Enhancement on Low Quality Fingerprint Images and Its Effect on Fingerprint Recognition System

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Abstract— **Fingerprint recognition is most consistent biometric identifier in use. The main reason behind the use of fingerprint biometric is that it is the most promising technique to identify the individual. The recognition rate of identification/verification systems depends on the quality of the fingerprint image. In fingerprint recognition system consists of two phases. These are extraction of suitable features of fingerprints and fingerprint matching. using these extracted features used to find the correspondence and similarity between the fingerprint images. The low quality of fingerprint images provides false minutiae at the stage of feature extraction and reduces the recognition rate of minutiae-based fingerprint matching systems. Enhanced fingerprint images improves the recognition rate but which substantially increased computational complexity. The main objective of this research is to develop an efficient and cost-effective scheme for enhancing fingerprint images that can improve minutiae extraction rate as well as effectively improve the recognition rate of a minutiae-based fingerprint matching system.**

Keywords- Fingerprint recognition,Fingerprint enhancement,Two stage filtering,minutiae extraction,fingerprint matching

I. INTRODUCTION

Efficient enhancement method is required to improve the quality of fingerprint images to provide good fingerprint recognition system [1-2]. Low-quality fingerprint images create spurious minutiae at the stage of feature extraction. Its leads to performance degradation of fingerprint matching. Low-quality fingerprint image is characterized by dryness, wetness, scars and so on. Fingerprint is dry due to the low temperature or lack of natural moisture in the skin, which produces broken ridges in the fingerprint image. The wetness of a fingerprint caused by the presence of excessive moisture in the skin, and it leads to conglutinated ridges in the fingerprint image. Scars are the evidences of a trauma, which leaves marks on the fingertip and thus create interruption in the natural flow of fingerprint ridges. There are several enhancement algorithms [6-8] have been proposed for fingerprint images in recent years. Enhancing fingerprint images is quite different from a general image enhancement. Improving minutiae extraction and recognition rate are the main goals in enhancing fingerprint images. An aggressive or weak enhancement algorithm [18] may create spurious minutiae leading to poor recognition rate. So incorporating enhancement algorithms in recognition systems are challenging task. A novel two-stage fingerprint image enhancement scheme that uses both spatial and frequency domain filtering [12] is proposed to improve the quality of fingerprint image. It aims at enhancing the quality of fingerprint images with a view to a better extraction of true minutiae and an improved fingerprint recognition rate.

II. TWO STAGE ENHANCEMENT SCHEME

Existing enhancement algorithms are not always satisfactory in enhancing low-quality fingerprint images. To overcome the demerits of all methods, we proposed a new and effective scheme for the enhancement of the images using two consecutive stages as shown in Fig. 1. This algorithm first enhances the images in the spatial domain with a spatial ridge-compensation filter and, then, enhances the images in the frequency domain. The parameters of frequency band pass filters are estimated from the original image and the first stage enhanced image [5].

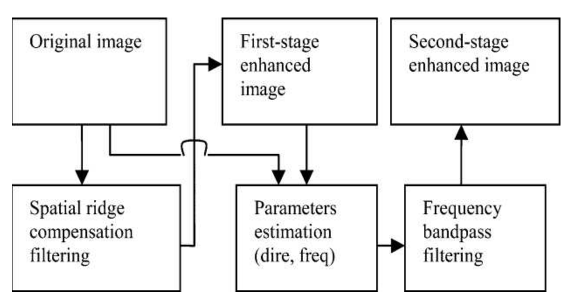


Fig. 1. Block diagram of two stage enhancement scheme

A. First Stage Enhancement: Spatial Domain

First enhances the fingerprint's local ridges [20] using the neighbor pixels in a small window with a weighted mask along the orientation of the local ridges. The ridge compensation filter compensate[10] defects in ridges in the spatial field.. Every pixels in the fingerprint is replaced with its weighted neighbor sampling pixels in a small window and with the controlled contrast parameters. It enhances the gray-level values of ridges' pixels and reducing the nonridge pixels' gray-level values. It can able to connect the broken bars and remove the smears in the fingerprint image.

B. Algorithm

1. Partition the fingerprint image into W×W nonoverlapping blocks.
2. Calculate normalized value of each pixel s

$$N(i,j) = M_0 + \frac{V_0}{V} \times (I_{FT}(i,j) - M)$$

where N is normalized image at pixel (i,j), M and V are mean and variance. M_0 and V_0 are the desired mean and variance of all blocks.

