An Effective Block-Processing Based Enhancement Scheme for Low-Quality Fingerprint Images

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Abstract— **Fingerprint recognition has been emerged as the most popular and widely used biometric technique because of its universality, distinctiveness, permanence, and accuracy. Automatic fingerprint authentication is considered as the most reliable means of biometric authentication. However reliable fingerprint recognition is still an open problem. The performance of an automatic fingerprint identification system depends critically upon the quality of the input fingerprint image. Feature extraction from poor quality fingerprints is the most challenging problem faced in this area. Usually,fingerprint images are enhanced in either the spatial domain or the frequency domain. An effective block processing based two-stage enhancement scheme for low-quality fingerprint images, is proposed in this work, by integrating spatial and frequency-domain filters. The first stage enhancement, which is completely in the spatial domain,helps in improving the contrast between the ridges and valleys by using a ridge compensation filter.By learning the ridge parameters from the first stage enhanced image, a second stage enhancement completely in the frequency domain is performed using a frequency bandpass filter.As a final step prior to the minutiae extraction, binarization and thinning operation is performed.**

Keywords- **Block-Procesing, Filtering, Fingerprint Enhancement, Frequency Domain, Spatial Domain**

I. Introduction

Among all biometric technologies,fingerprint recognition is the most popular and widely used one because of the fact that fingerprints are unique and persistent. A human fingerprint is a pattern characterized by alternating ridges and valleys on the surface of a fingertip. The set of ridgelines often flow in parallel, but intersect and terminate at some points. The local ride characteristics and their relationships determines the uniqueness of a fingerprint. The local ridge characteristics refer to the local discontinuities in the fingerprint pattern and the two most prominent and most discussed ridge characteristics are terminations(ridge endings) and bifurcations. Fingerprints are the most reliable human characteristics that can be used for people identification purposes due to its uniqueness and permanence. However the performance of an automatic fingerprint recognition/matching techniques depends critically upon the quality of input fingerprint image. The quality of a fingerprint image may be poor or significantly different because of various factors, such as wetness and dryness, pressure strength, smears, and so on, which lead to different types of degradation in fingerprint images. Existing low-quality fingerprint image enhancement techniques are not enough to meet the contexts of a high-performance verification system. Moreover, enhancement needs to be conducted in order to enhance the fingerprint image completely.

A human fingerprint is said to be the pattern of ridges and valleys (also called furrows in the fingerprint literature) on the surface of a fingertip. Each individual has unique fingerprints. The local ridge characteristics and their relationships determines the uniqueness of a fingerprint. A total of 150 different local ridge characteristics have been identified.(islands, short ridges, enclosure etc.). The local ridge characteristics in a fingerprint pattern are not evenly distributed. Most of the local ridge characteristics depend heavily on the impression condition and quality of fingerprints. The two most discussed and the most prominent local ridge characteristics, called minutiae, are ridge ending and ridge bifurcation. A ridge ending is defined as the point where a ridge ends abruptly. A ridge bifurcation is defined as the point where a ridge forks or diverges into branch ridges. A good quality fingerprint typically contains about 40–100 minutiae.

A critical step in fingerprint matching is to automatically and reliably extract minutiae from the input fingerprint images. Most of the minutiae extraction algorithms' performance relies heavily on the quality of the input fingerprint images. In an ideal fingerprint image, ridges and valleys alternate and flow in a locally constant direction and minutiae are the local ridge characteristics. The wrong ridge structural information can change the information of the minutiae points and reference points. So it can be fatal to recognition algorithms and also it may also cause some errors in feature extraction. Inorder to reduce the possibility of recognition error, a robust enhancement algorithm is required, especially for low-quality fingerprint images., Fingerprint images are of non stationary nature and therefore the complex ridge structures are not easily distinguished. All the existing enhancement techniques proposed in recent years are either based on spatial domain techniques or based on frequency domain techniques.

In the case of a high-performance verification system. only one-stage processing either in the spatial domain or the frequency domain for fairly low-quality fingerprint image enhancement is not enough to meet its context .Moreover, enhancement processes needs to be conducted in order to enhance the fingerprint image completely[2]. In order to overcome the shortcomings of the existing algorithms on the fairly poor fingerprint images with cracks and scars, dry skin, or poor ridges and valley contrast ridges, a novel and effective two-stage enhancement algorithm for low-quality fingerprint images is proposed through this work.The method integrates the spatial- and frequency-domain filters. This method adequately uses the information of the first stage enhanced image for the estimation of second stage filters' parameters.

