A STATIONARY WAVELET TRANSFORM APPROACH FOR IMPROVED FINGERPRINT RECOGNITION SCHEME

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ABSTRACT

Fingerprint recognition, a known biometrics for personal identification is used in securing confidential Data Contents. Fingerprint exhibits textured like patterns of whorls, loop etc in sector form which is then used for fingerprint matching. The existing method uses Gabor filter which does not provide much Robustness. In this Paper, a hybrid algorithm is overlaid in combination with SWT and PCA techniques for image denoising, thereby obtaining a visually sharper reconstructed inked fingerprint images. The Proposed matching approach proves more robust than existing techniques.

Keywords: Biometrics, fingerprint recognition, denoising, Gabor filters

1. INTRODUCTION

BIOMETRIC system is an imperative area of research in recent years. As they have distinct characteristics of distinctiveness and persistence to identify individuals such as an genuine person and imposter these qualities helps securing high Credential details.

Fingerprints of all individuals are unique. A fingerprint pattern holds ridges and valleys for extraction process. As some finger print images of inked type are of low contrast due to skin conditions, incorrect finger pressure etc different types of noises exists. Here the offline mode of fingerprint (i.e inked fingerprint) is described in detail and are considered for recognition as described in Fig 1.
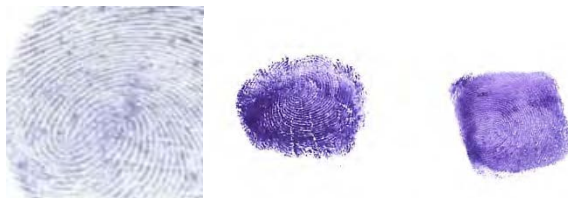

Fig 1. Inked fingerprints on paper

Several Proven existing techniques of fingerprint identification have been used in the literature. One among them was the minutiae type of approach of which showed genuine results only for good quality fingerprint images. But for the poor quality images it tends to be a very difficult task. Therefore it is not used for real time authentication applications. Also as they suffered from many issues for poor quality fingerprints they showed the imperfect results for matching purposes.

Hence a hybrid type of fingerprint matching approach is proposed with Image denoising techniques to eradicate various noises for a better reconstructed denoised image. This denoised image then combined orientation features and texture-based features by Gabor method for matching purposes which achieved effectiveness and efficiency for both high and low quality fingerprints.

2. RELATED WORKS

A lot of work has been carried out in various types of fingerprint identification.

Initially in biometrics especially for fingerprint identification ridge line features of minutiae point and texture features are used to obtain the fingerprint recognition system. Asker and Sabih proposed the PCA algorithm and Poincare index algorithm for improving the accuracy on a live-scanned fingerprint databases. Zhou Weina etal proposed an algorithm based on combination of wavelet transform with that of prewitt edge detection for fingerprint verification. Thereby providing various wavelets with their stable characteristics in

image transformation by means of Prewitt's edge detection . Authors of Jang and Yau used global and local features with pixel block size for achieving low FRR and Leon used combination of FFT and Gabor Filters with thinning algorithm for better Image Enhancement. Win and Sein of Japan proposed the Discrete Wavelet Transform (DWT) algorithm in texture feature-based approach. This method thereby identifies the low quality fingerprint from inked images on paper for denoising purpose.Later the author of Iman Alwan the color image denoising technique by using SWT which showed PSNR improvement upto 3.5 db. Jashanbir Singh Kaleka and Reecha Sharma provided a comparitive study on various wavelet types for achieving fast compression on images. Furthermore in the earlier stage author Chang proposed singularity detection in texture form for image enhancement in digitized type of images. Finally Authors such as Lam, Lee, and Suen implemented a comprehensive study on thinning methodologies with various differences for the ease of fingerprint matching. In this paper a texture based approach is used with SWT analysis with Sym type of wavelet.

3. OVERVIEW OF THE PROPOSED SYSTEM

The general outlay for the proposed fingerprint identification system is described in Fig. 2.

In the Initial stage, the input fingerprint image retrieved is preprocessed and enhanced. After enhancing the fingerprint, core point detection and cropping is done. Thus the final stage of texture and orientation features extracted are stored in the database.

For this paper, the input fingerprint image is first preprocessed for identification purpose to remove the noise and to achieve the enhanced image . Secondly, the core/reference point is found from the orientation of the enhanced images. Hence by using it the image of required size is cropped into sectors. Finally orientation features of the cropped fingerprint extracted are thus compared with all the fingercodes in the database.
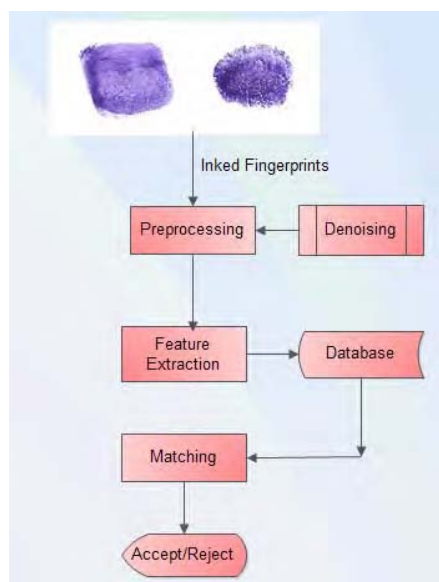

Fig.2 Overview of the Proposed System

A feature vector otherwise called as FingerCode generally collects the several characteristics for every sector in each filtered image. It includes both the global and local characteristics for ridges, valleys etc. Here a distance matching score is calculated to achieve the threshold acceptance for both the representation using Euclidean matching and gabor filter matching in the databases. They are yet then fused using sum based rule to achieve a final matching score. Hence the input fingerprint is recognized as a genuine attempt only incase if the final matching score is higher than a certain threshold, else it is considered as an imposter.

4. PREPROCESSING

An inked fingerprint type of images are considered as one among the noisiest type of images. As the fingerprint inked image may syffer from many discrepancies such as dirty, cut, scarred, creased, dry, wet, worn, etc a clear denoised image can't be achieved. Hence the image enhancement step were used to reduce this noise level using various techniques and to enhance the definition of ridges against valleys.

