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An Ideal Approach For Enhancing Fingerprint Ridges Using Wavelet Techniques

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Abstract: The essential component of fingerprint authentication, that is available for use in many security technologies, is fingerprint enhancement. The pre-processed fingerprint ridges aid in raising the level of fingerprint authentication. The shortcomings of the conventional systems of fingerprint enhancement are their inability to remove pores and their inability to control the normal breadth of ridge creation. The ridges are upgraded using the "Fingerprint ridge enhancement utilizing Trinary Wavelet and Gabor Filter (FPRE-TW-GF)" approach, which results in ridges with regular width and no pores. This technique combines the potent Gabor filter with a newly created Trinary wavelet. To obtain the necessary improvement on ridges, the Trinary wavelet can be used in conjunction with the minimum standard-deviation technique. The suggested method outperforms conventional techniques in terms of ridge enhancement, and it can be considered an addition to any fingerprint authentication mechanism.

Keywords: FINGER PRINT ENHANCEMENT, PORES REMOVAL, GABOR FILTER, TRINARY WAVELET, FINGERPRINT PRE-PROCESSING

Introduction

Fingerprints are ridges and valleys that appear on the surface of the finger, leaving an impression that can be used to identify a certain person. In many computer implementations where security is a chief issue, fingerprint recognition is immensely useful [1]. Nowadays, fingerprint improvement is a crucial step in achieving realistic fingerprint authentication [2]. The fingerprint acquiring device plays a key role in obtaining the accurate fingerprint image and it is the chief concern for fingerprint authentication. However, there are other elements, such as occupational marks, postnatal marks, creases, etc., which increase the detection of fake minutiae, lowering the overall performance of authentication. As a result, prior to minutiae extraction, enhancing processes or pre-processing are typically carried out. [3][4].

When a fingerprint image is enhanced, the noise is reduced, the contrast between the ridges and valleys is increased, or the pores are eliminated. Numerous techniques have been developed in the field of fingerprint enhancement [5]. The author Lin Hong et al. [6] describe a fingerprint enhancement approach employing orientation image and frequency image. This quick way of operation improves the ridge forms of a fingerprint. The drawback is that it is inappropriate for

fingerprints with low quality. A fingerprint enhancement method with a directional morphological filter is presented by the authors G. Milici et al. [7]. The flaw is the inadequate image enhancement.

By utilizing a Gabor filter, the author Miao-li Wen et al.[8] offer a method for enhancing fingerprint ridges. The shortcoming with this technique is the creation of block artifacts in the border region.

A fingerprint ridge improvement employing morphological technique and additive wavelet transform is expressed by the authors Fatma G. Tadros et al. [9]. False-ridge joining is a problem that has brought this procedure into disrepute. A fingerprint enhancement technique for noisy fingerprints was proposed by the author Thien Hoang Van et al. [10]. The orientation consistency is used to determine the size of the Gabor filter window. The drawback of this strategy is that, in certain circumstances, the bifurcation sites are incorrectly increased to Ridge-end points. Using the non-separable wavelet transform, the author Jiajia Lei et al. [11] proposed a fingerprint ridge enhancement technique to enhance the low contrast fingerprint region. The impact of pores may result in unintended ridge improvements, which is undesirable.

Scale-space theory is used to develop a fingerprint enhancement approach by Jiangang Cheng et al. [12]. False bifurcations are formed due to poor image quality and is considered as a major drawback. A Markov Random Field fingerprint improvement technique is presented by Kuang-chih et al. [13] (MRF). Overly enhanced corner ridges are the flaw. Using Wavelet theory, the authors Safar Hatami et al. [14] describe a strategy for improving fingerprints. The deficient thing is that the high contrast areas are identified as thick ridges.

By eliminating sounds, the author Sandeep Palakk et al. [15] offer a method for improving fingerprints. This method is based on rapid discrete curvelet transform. This technique can't get rid of the salt and pepper noise. A latent fingerprint improvement technique based on multi-scale patch oriented sparse representation is described by the authors Manhua Liuet et al. in their article [16]. This method's flaw is its ineffectiveness in processing fingerprints of poor quality. The method for improving fingerprint ridge structures described by Jing-Wein Wang et al. [17] is based on the two-dimensional discrete wavelet transform and singular value decomposition. The shortness of this procedure can be seen in the tiny ridges. A fingerprint enhancement technique is developed by the author Mubeen Ghafoor et al. [18] utilizing a two-dimensional short-time Fourier transforms. This method's flaw is its inability to remove pores.

The current techniques for fingerprint enhancement suffer from incorrect ridge connection, a lack of support for fingerprints of poor quality, a reduced ability to remove pores, and limited handling of low contrast fingerprints. The trinary wavelet transform, in addition to the Gabor filter and standard supported methods, is added to the suggested FPRE-TW-GF approach. Additionally, it eliminates pores and uses the normalizing process to stabilize the contrast. In section 2, the working technique is explained along with the proposed method. Section 3 provides a thorough explanation of the analysis portion, and Section 4 summarizes the suggested method's encouraging outcomes.

Proposed Method

In this work, plain type fingerprints are employed. Figure 1 shows the suggested method's whole workflow.

Trinary wavelet decomposition

A novel strategy in the realm of fingerprint enhancement is the trinary wavelet method. Three images are created from the deconstructed input fingerprint FP_{INP}. Three binary images that indicate their individual qualities are the final outputs of this segment. Using Equation 1, the first binary wavelet image is created.