3. Find orientation field, O_l(i,j) from the normalized image .
4. Apply the ridge compensation filter to the normalized image and thus obtain the first-stage enhanced image .

$$I_{ST}(i,j) = \frac{\left(\sum_{m=-(w-1)/2}^{(w-1)/2} \sum_{n=-(h-1)/2}^{(h-1)/2} N(i',j') \right)}{(((w-1)\times\beta+\alpha)\times h)}$$

$$i' = i + m\cos(O_l(i,j)) + n\sin(O_l(i,j))$$

$$j' = j - m\sin(O_l(i,j)) + n\cos(O_l(i,j))$$

where m and n are the locations of filter mask of size w×h. α and β are contrast parameters and (i',j') is the new axes of pixel coordinate to make the ridge compensation filter oriented along the local ridge direction.

C.Experimental Result On First Stage Enhancement

Fig.2 shows the main steps in first stage enhancement and Fig.3 represent the changes in the fingerprint image. The output of the first stage enhancement shows that the broken ridges are connected and remove the smears in the fingerprint. It also increases the ridge contrast. Gradient method for orientation estimation and smoothing method with Gaussian window to correct estimation. Iterations improve the effectiveness of scheme.

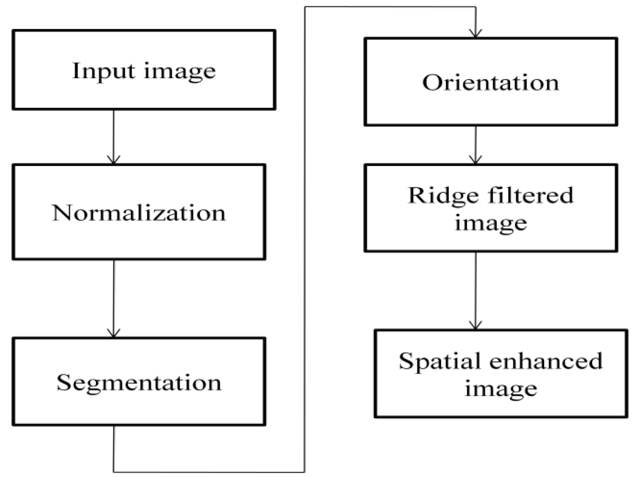


Fig. 2. Flow chart of first stage enhancement

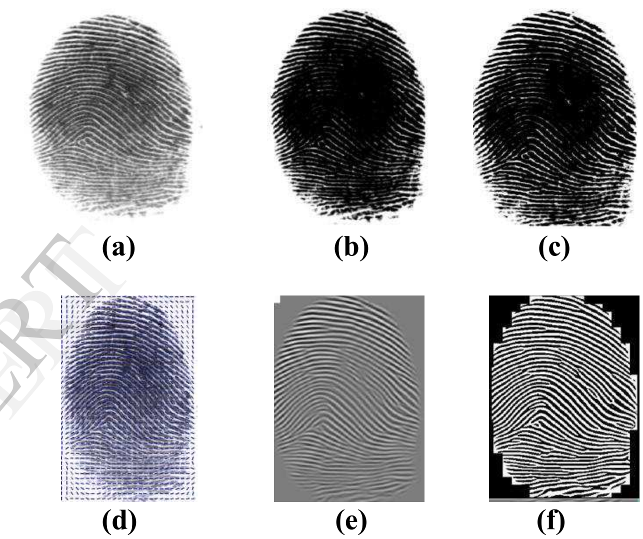


Fig. 3. (a) Orginal image (b) Normalization (c) Segmentation (d) Orientation (e) Ridge filtered image (f) First stage enhanced image

D. Second Stage Enhancement:Frequency Domain

Second-stage enhancement is performed to overcome the limitations of the first stage. Fingerprint image obtained from the first stage filter is further enhanced with an angular filter based on Gaussian function. In this the short time Fourier transform [16]is applied using Gaussian spectral window. The first-stage enhanced fingerprint image is partition into overlapped blocks. The block images are multiplied by a spectral window. Spectral window used in fingerprint image enhancement is the raised cosine window. We select Gaussian spectral window rather than the raised cosine window, since the Fourier transform or the derivative of a Gaussian function is also Gaussian. FFT of each block is obtained by a simple root filtering. The ridge orientation field is approximated and smoothened by a Gaussian kernel [19] to obtain a more accurate orientation field. The coherence image is then computed using orientation field. Angular filter is applied on each block FFT to obtain enhanced block. Enhanced fingerprint image is reconstructed combining all the block enhanced images. Segmentation method based on morphological operation is applied to enhanced fingerprint image.