Preprocessing stage mainly includes gray scale conversion, histogram equalization, denoising, binirization, thinning etc. Compression is performed to reduce the bit size. The so far achieved result is shown in Fig 3.
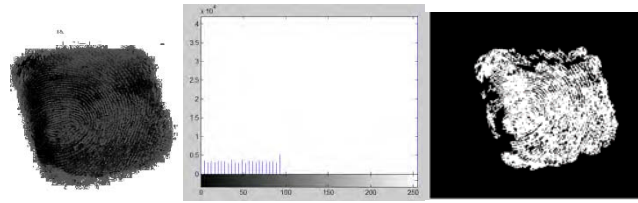
Fig 3.Gray scale conversion image with its histogram and binirization form

4.1 IMAGE DENOISING METHOD

In the past, fourier transform based techniques have been applied for removing noises in images and signals. Since Short Time Fourier Transform depends on 'Window size', preset resolution problem exists. Hence we go for Wavelet Transform Method(SWT) as they provide detailed spatial frequency information and may reduce the blurring effect. Thus an improved denoised image can be achieved.

4.1.1 PROCEDURE TO DENOISE THE FINGERPRINTS USING SWT

Stationary Wavelet Transfom as a shift invariant signal analysis provides complete characteristic of the analyzed signal and don't take much computation time in convolution process.The sequence of steps involved in the denoising algorithm are:

1. Load the noisy images of various types with index not exceeding matrix extensions.(If so go for Image Extension)

2. Apply Wavelet type with required level for decomposition.

3. Apply Stationary Wavelet Transform for image denoising;

4. Use hard thresholding method of penalize low/high for clear denoised images and

5. Achieve the result with its residuals(enhanced output).

In the Proposed approach Haar, db, coif and sym type of wavelets were applied and found that sym proves better in Maximum Normalization. So 'Sym' wavelet type is performed to obtain the least asymmetry with shift invariance.They do have the combined features of Discrete Wavelet transform and Continuous Wavelet Transform.

Here the denoising of images in combination with different types of noises(Speckle noise, Salt & Pepper Noise, Gaussian Noise)are taken into consideration. The values for the various reconstructed noisy images are specified in terms of PSNR. And the result is shown in Fig 6 & 7.
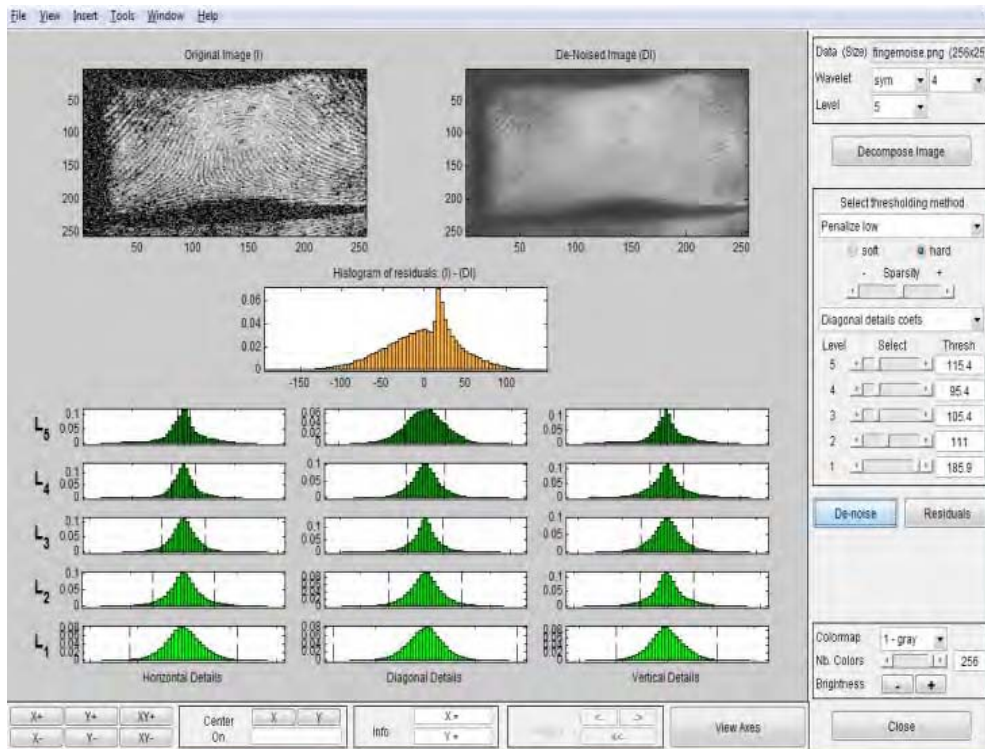

Fig 6.Achieved Denoised Image by SWT Technique

Here the Gaussian type of noisy image is denoised using Sym-4 with hard thresholding by using the method of Penalize Low. The details of five levels are described along with the Histogram specifying the noise details. Thus various levels are tried for Sym-4 and the corresponding results are specified in the Table 1.
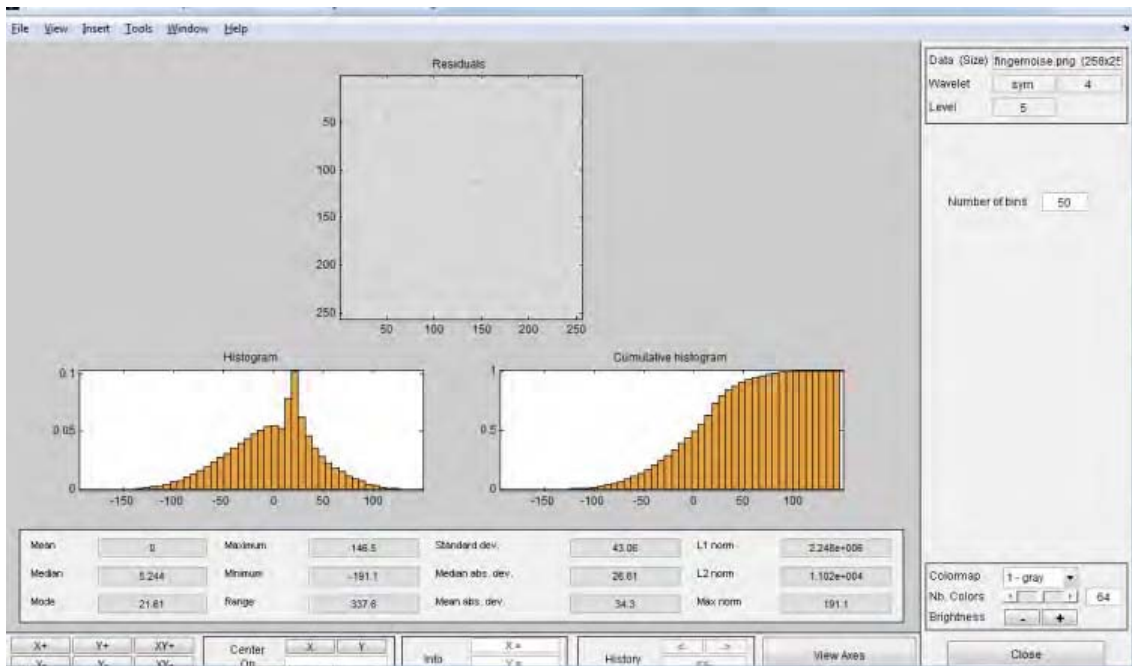
Fig 7. Enhanced Image with Histogram Specification