$Binary\_wavelet\_Image\_1 = Bit\_1(i, j) * 2 + Bit\_0(i,j) * 1$ (1)

$i \in [0, H-1]$ $j \in [0, -1]$

where

$Bit\_0(i, j)$-0^{th} bitof[i, j]th location of input image FP_{INP}

$Bit\_1(i, j)$ - 1^{th} bit of [i, j]th location of input image FP_{INP}

$Binary\_wavelet\_Image\_1$-Binaryoutputofwavelet image 1

H-Image height

The second binary wavelet image is obtained using Equation 2.

$Binary\_wavelet\_Image\_2 = Bit\_3(i, j) * 2 + Bit\_2(i, j) * 1$ (2)

where $Bit\_3(i, j)$ - 3rd bit of [i, j]th location of input image FP_{INP}

$Bit\_2(i, j)$ - 2nd bit of [i, j]th location of input image $FPINP$

$Binary\_wavelet\_Image\_2$ - Binary output of wavelet image 2

The third binary wavelet image is obtained using Equation 3.

$Binary\_wavelet\_Image\_3 = Bit\_7(i, j) * 8 + Bit\_6(i, j) * 4 + Bit\_5(i, j) * 2 + Bit\_4(i, j) * 1$ (3).

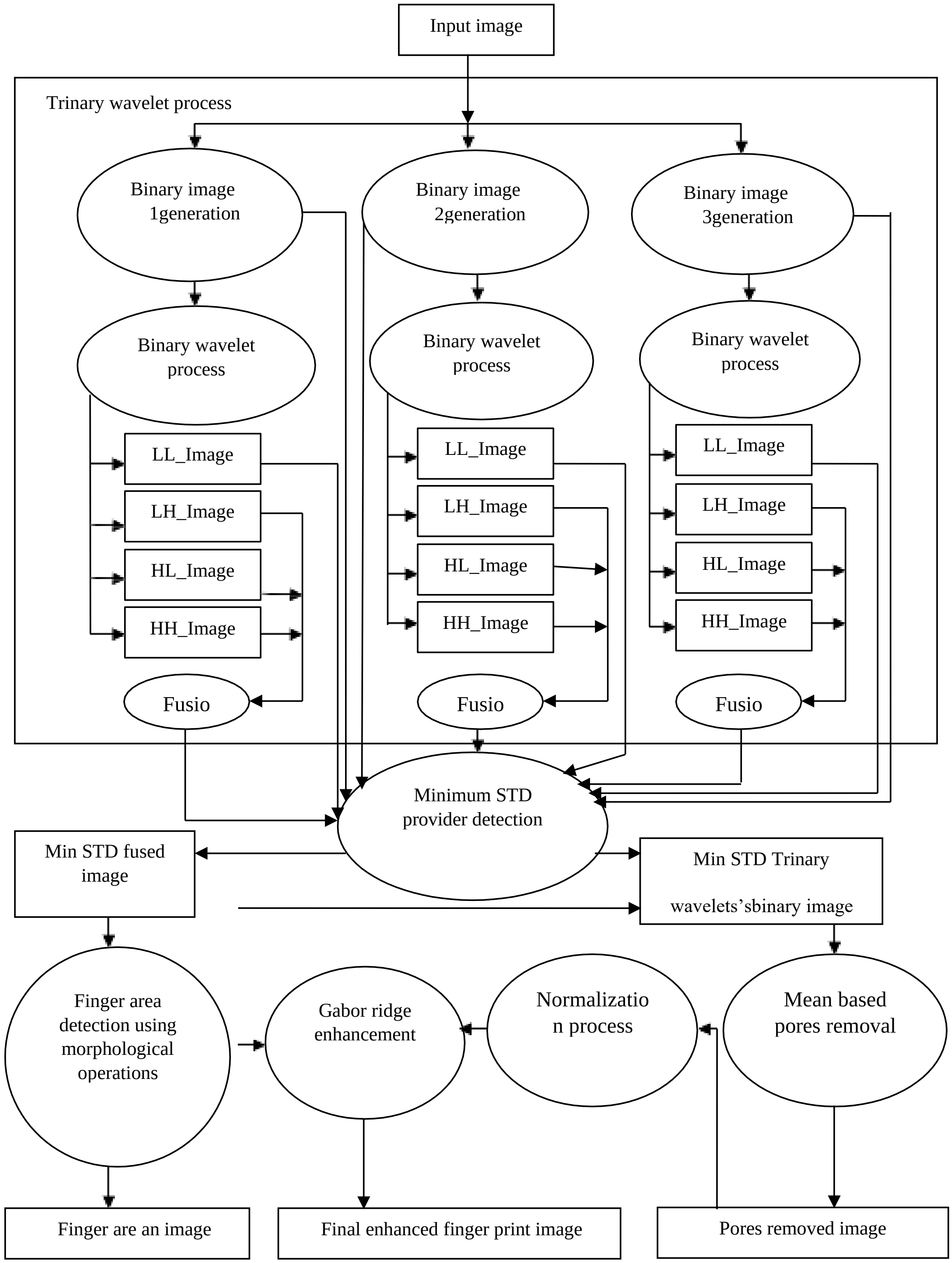
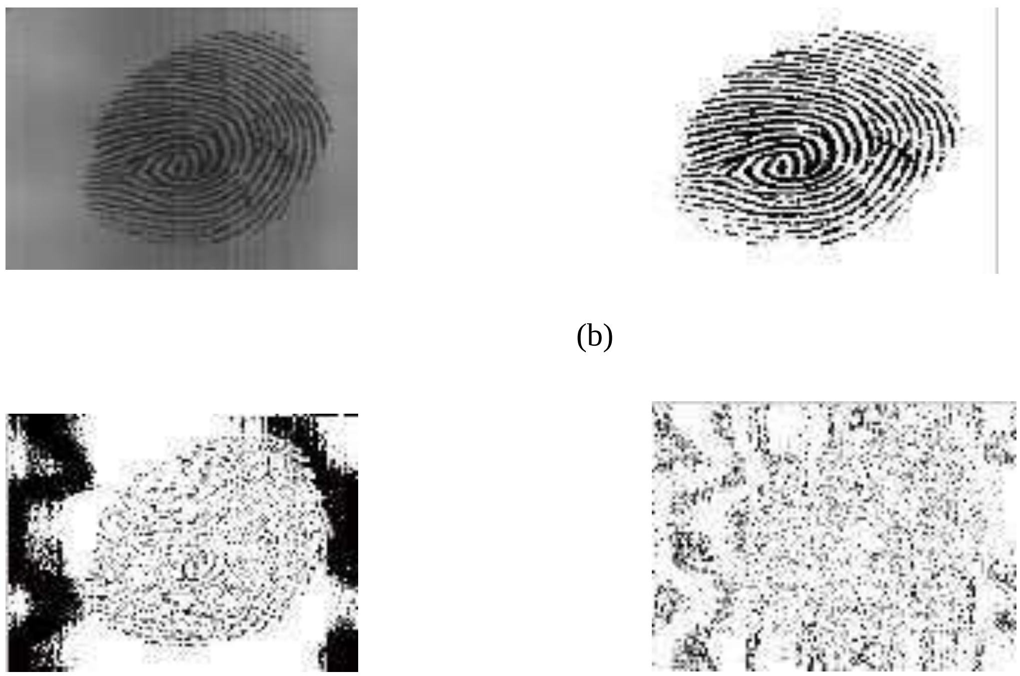