The local normalization reduces the variations in gray-level values along ridges and furrows in the first-stage processing,.The ridge compensation filter, uses the context information of the local ridges and is used to connect broken ridges and separate merged ridges. The first stage processing remedies the ridge areas and enhances the ridge contrast between the ridges and furrows. Although the first stage processing enhances the ridges, it blurs the images as the neighbouring pixel information is used in windowing operations.Thus, the first stage enhanced image is again enhanced using a second stage filter, that is, a tuned bandpass filter separable in the radial and the angular-frequency domains, inorder to improve the fingerprint image completely. This processing enhances the image very well because of the fast and sharp attenuation of the filter in both the radial and the angular-frequency domains[2].

The rest of the paper is organized as follows. Related works on fingerprint enhancement are introduced in Section II. The proposed method is explained in detail in Section III .The result analysis and discussion are given in section IV.Finally, concluding remarks given in Section V.

II. RELATED WORKS

In the recent past many enhancement techniques have been proposed for the fingerprint images. A majority of the existing enhancement techniques has been proposed in recent years, and some of them are based on spatial-domain methods and some are based on frequency domain methods. In [1] the authors found that a critical step in automatic fingerprint matching is to automatically and reliably extract minutiae from the input fingerprint images.In order to ensure a high performance automatic fingerprint identification/verification system, it is essential to incorporate a fingerprint enhancement algorithm in the minutiae extraction module of the system. So the system will be robust with respect to the quality of input fingerprint images In their work [1], a fast fingerprint enhancement algorithm, which can adaptively improve the clarity of ridge and valley structures of input fingerprint images based on the estimated local ridge orientation and frequency has been proposed.

In [5], the authors introduced a new approach for fingerprint enhancement based on short time Fourier transform (STFT) Analysis. STFT is a well-known signal processing technique to analyze non-stationary signals. Here the application of STFT to 2D fingerprint images is considered.The authors proposed an algorithm which simultaneously estimates all the intrinsic properties of the fingerprints such as the foreground region mask, local ridge orientation and local ridge frequency. However, , not all of the unrecoverable regions of the fingerprint can be recovered clearly, because of the complex input contexts of the low-quality images. Also,through a simple STFT analysis, it is difficult to accurately estimate some parameters of the filters. Thus, the algorithm needs to be improved to enhance the unrecoverable regions of low-quality images.

In[4],the authors found that all the most prominent fingerprint enhancement methods perform well for relatively high-quality images but less effectively for low-quality images, especially where the ridge patterns are very noisy and corrupt.The authors proposed an effective three step algorithm to enhance such low quality images.The method locally normalizes input images, computes the local ridge orientation, and then applies a local ridge compensation filter with a rotated window in order to enhance the ridges by matching the local ridge orientation.

In [2],authors proposed a novel and effective two-stage enhancement schemeby integrating the spatial domain and the frequency domain techniques and by learning from the underlying images.The fingerprint image is first enhanced in the spatial domain to remedy the ridge areas and enhance the contrast of the local ridges.This is done using a spatial ridge-compensation filter and by learning from the images.With the help of the first step, the second stage filter, i.e., a frequency bandpass filter that is separable in the radial and angular-frequency domains, is employed.

In[3],the authors proposed a novel procedure for fingerprint enhancement filter design. Fingerprint image identification is usually based on matching the features obtained from a query image against those stored in a database.In the case of poor quality fingerprint images, this matching process cannot be performed well. The authors proposed a new method is to quantify and justify the functional relationship between image features and filter parameters.Here, the enhancement process is completely adapted to the input image characteristics to improve its efficiency.

III. PROPOSED METOHD

An effective two stage enhancement scheme is proposed for low-quality fingerprint images.The architecture of the scheme is as follows.

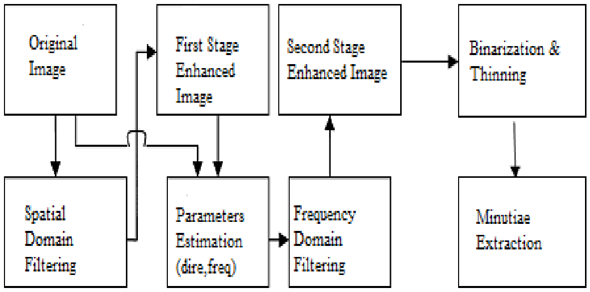

Fig. 1 The architecture of the proposed system

- *First-Stage Enhancement:*

The first-stage enhancement process mainly focuses on estimating the unbiased local orientation and compensating the possible defects by using the estimated orientation. The scheme consists of four steps: segmentation, local normalization, local orientation estimation, and local ridge-compensation filtering.