E. Algorithm

1. Partition the first-stage enhanced fingerprint image, $I_{ST}(i,j)$ into N×N overlapping blocks, $I_B(i,j)$.

2. Remove the DC content of $I_B(i,j)$ as

$$I_B(i,j) = I_B(i,j) - avg(I_B(i,j))$$

3. Multiply each of the overlapping blocks by the proposed Gaussian spectral window W, as

$$I_B(i,j) = I_B(i,j) \times W(i,j)$$

4. Apply FFT on each block to obtain block FFT $I_{BFFT}(\omega_1, \omega_2) = FFT(I_B(i,j))$.

5. Perform root filtering on $I_{BFFT}(\omega_1, \omega_2)$

6. Compute the orientation field, $E\{\theta\}$ using the probabilistic approximation

$$E\{\theta\} = \frac{1}{2}\tan^{-1}\left\{\frac{\int_\theta p(\theta)\sin(2\theta)d\theta}{\int_\theta p(\theta)\cos(2\theta)d\theta}\right\}$$

where $p(\theta)$ is the probability density function of the orientation field θ, which is a random variable.

7. The second-stage orientation field, $O_{TS}(i,j)$ is then obtained by smoothing $E\{\theta\}$ with a Gaussian kernel, $G(i,j)$ of size K×K as

$$O_{TS}(i,j) = \frac{1}{2}\tan^{-1}\left\{\frac{\sin(2E\{\theta\} * G(i,j))}{\cos(2E\{\theta\} * G(i,j))}\right\}$$

8. Compute the coherence image $C(i,j)$ to adapt the angular bandwidth of the third-stage filter as

$$C(i_0, j_0) = \frac{\sum_{(x,y)\in N} \left|\cos\left(O_{TS}(i_0, j_0) - O_{TS}(i_x, j_y)\right)\right|}{N \times N}$$

where $C(i_0, j_0)$ and $O_{TS}((i_0, j_0)$ are the coherence and orientation, respectively, at the central block, and $O_{TS}(i_x, j_y)$ is the orientation of the neighboring blocks.

9. Compute the Gaussian angular filter, F_A centered around $O_{TS}(x,y)$ and the bandwidth inversely proportional to $C(x,y)$ for each overlapped block as

$$F_A(\varphi) = \begin{cases} \exp\left(-C_\varphi * \left(\frac{\varphi - \varphi_c}{\varphi_{BW}}\right)^2\right), & if\ |\varphi| < \varphi_{BW} \\ 0, & otherewise \end{cases}$$

where φ_{BW} is the support and φ_C is the center of the angular filter.

10. Apply the angular filter F_A over each block to obtain the enhanced blocks in FFT domain as

$$I_{ENBFFT}(\omega_1, \omega_2) = I_{BFFT}(\omega_1, \omega_2) * F_A$$

11.Compute the enhanced blocks, $I_{ENB}(i,j)$ in the spatial domain by inverse fast Fourier transform (IFFT) as

$$I_{ENB}(i,j) = IFFT(I_{ENBFFT}(\omega_1, \omega_2)$$

12.The third-stage enhanced fingerprint image, $I_{TS}(i,j)$ is obtained by combining all the enhanced blocks $I_{ENB}(i,j)$.

13. Finally, a segmentation is applied to enhanced fingerprint image.

F. Experimental Result on Second Stage Enhancement

Fig. 4. Shows main steps involved in two stage enhancement and Fig. 5. Shows the output of these steps. From the output we concluded that the quality of the fingerprint image can be enhanced if two stages are used. The problems of broken ridges, scars/creases, falsely conglutinated ridges, smears and poor contrast could be dealt with effectively using two stage enhancement.