The Enhanced image achieved through Stationary wavelet transform by Sym-4 shows good image along with the various details and Maximum Normalization. The maximum norm values for various types of noisy images using hard thresholding method is given in Table 1.

Table 1.Maximum Normalization Results of Various types of Noisy images

S.No	Noisy Image type	Wavelet	Level	Max Norm
1.	Gaussian	Haar	1 2 3 4 5	69 86 92 93 94
		Db-4	1 2 3 4 5	83 89 93 96 98
		Sym-4	1 2 3 4 5	79 88 92 94 99
2.	Salt & Pepper	Haar	1 2 3 4 5	12 21 32 54 68
		Db-4	1 2 3 4 5	16 35 41 56 62
		Sym-4	1 2 3 4 5	14 32 48 53 69
3.	Speckle	Haar	1 2 3 4 5	14 25 42 62 75
		Db-4	1 2 3 4 5	23 39 51 67 79
		Sym-4	1 2 3 4 5	24 40 53 68 80

Since the results in table1 shows the maximum normalization for various types of noisy images, we go for Gaussian denoised image. Hereafter Gaussian type of denoised image based on sym wavelet is taken into consideration.

4.1.2 PCA ANALIZATION

Principal component analysis which is an orthogonal transformation is taken into consideration mainly to convert a set of possibly correlated variables into a linearly uncorrelated variable called principal analysis. It is the simplest technique among multivariate analyses and is related to factor analysis.The PCA transformtion that helps to preserves dimensionality is given in Eq 1.

$$Y^T = X^T W$$

$$= V\Sigma^T W^T W$$
$$= V\Sigma^T \qquad\qquad (1)$$

The following Procedure is used to obtain the Multivariate PCA Analysis:

    1. Load the Required Image Signal either from the workspace

    2. Check for 'Matrix Index Dimensions' and perform decomposition.

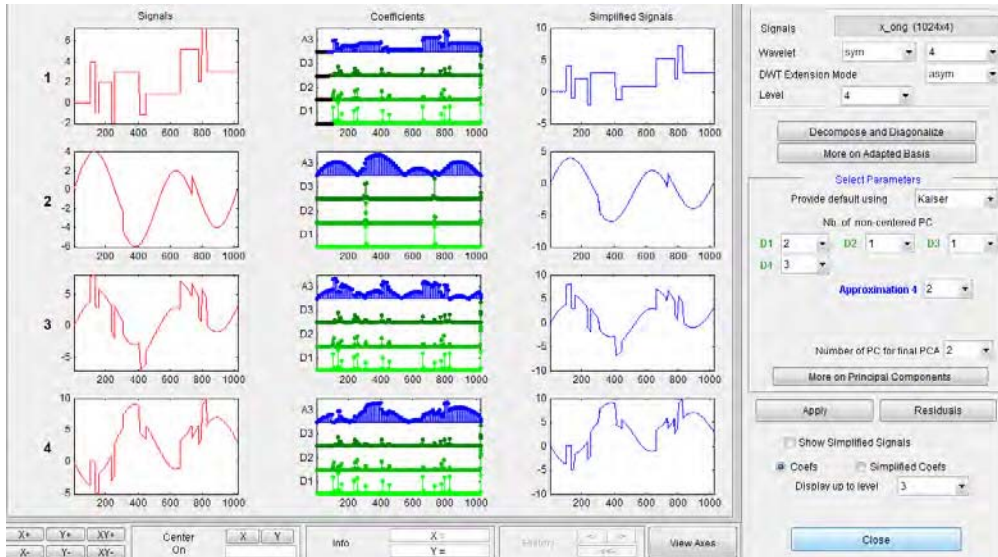   3. Provide the Parameters and achieve the results with residuals.

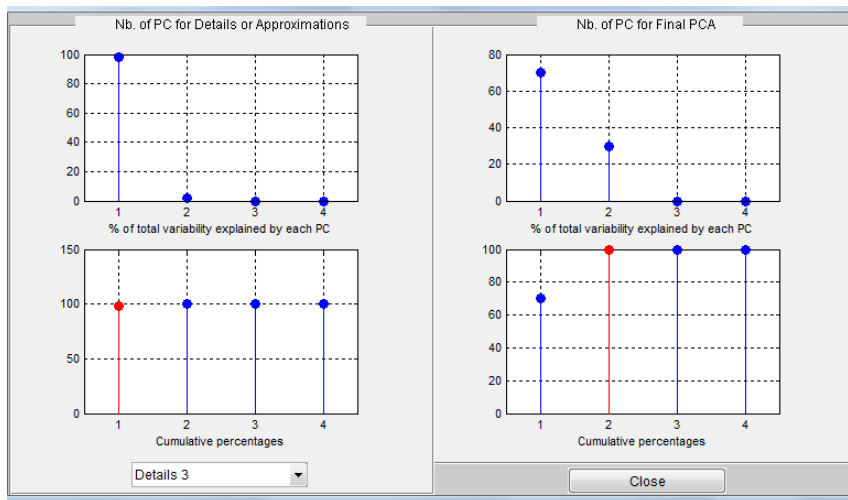Fig 8. Multiscale Principal Component Analysis for image signal

Fig 9. Obtained Graph Values in Grid form

The above Fig 8 and 9 shows the co-efficient form of signals and simplified signals for the denoised image. The Graph values obtained in the grid form indicates the preservance of dimensionality of the image. Hence the Sym-4 wavelet uses Kaiser form of parameter selection with 4 levels. Thus the Cumulative percentage is obtained in grid form.