i. Segmentation

Segmentation process separates the foreground regions in the fingerprint image from the background regions. The clear fingerprint regions containing the ridges and valleys correspond to the foreground regions, which is the area of interest. The regions outside the borders of the fingerprint area corresponds to the background region, which do not contain any valid fingerprint ridge characteristic.

ii Normalization

The normalization process reduces the local variations in the intensity distributions and standardizes the intensity values so that the local orientation can be estimated with increased accuracy.This operation does not change the clarity of the ridge and valley structures. But it reduces the variations in gray-level values along ridges and valleys, which is useful in the further processing steps.

Let ,$I(i, j)$ denote the gray-level value at pixel (i, j), M and V denote the estimated mean and variance of the image I, respectively, and $G(i, j)$ denote the normalized gray-level value at pixel (i, j). The normalized image G(i,j) can be defined as follows:

$$G(i,j) = M0 + coeff * (I(i,j) - M)$$

$$coeff = \frac{v0}{v}$$

M_0 and V_0 are the desired mean and variance values, respectively.

iii.Orientation Estimation

The direction of ridges in different parts of a fingerprint image varies. The orientation estimation step determines the dominant direction of the ridges in different parts of a fingerprint image.Gradient method is used for orientation estimation.The normalized image is divided into non-overlapping blocks of size W*W.A single orientation is assigned to a single block, which corresponds to the most probable or dominant orientation of that block.The horizontal gradient value $G_x(u, v)$ and the vertical gradient value $G_y(u, v)$ corresponding to a pixel are obtained using simple gradient operator such as sobel mask.The horizontal and vertical gradients of a block, i.e., G_{xx} and G_{xy} , are obtained by adding up all the pixel gradients of the corresponding direction.

iv. Ridge-Compensation Filtering

This step enhances the fingerprint's local ridges using the neighbor pixels in a small window with a weighted mask along the orientation of the local ridges. Each pixel in the fingerprint is replaced with its weighted neighbor sampling pixels in a small window and with the controlled contrast parameters along the orientation of the local ridges.

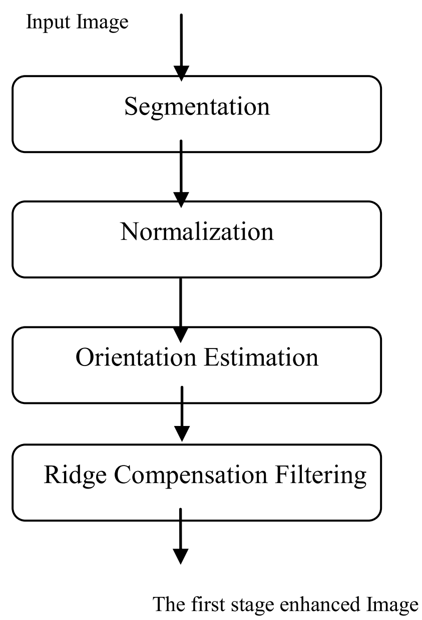

Fig.2: Diagram of the whole process of the first-stage enhancement.

- *Second-Stage Enhancement:*

The result of the first stage enhancement process increases the ridge contrast between the ridges and furrows in a direction perpendicular to the ridges.This processing may blur the image as well. In order to overcome this, a second-stage enhancement process is integrated to the spatial filtering process. The second stage enhancement uses a tuned bandpass filter,ie, a frequency bandpass filter which is separable in the radial and angular domains, respectively. The steps involved in second stage processing are:

i. Local Orientation & Frequency Estimation

By learning from the first stage processing, this step determines the dominant direction of the ridges in different parts of the fingerprint image, for obtaining a new orientation map. As in the first-stage filtering, which used the gradient method for orientation estimation, the same steps are followed to obtain the orientation of each pixel/block.

