the image of size 256 × 256 into contiguous non overlapping square blocks that are almost invariably powers of two which are $2^d \times 2^d$ where d = 1, 2, 3, 4. The dimensions of the blocks are 2 × 2, 4 × 4, 8 × 8, 16 ×16, 32 × 32, 64 × 64 and 128 × 128 [10].

Algorithm

a) Reference image of size N x N is taken.
b) The image is partitioned into block size M x M where M varies from 2 to 128.
c) Fractional Wavelet coefficients for each block are computed.
d) Approximation coefficients CA1 of such blocks are considered and mean μ of these coefficients are computed and stored in array A.
e) Steps 2, 3 and 4 are repeated for test image. Mean of the test image's approximation coefficients CA2 are computed and stored in array B.
f) The 1D arrays of A and B are compared.
g) One mean value of test image in array A is compared with all mean values of reference images in array B and if it matches with anyone then the count is incremented and this process is repeated for all mean values of test image.
h) If the number of matching values are greater than or equal to the threshold value which is the number of mean values of block size then the fingerprint is matched.

The approximation coefficient CA1 only is considered as they contain most of the information and is rather justified in Section V. The block based coefficients mean is calculated as

$$\overline{X_M} = \sum_{k=0}^{N-1} k.g(k) / \sum_{k=0}^{N-1} g(k) \qquad (2)$$

where g (k) and N represents the approximation coefficients and no of mean values of the blocks of the image. The threshold value for fingerprint image authentication is given by θ_{th} and it is $\geq$ Number of mean values of $\overline{X}_M$. For an image of size 256 x 256, 2 x 2 size blocks gives mean values of 16384 and the threshold value for this would be ≥ 16384. The authentication is performed for images in database DB_1 and it is proved that FrWT transform in particular B-Splines outperforms and retrieves even shift variant and rotation variant images.

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5. PERFORMANCE MEASURES

In this section we present some of the parameters like energy, SSIM, UIQ, FAR and FRR to evaluate the performance of FrWT.

5.1. Energy conservation

In order to support our claim that FrWT possess more energy compaction when compared to discrete wavelet transforms which provide a framework for analyzing the signal multiresolution feature. These wavelets are attractive because of their time-frequency localizations. In particular B-Spline wavelets tend to Gabor functions as the order of the spline increases. The Gabor functions are modulated Gaussians as per uncertainty principle and have maximum energy concentration in both time and frequency domains.

Table-4. Energy compaction of a fingerprint image with real wavelets and FrWT.

Wavelet type	Approximation energy concentration in %
Real Wavelet(db)	94.162
FrWT	98.2303

The Table-4 shows the superiority of FrWT where the energy compactions in approximation coefficients are more compared with real wavelets.

5.2. Comparisons of energy compaction of fingerprint image for varying orders of FrWT and its types

The significance of FrWT with respect to integer and fractional orders are discussed in this section.

5.2.1 Integer order of fractional wavelets

Comparative study of different types of FrWT and its energy compaction in approximation coefficients for different values of integer order are depicted in Table-5 where +,-,* indicates causal, anticausal and symmetric filters. The integer order of FrWT provides energy compaction with higher order, i.e. more number of coefficients and thus consumes more time for authentication.

Table-5. Energy compaction of fingerprint image in approximation coefficients with single level decomposition for integer order values.

Order	+ortho	+dual	+bspline
1	99.0560	99.6572	99.6572
5	99.1937	99.9065	99.9065
10	99.2089	99.9494	99.9494

5.2.2. Fractional order of fractional wavelets

Table-6 shows that energy is preserved without any loss and hence image can be reconstructed and subsequently authenticated using fractional order of FrWT. In our discussion fractional orders are confined from 2.1 to 2.9, and B-splines prove to perform better as they possess symmetry property with respect to the filter bank implementation. The tabular column provides us the energy compaction for fractional orders of a second order system and it is further observed that the fractional order 2.9 preserves energy of 99.1965 and is equivalent to performance of integer order of 10. The fractional orders are preferred since energy compaction is more even at lesser order. This in turn yields fewer coefficients and consumes less time for authentication.

Table-6. Energy compaction of fingerprint image in approximation coefficients with single level decomposition of fractional order values.

Order	+ortho	+dual	+bspline
1	99.0560	99.6572	99.6572
5	99.1937	99.9065	99.9065
10	99.2089	99.9494	99.9494

5.3. SSIM and UIQI

One of our aims is to justify the fact that Fractional Wavelet Transform performs better by computing two other parameters namely SSIM and UIQI.

a) SSIM (Structural Similarity Index Measure) is an index measuring the structural similarity between two images. Its value lies between -1 and +1 when two images are identical, their SSIM is close to unity. It is a measure of structural similarity (SSIM) that compares local patterns of pixel intensities that have been normalized for luminance and contrast [11].
b) Universal Image Quality Index is a quality index that models any distortion as a combination of three factors like correlation, luminance distortion and contrast distortion. It accounts for the first and second order statistics of the original and reconstructed image. The parameters are measured between original image and reconstructed image using Fractional wavelet Transform for fractional orders and integer orders and are shown in Table-7.

Table-7. Performance parameters.

Parameters	SSIM	UIQI
Fractional order	0.978	0.92
Integer order	0.812	0.77

5.4. FAR and FRR

The performance evaluation of this algorithm was determined with two performance standards FAR and FRR.A tradeoff between false retrieval and false rejection exists to distinguish a correct image in database. The FRR can be defined as the probability of a registered user being wrongly rejected by the biometric system. The FAR can be defined as the probability of an impostor being wrongly authorized by the biometric system. The comparison of two parameters FAR and FRR for integer orders and fractional orders are made and it is observed that fractional orders performs better compared to integer orders and are shown in Table-8. Further FAR and FRR are computed for different types of Fractional wavelets and it is observed that the performance of B-spline proves to be better because of its compactness and are shown in Table-9.