4.1.3 PSNR CALCULATION:

    The PSNR is generally used to compute the peak signal-to-noise ratio, in decibels, between two images. A good reconstructed image is achieved on the basis of highest PSNR value rate As the uncompressed image takes more space in database, the compression technique is focussed to avoid storage issue. Thus Mean Square Error is calculated to achieve PSNR values. The lower the value of MSE, the lower the error.

The various PSNR values for different noisy images with error rates are given in Table 2.

Table 2. Comparison Table for Various Noisy images with PSNR and MSE values

S.No	Noise Type	M.S.E	Max Error	L2 Norm Ratio	P.S.N.R	B.P.P	Compare Ratio
1.	Gaussian	6.256	41	99.97%	40.17	11.8698	148.37%
2.	Speckle	1.189	51	99.98%	47.38	3.1097	38.87%
3.	S & P	1.458	45	99.97%	46.49	3.2265	40.33%

The values in the above table are achieved based on 'Sym 4' wavelet with Adaptively Scanned Wavelet Difference Reduction (ASWDR) compression methods as it takes minimum loop iterations.
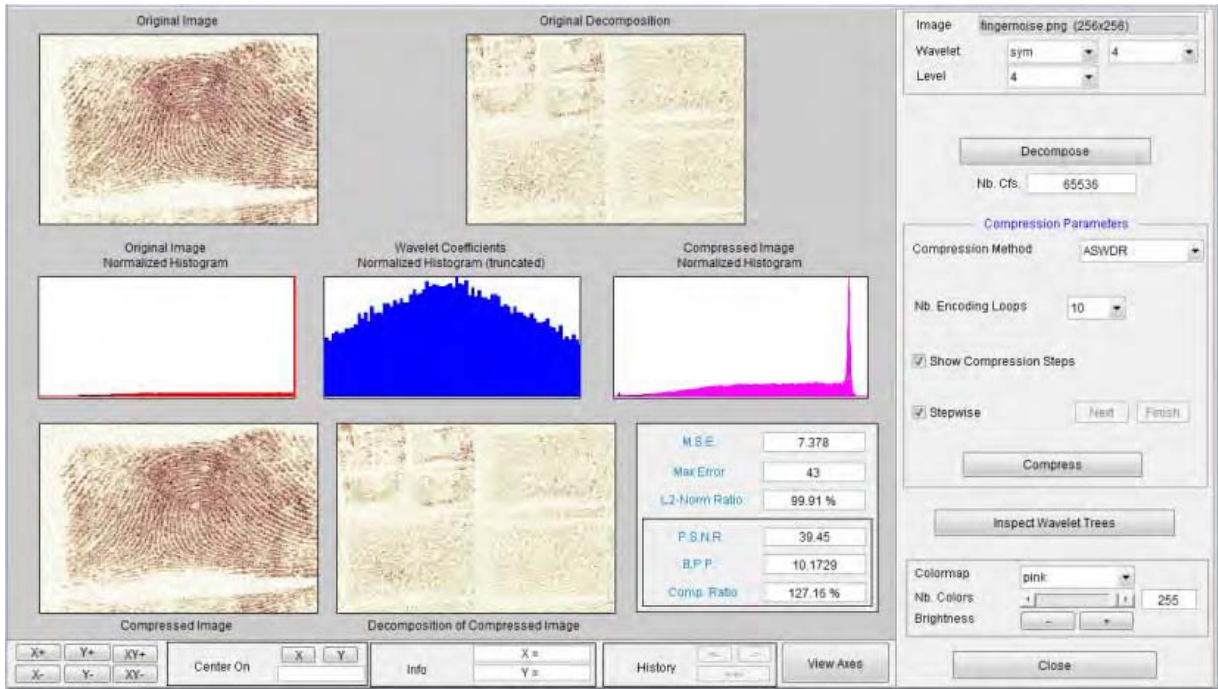

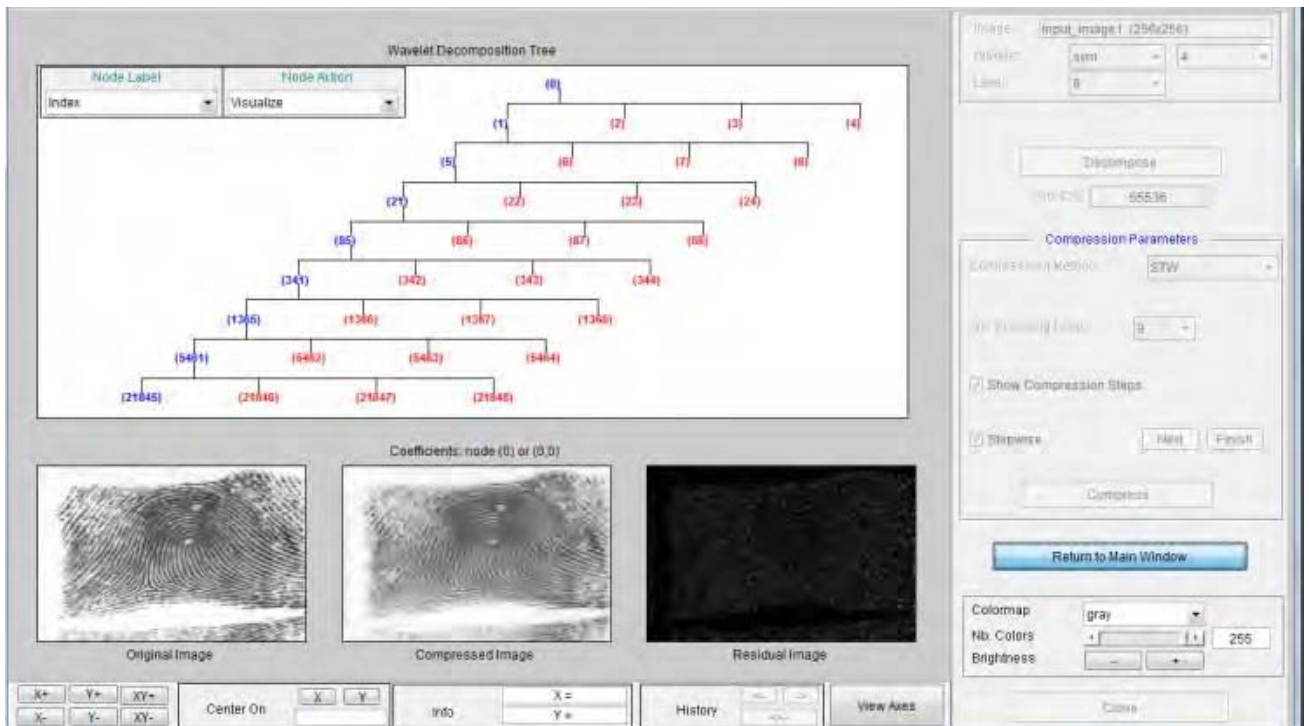Fig 10. Results of Compressed image for Gaussian type of Noisy Image