Frequency indicates the inter ridge separation in different parts of the fingerprint image. The FFT,ie, F = FFT(block_img) is applied to each block to determine the local frquency.The new frequency is computed using the frequencies both from the enhanced image and the original image.The new frequency is calculated as the average value of its neighbour if the difference of frequencies from the enhanced image and the original image is larger than a threshold value, or else it equals the frequency that is acquired from the enhanced image.

ii. Coherence Image

The orientation of the central block and those of its neighbours in the orientation map is calculated inorder to obtain the coherence image.There exists high coherence when the orientation of the central pixel $\theta(x, y)$ of a window is similar to each of its neighbours.The bandwidth of the angular filter is determined using the obtained coherence image.

iii. Frequency Bandpass Filtering

The first stage enhanced image is divided into overlapping subimages.Then the FFT of each subimage is obtained by removing the dc component, F = FFT (block_fltimg).The angular filter Fa is applied in the FFT domain.This filter is centered on the local orientation image.The bandwidth of the angular filter is inversely proportional to the coherence image. As the next step, a radial filter Fr is applied.The applied radial filter is centered on the local frequency image.Then the block is filtered image in the frequency domain is obtained, i.e., F = F × Fa × Fr. In the final step of the enhancement process, the enhanced image is reconstructed using the inverse fourier transform,ie, Enhimg = IFFT(F). The Enhimg is the final enhanced image of the integrated spatial and fourier domain enhancement process.

iv. Binarization & Thinning

In the case of binary images there are only two levels of interest:the black pixels that represent ridges, and the white pixels that represent valleys. Mostly minutiae extraction processes are performed on binary images.The binarization process converts the grey level image into binary image.As a result of the binarization process,the contrast between the ridges and valleys will be increased.This improves the minutiae extraction process. In binarisation process the grey-level value of each pixel in the enhanced image is examined, and, if the value is greater than the global threshold, then the pixel value is set to a binary value one; otherwise, it is set to zero. The result of binarization is a binary image with only two levels of information, the foreground ridges and the background valleys.

Thinning is performed as a final step in the image enhancement process.This step can be considered as a morphological operation that eliminates the foreground pixels that are not one pixel wide.The thinning operation is performed in two sub iterations using a standard thinning algorithm.

v. Minutiae Extraction

For the purpose of evaluation of the performance of the enhancement scheme,minutiae extraction is performed. Crossing Number (CN) concept [1, 16, 20] is employed for minutiae extraction . In this process,skeleton image where the ridge flow pattern is eight-connected.For the purpose of extracting minutiae, the local neighbourhood of each ridge pixel is scanned in the image using a 3×3 window. The CN value is then computed as half the sum of the differences between pairs of adjacent pixels in the eight-neighbourhood. T he properties of the CN is shown in table1.The ridge pixel can then be classified as a ridge ending, bifurcation or non-minutiae point. For example, a ridge pixel with a CN of one corresponds to a ridge ending, and a CN of three corresponds to a bifurcation.

CN	Property
0	Isolated Point
1	Ridge Ending Point
2	Continuing ridge Point
3	Bifurcation Point
4	Crossing Point

Table 1: Properties Of the Crossing Number

IV. RESULT ANALYSIS AND DISCUSSION

Experiments are conducted using the database FVC2004 DB2_a, which primarily contains low-quality images. In the experiments, first, we applied our enhancement algorithm and, then, followed the minutiae extraction method. The results shows that the proposed method is effective combined with the minutiae-extraction method.The results are compared with two input contexts: the original image and our proposed enhanced image. It can be seen from the table that when the input is an original image, there are many false minutiae. When our proposed enhanced image is used as input, the number of false and missing minutiae is less than that when the original image is used.

The terms True minutiae ratio (TMR), false minutiae ratiov(FMR), dropped minutiae ratio (DMR), and exchanged minutiae ratio (EMR) can be defined as the as the ratio of the number of true minutiae, false minutiae, dropped minutiae, and exchanged minutiae divided by the number of total minutiae, respectively

	TMR(%)	FMR(%)	DMR(%)	EMR(%)
Original Image	36.4	34.5	17.7	11.4
Enhanced Image	95.4	2.33	1.14	1.13

Table2: AVERAGE TMR (%), FMR (%), DMR (%), AND EMR (%) Performance of the System Combined With the Original Image.

V. CONCLUSION

An effective two-stage enhancement algorithm by integrating the spatial domain and the frequency domain techniques has been proposed through this work. The main focus of the enhancement scheme is low-quality images, the first-stage enhancement scheme has been designed to use the context information of the local ridges to connect or separate the ridges. Based on this spatial filtering, the broken ridges will be connected and the merged ridges will be separated effectively; thus, the fingerprint ridges can be remedied and recovered well. In the second-stage processing, the filter is separable in the radial and angular domains, respectively. Its parameters have adequately been determined by the information of both the original image and the enhanced images of the first stage instead of acquiring from the original image solely. Thus, the proposed two-stage scheme enhances the fingerprint images significantly.

VI. REFERENCES

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