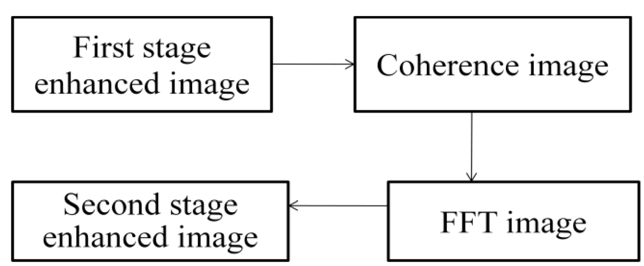
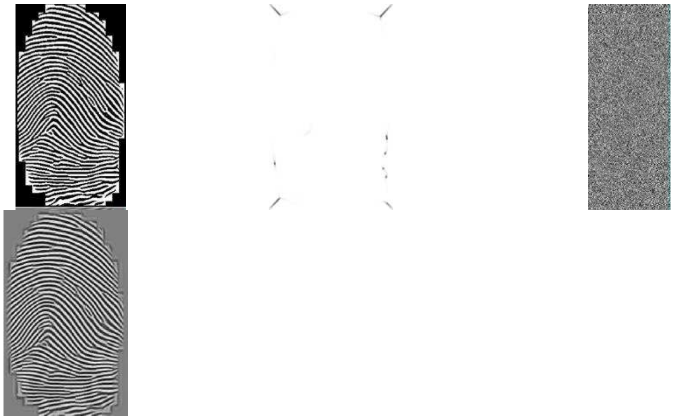


Fig. 4. Flow chart of second stage enhancement



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

Fig. 5. (a) First stage enhanced image (b)Coherence image (c)FFTimage (d) Second stage enhanced image

III..EFFECTIVENESSOF THE PROPOSED ENHANCEMENT SCHEME IN FINGERPRINT RECOGNITION

Fingerprint recognition systems[11] are mainly two categories: (1) automatic fingerprint verification system (AFVS) and (2) automatic fingerprint identification system (AFIS). Automatic fingerprint verification system (AFVS) verify the identity of an individual by comparing the captured fingerprint with previously stored fingerprint template(s) of that individual in a database. AFVS performs a one-to-one comparison to clarify the identity obtained by that individual is true or not. A verification system accepts the claimed identity as a genuine match or rejects it as an imposter match. An automatic fingerprint identification system (AFIS) recognizes the identity of an individual by searching the entire fingerprint database. AFIS performs one-to-many comparisons for a match to establish the identity of that individual. If the claimed identity is present in the database, the identification system returns a genuine match as a result; otherwise it rejects the identity claimed by that individual as an imposter match. In this, a two-stage filtering scheme to enhance fingerprint images has been proposed. Effectiveness and usefulness of the proposed enhancement scheme are examined in fingerprint feature extraction[9] and matching for fingerprint recognition application. A minutiae extraction algorithm [21-22] is applied to the original and enhanced images in order to show the effectiveness of the proposed enhancement scheme. Minutia-based matching algorithm [3]is also applied to the set of extracted minutiae using a hybrid shape and orientation descriptor in order to find similarity between two fingerprints[17].

A. Minutiae Extraction

The reliability of minutiae-based fingerprint recognition systems depends on an accurate detection of fingerprint minutiae[9,14]. Accurate extraction of minutiae is heavily dependent on the quality of the fingerprint image. Minutiae extraction methods are mainly two categories: 1) features extracted from the binary images of gray-scale fingerprints and 2) features extracted directly from gray-scale images. This method mainly consists of two steps: binarization and thinning. The gray-scale fingerprint image is transformed into a binary intensity of black (0) or white (1). This transformation is performed by applying a threshold value, t, to the fingerprint image. The pixel values of the gray-scale image are compared with t for finding the binary image. Pixel value larger than the threshold is set to one and any value smaller than the threshold is set to zero.

$$I_b(x,y) = \begin{cases} 1, & \text{if } I(x,y) \geq t \\ 0, & \text{otherwise} \end{cases}$$

where I(x,y) is the grey-level fingerprint image and t is the threshold. The binarized image I_b(x,y) undergoes a thinning operation which reduces the thickness of all ridges to a single pixel. The image obtained after the thinning operation, namely, the skeleton image contains the locations and orientations of the minutiae similar to that in the input fingerprint image. The skeleton/thinned image is obtained by applying a simple morphological thinning operation. The thinned binary image is analyzed in order to extract and store minutiae information. In order to obtain the minutiae information, the Rutovitz crossing number] is used within a 3×3 window centered at each pixel p a**s**

$$cn(p) = \frac{1}{2}\sum_{i=1}^{8}\left|val(p_{(i \bmod 8)}) - val(p_{i-1})\right|$$

Where cn(p) is crossing number of a pixel p and val(p) $\in$ {0,1}is the binary image pixel value. The crossing number is used to identify minutiae pixel location, as ridge ending having cn=1, bifurcation having cn=3, core point having cn=5 and delta point having cn>5 within the thinned image. To show the effectiveness of the enhancement scheme minutiae extraction algorithm is applied to the original image and the enhanced image.