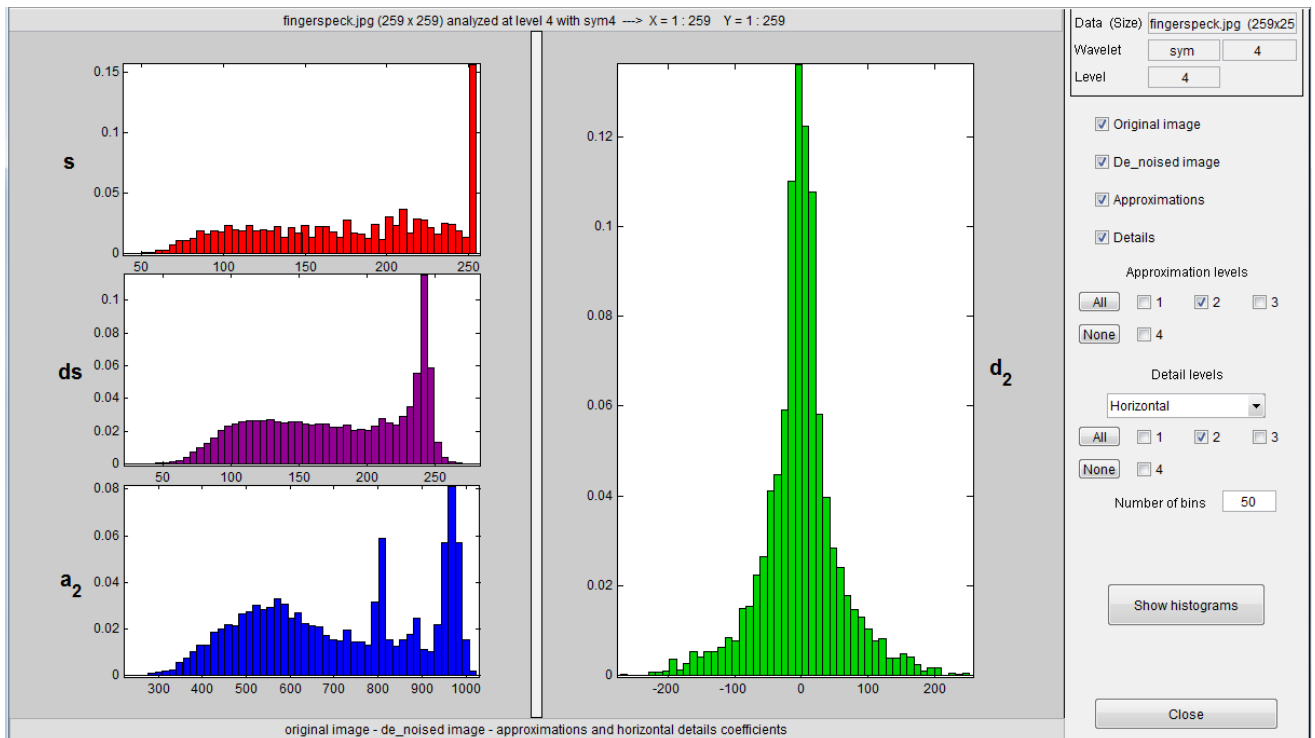Fig 11. Inspected Wavelet trees with achieved residuals

Fig 12. Graph of Histogram Coefficient details for Original and Denoised image
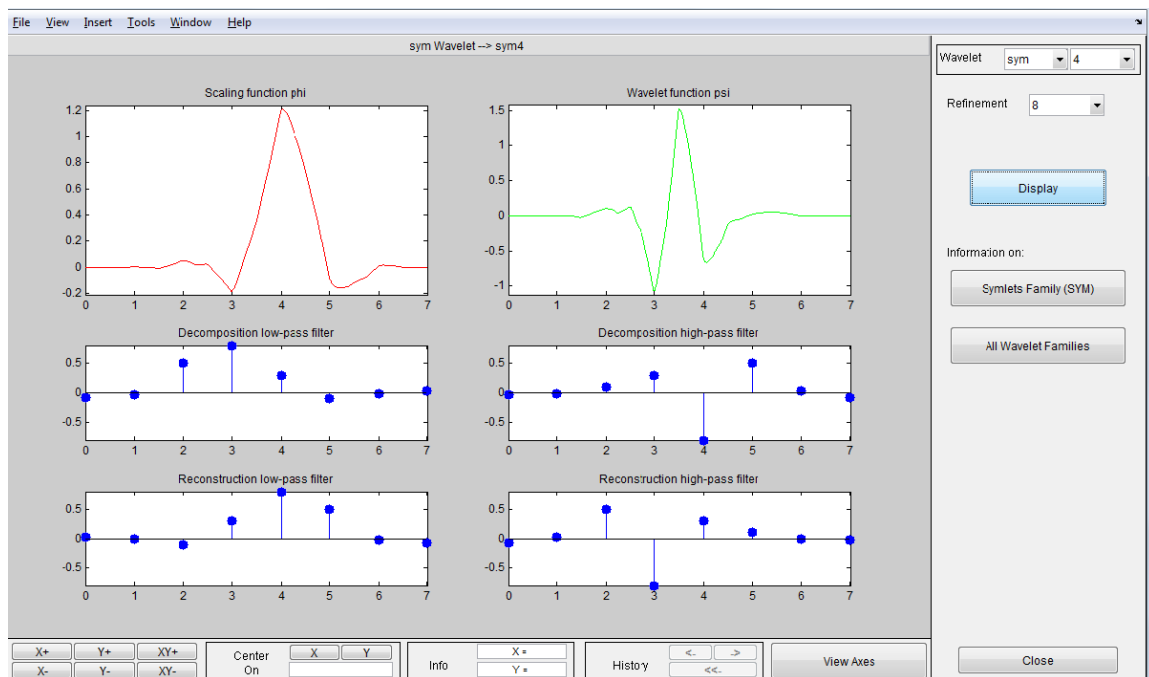

Fig 13. Symlet-4 type of Graph display

The Fig 10 and 11 shows the compressed image for the Gaussian type of noisy image with its histogram specifications. Here the ASWDR improves the rate distortion and retains the features of low complexity, progressive SNR etc.The Inspected wavelet trees clearly visualize the residual image from the compressed form of image.