Figure1. Block diagram of the proposed finger print enhanced method

The decomposition of the input fingerprint picture into the three binary images, Binary wavelet Image_1, Binary wavelet Image_2, and Binary Wavelet Image_3, is depicted in Figure 2(b).



(a) (b) (c) (d)

Figure2. Representation of decomposition section of Trinary wavelet, a) QueryFingerprint_image_1 b) Binary_wavelet_Image_1c) Binary_wavelet_Image_2d) Binary_wavelet_Image_3.

Trinary wavelet process

With the help of a binary wavelet technique based on Equations 4 and 5, the Trinary wavelet process divides the Binary Wavelet Image 1 into L image and H image.

$$(\text{i}, \text{fi}x\ ()) = Binary\_wavelet\_Image\_1\ (\text{i}, \text{j}), 2 \text{ if j } mod\ 2 = 0 \qquad (4)$$

$$(\text{i}, \text{fi}x\ ()) = x\text{o}\ (Binary\_wavelet\_Image\_1\ (\text{i}, \text{j}), Binary\_wavelet\_Image\_1\ (\text{i}, \text{j} - 1)), \text{ if j } mod\ 2 = 1 \qquad (5)$$

$\text{i} \in [0, H - 1]\ \text{j} \in [0, - 1]$

Figures 3(c) and 3(d) show examples of this (d). By modelling Equations 4 and 5, based on a column-wise method, the L picture is divided into the LL image and the LH image. The simulation of Equations

4 and 5 based on a column-wise method results in the decomposition of the H picture into HL image and HH image.

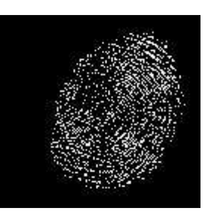
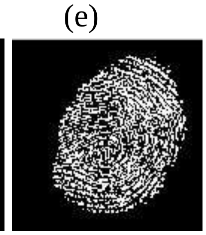
The LL picture is shown in Figure 3(e), the LH image is shown in Figure 3(f), the HL image is shown in Figure 3(g), and the HH image is shown in Figure 3(h).
Using the LH, HL, and HH pictures of Binary wavelet Image 1, the Fused image, referred to as Fused wavelet Image 1, is produced based on Equation 6.


(a) (b)


(c) (d)

(e)

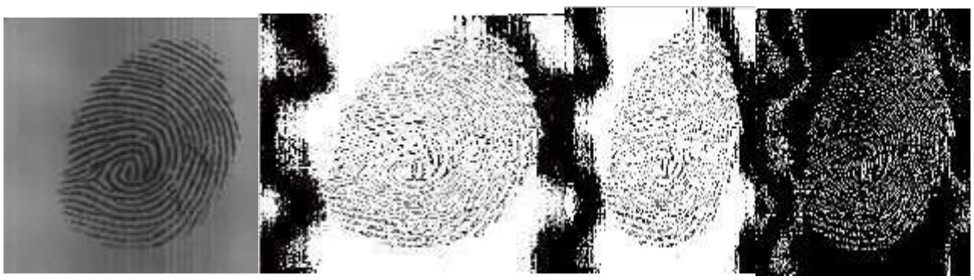


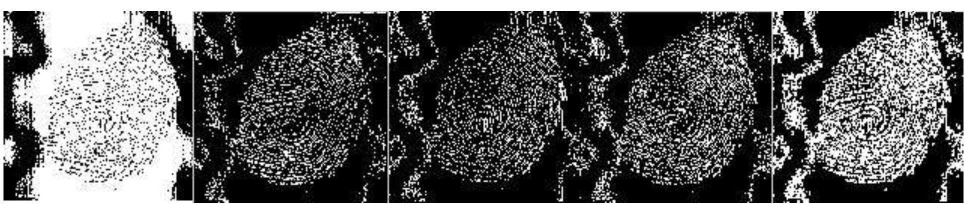
(f) (g) (h) (i)

Figure 3. Representation of Wavelet processing of Binary_wavelet_image_1, a) Query Fingerprint_image_1, b) Binary_wavelet_image_1, c) L Image, d) H Image, e) LL Image, f) LH Image, g) HL Image, h) HH Image, i) F used image.