Table-8. FAR and FRR for different orders.

Type of fractional order	FAR	FRR
Fractional wavelets for integers	0.0%	0.035%
Fractional wavelets for fractional values	0.0%	0.022%

Table-9. The FAR and FRR of different types of FrWT.

FrWT	Type of fractional wavelets					
	Ortho		Dual		B-spline	
	FAR	FRR	FAR	FRR	FAR	FRR
Integer values	0.0%	0.035 %	0.0 %	0.032%	0.0 %	0.03 %
Fractional order	0.0%	0.028 %	0.0 %	0.022%	0.0 %	0.022%

5.5. Comparison with existing algorithms

In this section, we compare the performance of the proposed method with other methods.

Results of Table-10 reveals the retrieval of fingerprint images from database DB1_B for block based approach and is compared with other existing algorithms. The performance analysis shows that FAR and FRR were least with proposed algorithm, which is highly essential for biometrics, for authentication of fingerprint images.

Table-10. Comparative study of related work on fingerprint authentication.

Reference	Methodology	Performance	
		FAR	FRR
Ramandeepkaur, Parvinder S. Sandhu and Amir Kamra [12]	Common minitaue based	0%	8.18%
V. Conti, C. Militello and F. Sorbello, S. Vitabile [13]	Pseudo-singularity points	1.22%	9.23
Nurbeksaparkhojayer and Dale. R. Thompson [14]	Hotelling ‘s algorithm	0%	0.1%
Mohammad S. Khalil, DzulkifliMuhammad, Qais Al -Nuzaili [15]	Texture of fingerprint image	0.62%	0.08%
G. K. Rajini, G. Ramachandra Reddy [10]	Block based approach of fingerprint a authentication using wavelets	0%	0.04%
Proposed method	FrWT approach	0%	0.021%

6. CONCLUSIONS

Fractional Wavelets provide a unified framework for a number of applications, which had been developed independently for various 1D and 2D signal processing. We showed that the corresponding fractional and generalized B-spline wavelets behave like multiscale differentiation operators of fractional order. This is in contrast with classical wavelets whose differentiation order is constrained to be an integer. This property is well suited for biometrics in particular fingerprint image authentication. Block Based Approach is carried out in finding the mean values of blocks of the image’s fractional wavelet transform coefficients. When detecting the parameters like FAR and FRR our proposed algorithm is showing superior performance with respect to image authentication. The reliability and simplicity involved in our algorithm has high potential in face recognition and video processing. The experimental parameters like energy, SSIM, UIQI, FAR and FRR demonstrate the efficiency of the proposed Block Based Approach of Fractional Wavelet Transform producing significant good results. The multiresolution nature of FrWT is ideally suited for browsing image database for authentication.

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REFERENCES

[1] Selesnick I.W., Baraniuk R.G. and Kingsbury N.C. 2005. The dual-tree complex wavelet transform. Signal Processing Magazine, IEEE. 22(6): 123-151.

[2] M.Unser M. and T. Blu. 1999. Construction of fractional spline wavelet bases. Wavelet Applications in Signal and Image Processing. 7: 422.

[3] Unser M. and Blu T. 2003. Wavelet theory demystified. IEEE Transactions on signal processing. 51(2): 470-483.

[4] Blu T. and Unser M. 2000. The fractional spline wavelet transform: definition end implementation. Acoustics, Speech, and Signal Processing, Proceedings of International Conference. pp. 512-515.

[5] Shi and *et al*. 2012. A novel fractional wavelet transform and its applications Science china Information Sciences. 55(6): 1270-1279.

[6] Bhatnagar G., Wu Q. M.J. and Raman B. 2012. A New Fractional Random Wavelet Transform for Fingerprint Security. Systems, Man and Cybernetics, Part A: Systems and Humans. IEEE Transactions on. 42(1): 262-275.

[7] M. Unser and *et al*. 1993. A family of polynomial spline wavelet transforms. Signal processing, Elsevier.

[8] http:/www.epfl.com/algorithms.html.

[9] Strang G. and Ngugen T.Q. 1996. Wavelets and Filter Banks. Welleseley-Cambridge Press, Cambridge MA. pp. 103-108.

[10] Rajini G.K. and G. Ramachandra Reddy. 2012. Block based approach of fingerprint authentication using wavelets. European Journal of Scientific Research. 88(2): 251-260.

[11] Zhou Wang, Bovik A.C., Sheikh H.R. and Simoncelli E.P. 2004. Image quality assessment: from error visibility to structural similarity. Image Processing, IEEE Transactions on. 13(4): 600-612.

[12] Kaur R., Sandhu P.S. and Kamra A. 2010. A novel method for fingerprint feature extraction Networking and Information Technology (ICNIT) 2010 International Conference on. pp. 1-5.

[13] Conti V., Militello C., Vitabile S. and Sorbello F. 2010. Introducing Pseudo-Singularity Points for Efficient Fingerprints Classification and Recognition. Complex. Intelligent and Software Intensive Systems (CISIS), International Conference on. pp. 368-375.

[14] Saparkhojayev N. and Thompson D.R. 2009. Matching electronic fingerprints of RFID tags using the Hotelling's algorithm. Sensors Applications Symposium IEEE. pp. 19-24.

[15] Khalil M.S., Muhammad D. and AL-Nuzaili Q. 2009. Fingerprint Verification Using the Texture of Fingerprint Image Machine Vision, Second International Conference on. 6: 27-31.