Also the Histogram details for original image(s), denoised image(ds), approximation result(a_2) and horizontal details(d_2) are shown in the Fig 12. A sample of sym-4 graph display are also being displayed above in Fig 13.

5. FEATURE EXTRACTION

Fingerprint extraction of enhanced image holds certain quantitative feature measurements called as 'feature vector'. This Fingerprint usually represents both frequency content and orientation details. Typically the Gabor filter achieves best results in extracting this useful informations. And also for distance measurements this average absolute deviation from mean (AAD), is used by the filtered images. These feature vectors (by means of tessellation) constituting the Gabor texture pattern is used for matching. Here the Extraction process is featured for Gaussian type of enhanced image.

The steps involved in this extraction algorithm are:

1) Finding the orientation structure of the enhanced/denoised fingerprint.

2) Determining the core point and specific region for the above enhanced fingerprint image.

3) Then tessellate the step2.

4) And crop the region of interested pattern in specific directions by means of Gabor filter.

5) Finally the average absolute deviation from the mean (AAD) for required direction is computed in filtered images to obtain the Finger Code and is then stored.

5.1 RIDGE ORIENTATION DETECTION

This is done mainly to detect the local ridges in the fingerprint image. Reliable orientation extraction in low-quality regions is still an ongoing issue. In the proposed system, gradient based approach is used for extraction of ridge direction. Here the Sigma of the denoised Gaussian derivative is used to compute image gradients for achieving the orientation image.The orientation image is computed by the sequence of steps:

1. The denoised image achieved by SWT is used as the input image.

2. It is then used in ridge orientation procedures by applying the required parameters.

3. Thus the achieved result shows the orientation image in radians and an orientation measure between 0 and 1 is considered to be reliable.

Thus the Gradient based Ridge Oriented Image with various levels were shown below
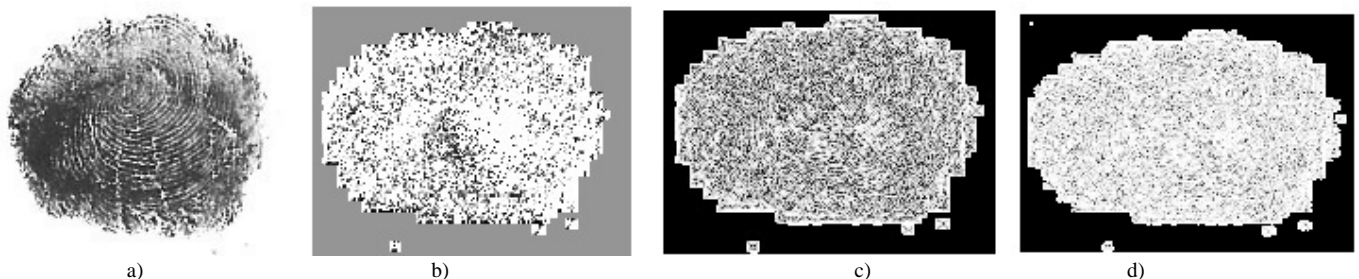

a) b) c) d)

Fig 14. a) Input image b) Orient image c) Coherence image d) Reliability image

5.2 CORE POINT DETECTION

Fingerprints have various types of landmark structures.Here by using the determined reference point the fingerprint image is detected to achieve the ROI area. Since several methods are there to calculate this reference point.This Paper uses the Poincare Index Method as it is a classical and ease of algorithm to detect singular points. The Computation is achieved by,

$$Poincare(x,y) = (1 / 2 \pi) \sum_{k=0}^{N-1} \Delta(k)$$

(2)

Thus the Center of image computed by this method is then implemented for filtering the specific ROI region.

5.3 GABOR FILTER-BASED TEXTURE EXTRACTION

Gabor filters are found mainly for texture representation. They hold the property of both frequency-selective and orientation-selective. As Gabor are said to be self similar as they helps in extracting useful features from the image. The various steps used in texture extraction is given below

5.3.1 ROI EXTRACTION: In this process the region of interest is extracted by using the reference point value. Else otherwise it is cropped using the roifilt2 method for segmenting the sector area.

5.3.2 NORMALIZATION: The segmented region is thus normalised separately to obtain a constant mean and variance before filtering. If it is of color image then it is converted to HSV and the value is normalised to 0-1

before being converted back to RGB. Normalizing the extracted image adjust the range of pixel intensity values, thereby referred to as "Contrast Stretching".

5.3.3 IMAGE FILTERING: Further in this process a 2-D Gabor filter is applied. Being a multi resolution filter it satisfies uncertinity principles. These filters thus extracts local frequency and orientation information i.e (lower most bound of time-spectrum resolution). A 2D Gabor filter can be expressed by,

$$f(x, y, \omega, \theta, \sigma_x, \sigma_y) = \frac{1}{2\pi \sigma_x \sigma_y} \exp\left[\left(-1/2\left(\left(x/\sigma_x\right)^2 + \left(y/\sigma_y\right)^2\right) + j\omega\left(x\cos\theta + y\sin\theta\right)\right)\right] \quad (3)$$

Where σ = is the spatial spread

ω = frequency

θ = orientation

Thus the Gabor based filtered image is given in Fig 18.

5.4 GABOR FEATURE VECTOR

By detecting the vector for every sector we obtain specific structures in the image. In our Process the edges of the fingerprint is being rectified for pattern matching with the database template.