Figure 3 shows the results of binarizing the fused wavelet Image 1 with the threshold 0. (i). The L image and H image are created by decomposing the Binary wavelet image 2. The LL, LH, HL, and HH images are decomposed from these two original photos.



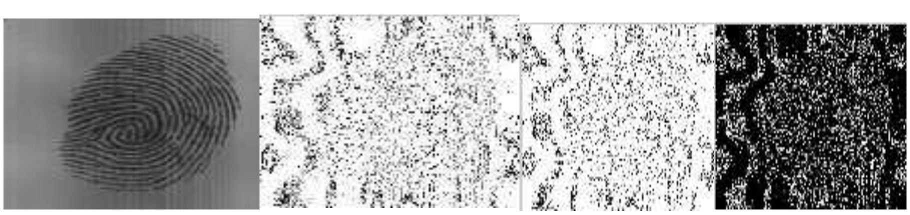
(a) (b) (c) (d)



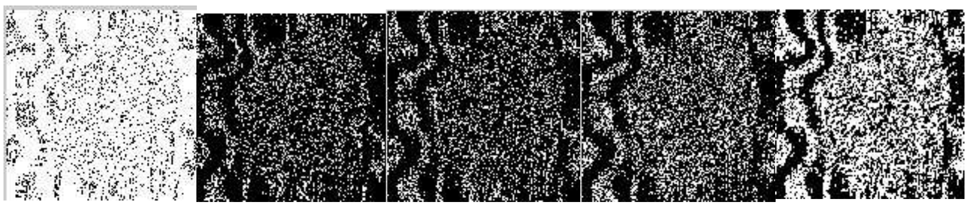
(e) (f) (g) (h) (i)

Figure4. Representation of Wavelet processing of Binary wavelet image2, a) Query Finger print image 1 b) Binary wavelet image 2, c) L Image d) H Image e) LL Image f) LH Image g) HL Image h) HH Image i) F used image.

The result images that were recovered from Binary wavelet image 2 are shown in Figure 4. L image and H image are created from the binary wavelet decomposing the Binary wavelet image 2. The LL, LH, HL, and HH images are decomposed from these two original photos



(a) (b) (c) (d)



(e) (f) (g) (h) (i)

Figure5. Representation of Wavelet processing of Binary wavelet image 3, a) Query Fingerprint image 1, b) Binary wavelet image 3, c) L Image, d) H Image, e) LL Image, f) LH Image, g) HL Image, h) HH Image, i) Fused image.

The Figure 5 describes the resultant images decomposed from Binary wavelet image 3.

Fingerprint ridge enhancement

The resultant LL image is referred to as LL' since it is the one with the lowest standard deviation amongst the three LL images. The result of the trinary wavelet procedure on the LL' image is shown in Figure 6(c). The associated fused picture is referred to as FI'. The FI' image is shown in Figure 6(b). It is indicated as BI' for the associated Binary wavelet image, the picture fused Due to the wavelet technique, FI has been shrunk to a size that is only half that of the original image. In order to accomplish the morphological dilation operation, a 3x3 square structural element is used. The final image is depicted as the fingerprint region image FAI' in Figure 6. (e).