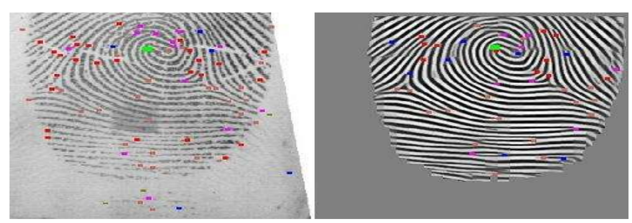


Fig. 5. Minutiae from (a) Original image. (b) Enhanced image

B. Fingerprint Matching

Two fingerprint templates are compared based on the degree of similarity between the two fingerprint images. The matching decision [13]of the two fingerprint images is based on a threshold value. The similarity score between 0 and 1 indicates whether or not the fingerprint under consideration is the same as the reference fingerprint. Minutiae-based matching extracts minutiae from two fingerprints and stores them as sets. Non-minutiae based matching uses more reliable features. In this a matching algorithm based on a hybrid shape and orientation descriptor is applied to both the original and enhanced images. This method involved two steps: adaptive greedy registration and matching[15].

IV. PERFORMANCE RESULTS AND COMPARISON

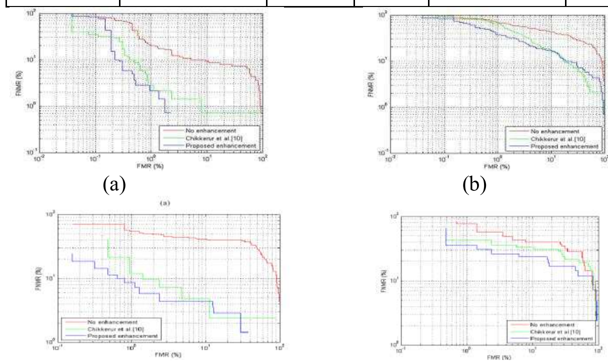
The effectiveness of fingerprint image enhancement on fingerprint recognition are evaluated in terms of equal error rate (EER), receiver operating characteristic (ROC) curves and average CPU time for fingerprint template formulation[4].

Table1EER(%)using original and enhanced fingerprint images

Finger print images	FVC2002		FVC2004	
	DB1	DB2	DB3	DB4
Original image	9.36%	29.36%	31.43%	37.22%
Enhanced by STFT	2.17%	14.29%	28.09%	4.76%
Enhanced by proposed	1.42%	13.63%	18.57%	4.28%

Table2 CPU times (s) for the fingerprint template formulation and matching scheme

Module	Finger print image	FVC 2002		FVC2004	
		DB1	DB 2	DB1	DB2
Templa te formati on	With no enhancem ent	23.1	26. 6	41.17	28.59
	enhancem ent using STFT	25.6	32. 2	44.63	22.2.09
	enhancem ent using the proposed scheme	20.5	24	35.76	21.26
Matchi ng	with no enhancem ent	8.2	5.1	32.5	68.9
	enhancem ent STFT	6.7	6.8	23.4	41.3
	enhancem ent using the proposed method	3.9	4.6	21.3	16.4



(a) (b) (d) (e)

Fig. 6 ROC curves for FVC2002 (a) DB1 and (b) DB2 and FVC2004(c)DB1(d)DB2 original and enhanced images

V. CONCLUSION

Fingerprint enhancement algorithms are most commonly used operation to improve the feature extraction and matching in fingerprint recognition system. Broken ridges, smears, scars/creases and falsely connected ridges in fingerprint images will affect enhancement algorithms . Many methods have been proposed to overcome these difficulties to improve the quality of fingerprint images. This will result in an increased computational complexity in enhancing fingerprint images. So proposed computationally efficient technique for fingerprint enhancement that can meet not only the challenges arising from the need for accurate estimation of global features of the fingerprints, but also deal effectively with the problems resulting from the block processing of fingerprint images. This enhanced image is applied to the fingerprint recognition system and performance is evaluated.

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