As said earlier the absolute deviation technique for each sector is calculated for all filtered images for further step. The feature vector (Finger Code) for a specific structure called as 'Gabor texture pattern' is used in finding the Gabor matching. Thus the feature extraction algorithm is depicted in Fig. 17
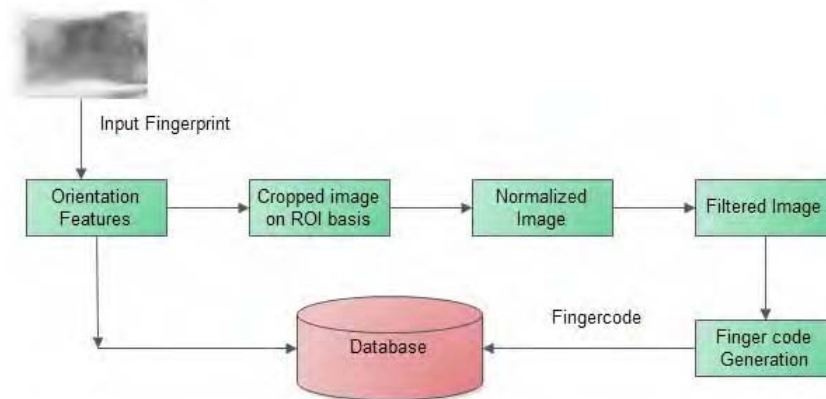

Fig 17. Proposed Feature Extraction algorithm

The Fig 18. Prescribed below shows the output of cropped denoised image with that of Direction oriented image, Gabor extracted image and segmented ROI image. Also the sample image of a fingerprint has been described for specification of various features i.e core, ridge ending, delta and bifurcation.
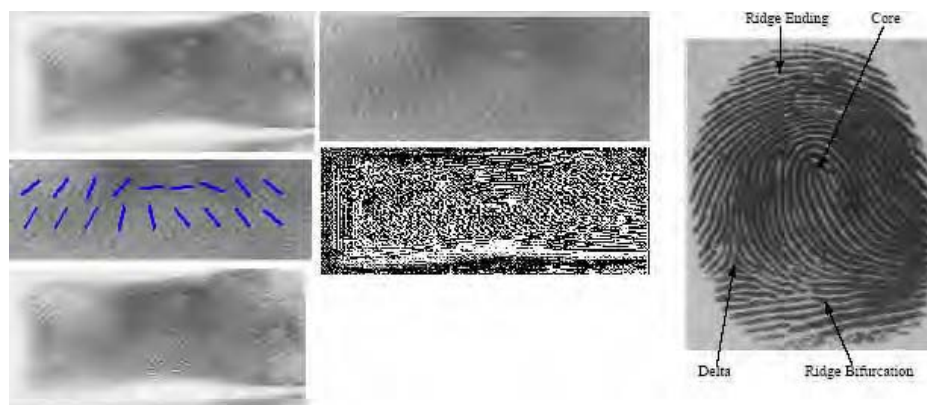

Fig 18.Denoised Gaussian Image with Oriented form, Gabor extraction, Cropping and ROI form

6. MATCHING

6.1 ORIENTATION MATCHING

In this step, the correlation among the denoised image and the original image A and B, is computed as below. The matching score between two orientation fields is defined as

$$S(A,B) = 1/N \ \Sigma \ \delta(i,j)$$
$$(t,j) \ \Omega$$

Where Ω is the intersection of the two effective regions and

N is the number of points in Ω.

Thus if the obtained score S (A, B) satisfies a specific threshold value , then the two orientation fields are considered to be "matched".

6.2 FINGER CODE MATCHING

This code matching is based on determining/finding the Euclidean distance between the feature extracted FingerCode and the original fingercodes. Thus a minimum distance score is considered to be best for the fingerprint matching. They are then fused with the orientation matching by some method.

7. THRESHOLD SCORE LEVEL

Finally the resultant scores are calculated by combining the above two methods to generate a single threshold score for verification. As there were several methods mentioned in the existing techniques in score fusion, this paper focus on the sum based rule used in [9]. As the Finger Code Matching by Gabor method(FCM) and Orientation Code Matching (OCM) uses the alpha method with n and n-1 they are being fused finally by sum method. Thus the final Resulting score (FRS), is computed by equation 4.

$$FRS = \{(\alpha * GMS) + ((1-\alpha) * OMS)\}$$
(4)

Where 'α' represents either 0 for genuine fingerprint matching.

1 for imposter fingerprint matching.

8. EXPERIMENTAL RESULTS

The achieved result is tested on different type of denoised inked images thereby obtaining a good PSNR values with PCA performance analysis for further extraction process.The Comparison flow of Gaussian image with ASWDR and SPHIT are shown in Fig 19.

	Signal	fingernoise.png (256x256)	Compression Method	ASWDR		M.S.E	6.897
	Wavelet	sym	4			Max Error	43
	Level	4	Nb. Encoding Loops	10		L2-Norm Ratio	99.86 %
						P.S.N.R	39.74
						B.P.P	30.4171
						Comp. Ratio	126.74 %

a)   b)   c)   d)   e)

	Signal	fingernoise.png (256x256)	Compression Method	SPIHT		M.S.E	23.41
	Wavelet	sym	4			Max Error	44
	Level	4	Nb. Encoding Loops	10		L2-Norm Ratio	99.50 %
						P.S.N.R	34.44
						B.P.P	14.2246
						Comp. Ratio	59.27 %

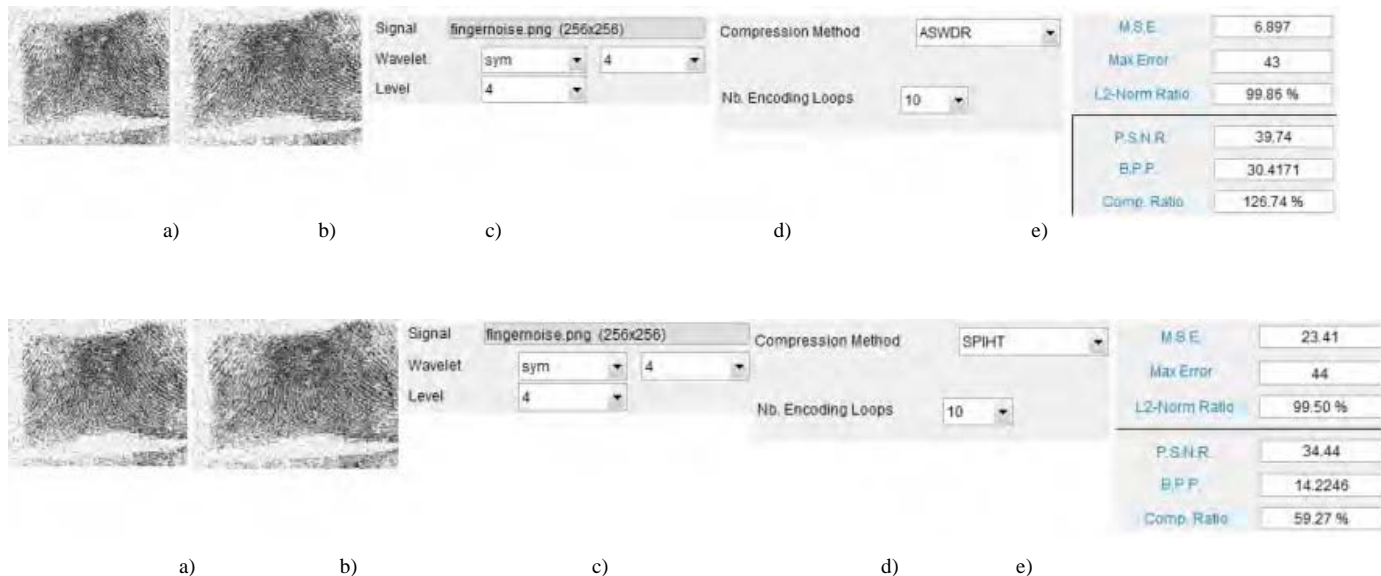a)   b)   c)   d)   e)