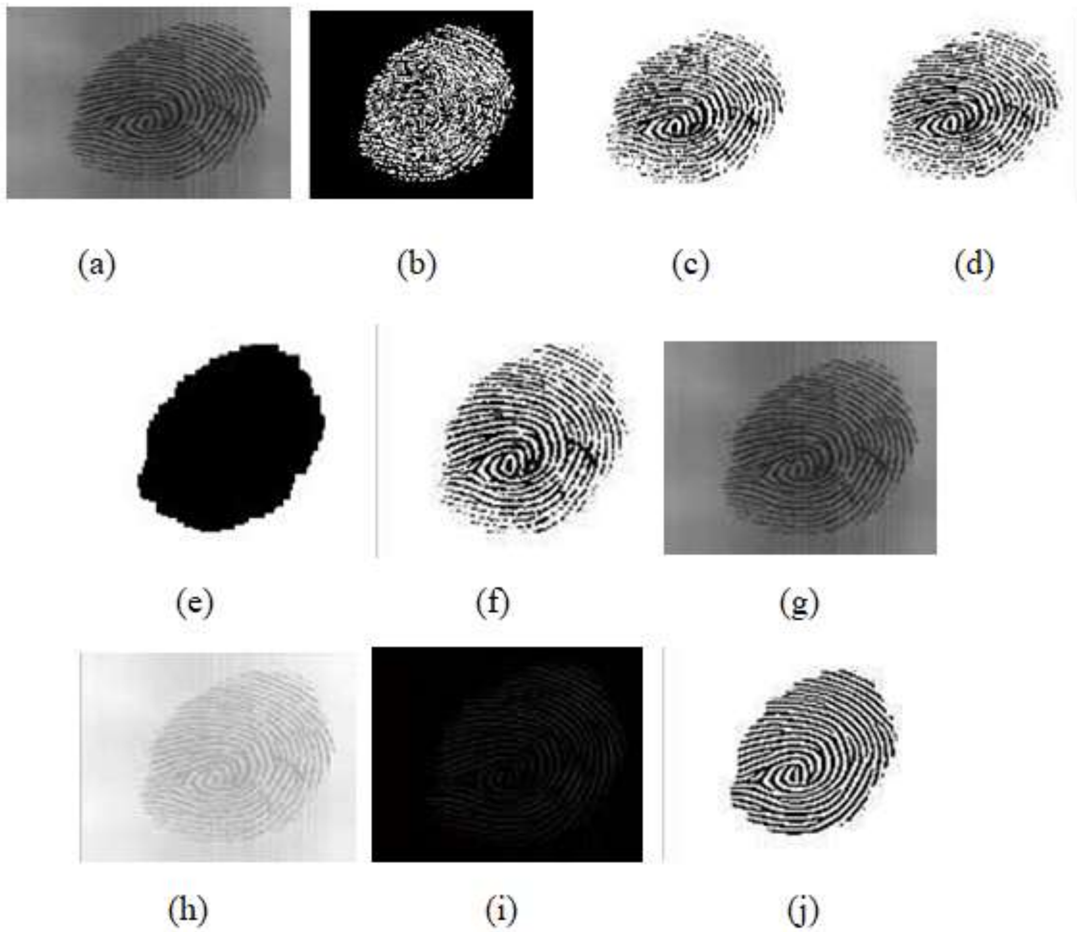


Figure 6. Steps of ridge enhancement process, a) Query fingerprint image 1, b) Output of Minimum Std providing Fused Trinary wavelet, c) Output of Minimum Std providing LL Image from Trinary wavelet process, d) Output of Minimum Std providing Binary Image from Trinary wavelet, e) Finger area image, f) Pores removed image in binary form, g) Pores removed intensity image, h) Normalized image i) Gabor based ridge enhancement, j) Final ridge enhancement

The Binary wavelet image matching to minimal STD provider is used to determine the locations of the ridge structures. Both the raw fingerprint image and the BI' image are employed to calculate the mean intensity value. By using a window of 3x3 and taking into account a hole by surrounding it with at least 4 ridge pixels, with the exclusion of non-fingerprint-area, the locations of the pores are determined from the BI' image. The gaps in the input fingerprint image are eliminated using the Mean-ridge-intensity value. The elimination of pores is accomplished by combining the use of BI', FAI', and FPINP pictures. Better pore elimination is achieved with this new approach. The pores-free image PF', which is displayed in Figure 6(g), is an intensity image with pores eliminated.

The pores-free image PF' is undergone the normalization process which stretches the low contrast image to make a stabilized contrast image. The entire normalization process is explained in [19]. The Normalized image output is shown in 6(h) and it is noted as NI' displayed in 6(h).

Using the normalized image NI', the Gabor filter-based ridge improvement technique is improved. A sinusoidal plane wave with the specific orientation and frequency, regulated by a Gaussian envelope, makes up a 2-D Gabor filter [20]. Figure 6 displays the improved ridges in their final form (j).

Analysis and discussion

Three currently used techniques for fingerprint enhancement is used to evaluate this work utilizing efficient analytical metrics. The terms for those fingerprinting techniques are:

- Fingerprint enhancement using Multi-Scale Patch based Sparse Representation (MSPSR) [16]
- Fingerprint enhancement using Two Dimensional Discrete Wavelet Transform and Gaussian Template (2DDWTGT) [17]
- Fingerprint enhancement using two- dimensional short-time Fourier transform analysis (2DSTFT) [18]

The proposed work is evaluated using the two fingerprint databases listed below:

- NIST Special Database 301 (NIST301) [21]
- FVC 2006 database (FVC2006) [22]

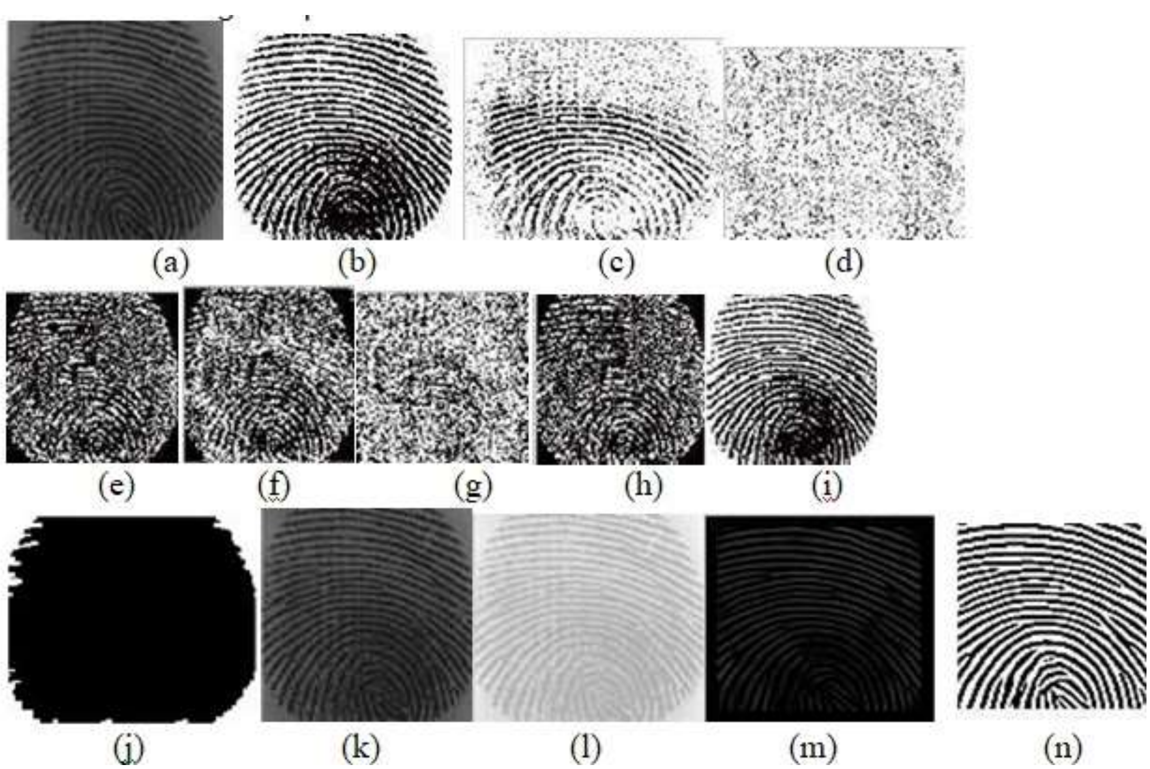


Figure 7. Fingerprint enhancement process for fingerprint Image 2, a) Query image, b) Binary wavelet image 1, c) Binary wavelet image 2, d) Binary wavelet image 3, e) Fused wavelet image for Binary wavelet image 1, f) Fused wavelet image for Binary wavelet image 2,g) Fused wavelet image for Binary

wavelet image 3,h) Minimum Std providing Fused wavelet image, i) Minimum Std providing LL Image from trinary wavelet process, j) Finger area image, k) Pores removed image, l) Normalized image, m) Gabor enhanced ridges, n)Final enhanced ridges.

Table1. AnalysisofRSSFCMonFVC2006database

Database Name	Image Name	RSSFCM			
		MSPSR method	2DDWTGT method	2DSTFT method	Proposed FPRE-TW-GF method
FVC2006	FVC_IMG1	9	7	5	4
	FVC_IMG2	9	6	3	2
	FVC_IMG3	6	8	7	3
	FVC_IMG4	8	9	6	1
	FVC_IMG5	9	7	5	4

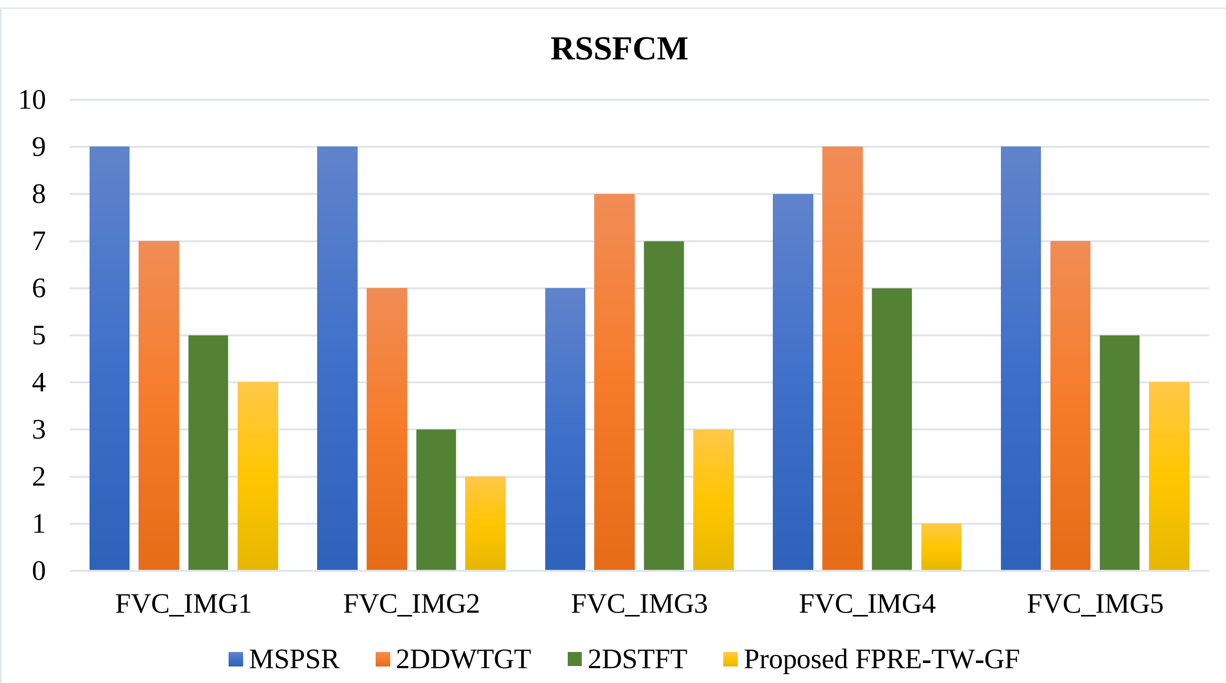


Figure8. ChartforRSSFCManalysisforFVC2006database

With MATLAB version 15, the coding work is carried out. The full implementation of the suggested strategy for improving fingerprints is shown in Figure 7. The system's input is the fingerprint image 2, which is shown in Figure 7. (a). Figure 7(j) displays the image of the finger area. Figure 7(k) displays the image with the pores eliminated. Figure 7(i) displays the image after being normalized. Figure 7(n) shows the ridges that were increased by Gabor.

Table2. AnalysisofRSSFCMonNIST301database

Database Name	Image Name	RSSFCM			
		MSPSR method	2DDWTGT method	2DSTFT method	Proposed FPRE-TW-GF method
NIST301	NIST_IMG1	10	8	6	5
	NIST_IMG2	9	8	5	3
	NIST_IMG3	8	6	5	2
	NIST_IMG4	9	8	4	4
	NIST_IMG5	8	7	5	2