Fig 19. Comparison diagram for denoised image using ASWDR and SPIHT

The overall result of the proposed system is compared with the filterbank-based fingerprint matching. This algorithm proposed in [4] utilizes only texture information for representing the fingerprint and is shown in fig 21. But here the orientation features with the Gabor Texture Technique is used to compute the oriented FingerCode. And the result is tested with fingerprint images in the database. Hence the proposed system proves

efficient for low quality inked fingerprint images with low computation time. Thus the Comparison charts for Fig.20 and Fig.21 were shown below
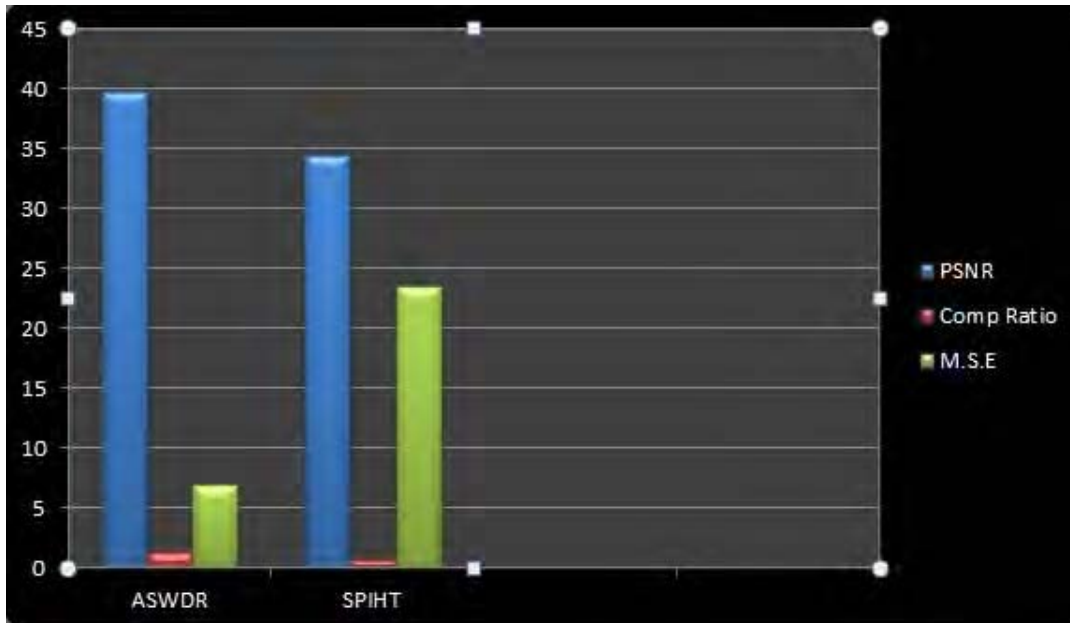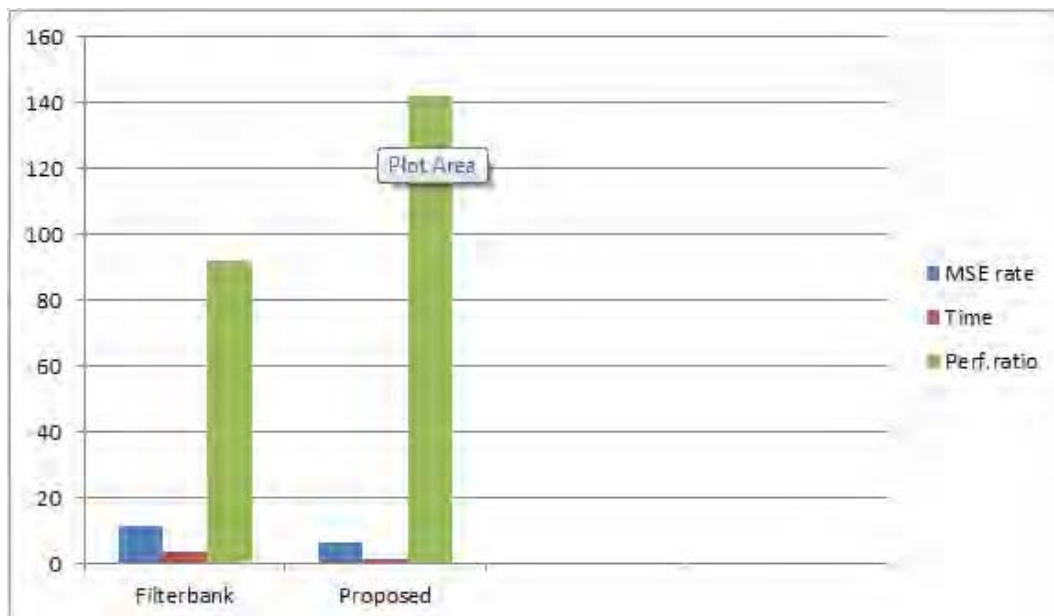

Fig.20 Comparison Chart for low MSE error rate

Fig.21 Comparison chart for performance ratio

9. CONCLUSION

Hence our proposed fingerprint matching scheme utilizing both orientation and texture information have been presented. Here the various noises of inked fingerprint type are denoised using shift-invariant of SWT technique with PCA analysis thereby achieving an improved denoised image for verification process. According to the experimental results, additional orientation matching improves the performance , robustness to image distortion and is finally effective and efficient for low quality and rotated inked images.

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