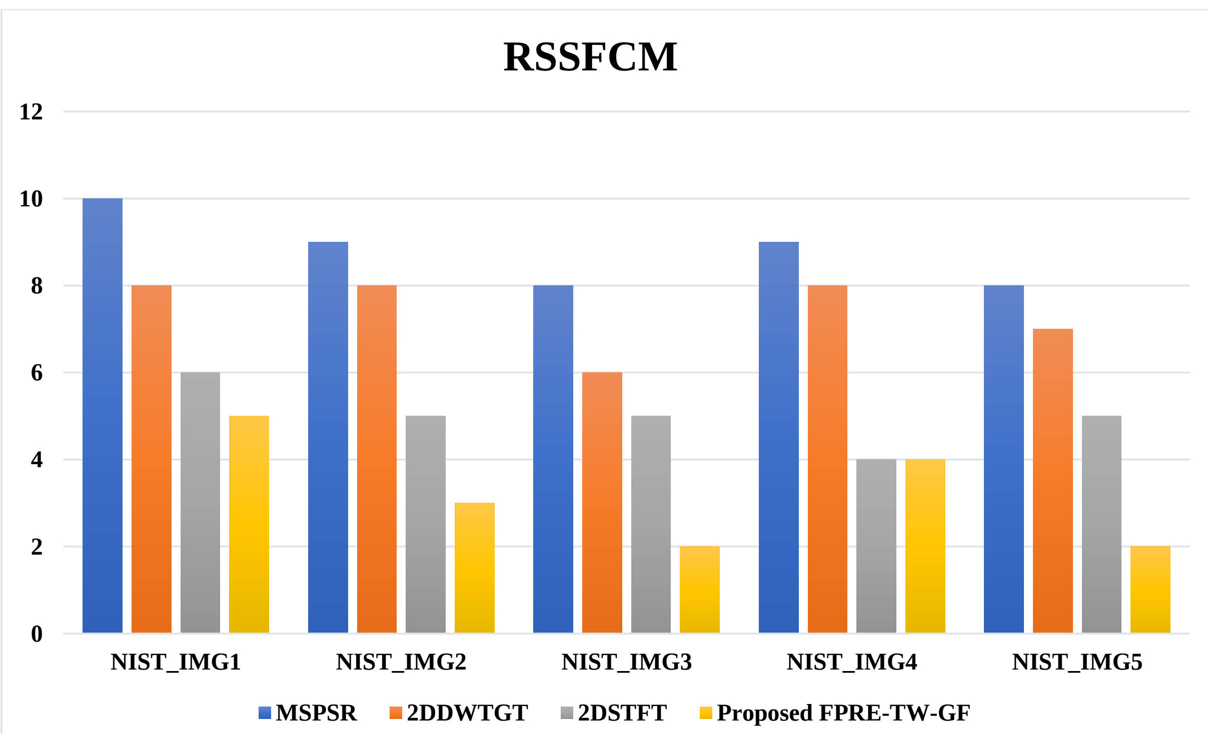


Figure9.ChartforRSSFCManalysisforNIST301 database

The results of the RSSFCM-based study on the NIST301 database are shown in Table 2 and Figure 9. The proposed method outperforms the existing Depending on the Ridge Structure Segmentation Failure Counts Metric, the proposed approach is assessed (RSSFCM). The analysis using RSSFCM based on the FVC2006 database is shown in Table 1 and Figure 8. The suggested approach has many advantages over the current ones, i.e it fails when experiencing fewer ridges ones in terms of benefits, as it encounters failure in a smaller number of ridges

The four techniques of the proposed method are compared using Mean Based Quality Measurement (MQM) for fingerprint enhancement on the FVC2006 database. To depict the average intensity following fingerprint enhancement, the MQM analysis is conducted

Table3. AnalysisofMQMonFVC2006 database

Database Name	**Image Name**	**MQM**			
		MSPSR method	**2DDWT GT method**	**2DSTFT**	**Propo sed meth**
FVC2006	FVC_IMG1	141.24	137.89	133.89	126.27
	FVC_IMG2	141.19	138.76	133.13	127.65
	FVC_IMG3	142.13	140.84	133.43	125.87
	FVC_IMG4	143.82	141.56	136.02	124.35
	FVC_IMG5	142.87	139.45	135.98	126.04

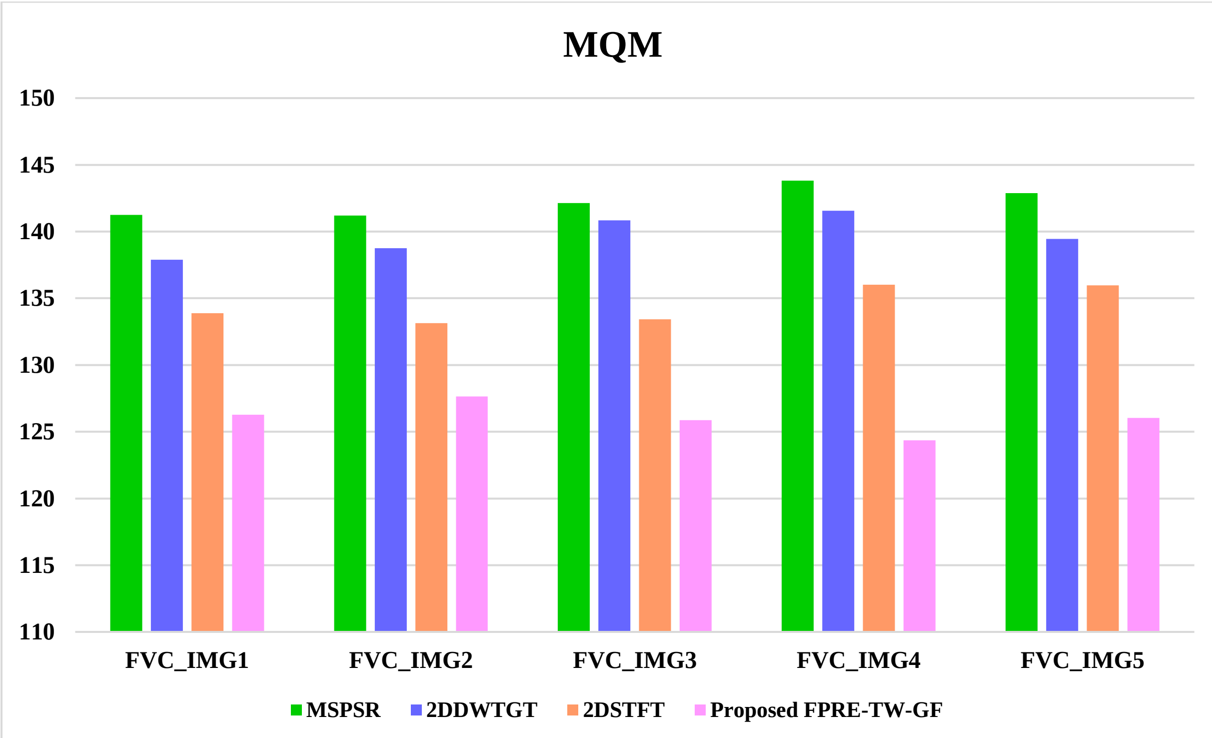


Figure10. ChartforMQManalysisforFVC2006 database

Results from the MQM assessment are reported in Table 3 and Figure 10, demonstrating the effectiveness of the suggested approach. The ideal approach for contrast enhancement is thought to generate improvements that are much closer to the average intensity of the population, or 128. The suggested approach yields results that are significantly closer to the intensity value of 128.

Table4. Analysis ofMQMonNIST301 database

Database Name	Image Name	MQM			
		MSPSR method	2DDWTGT method	2DSTFT method	Proposed FPRE-TW-GF
NIST301	NIST_IMG1	142.32	139.43	134.02	122.96
	NIST_IMG2	143.11	138.32	132.97	122.56
	NIST_IMG3	140.87	137.94	135.23	124.15
	NIST_IMG4	145.92	139.33	135.29	125.76
	NIST_IMG5	144.28	141.87	137.13	125.87

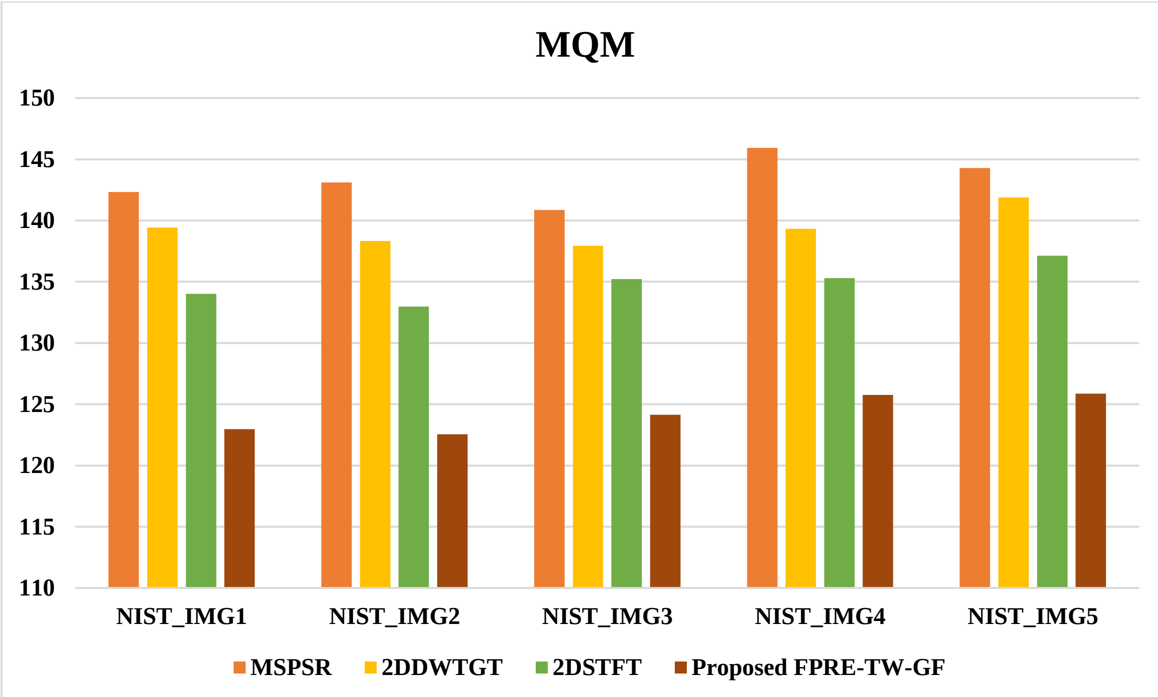


Figure11. Chart forMQManalysisforNIST301database.

Results from the MQM analysis are reported in Table 4 and Figure 11, demonstrating the effectiveness of the suggested approach. The suggested approach yields results that are significantly closer to the intensity value of 128. The significantly enhanced image is NIST_ IMG4.

Conclusion

The improved ridges in this article clearly highlight the bifurcations and ridge-ends, which substantially aids in the authentication and extraction of minute features. The primary algorithms in this work are the Gabor filters and the Trinary wavelet transform. For this study, datasets like FVC2006 and NIST301 are used. This study demonstrates that, when it comes to RSSFCM assessment, the FVC2006 database can be significantly more appropriate than the NIST301 database. The investigation demonstrates that, in comparison to the NIST301 database, the FVC2006 can be adaptively fitted to the suggested approach for MQM analysis. The study's findings show that the proposed method for fingerprint enhancement outperforms the ones already in use. The difficulty with future improvements is how to remove noise from noisy fingerprints.

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