CHAPTER 5

A Preprocessing Stage and Post Processing Stage

The preprocessing and post processing has multiple stages like normalization, enhancement, binarization and thinning, removal of bridges and spurs, and finally minutiae extraction and purification. Among them fingerprint enhancement, minutiae extraction and purification are the main stages of preprocessing and post processing.

5.1 Fingerprint Enhancement

The Image enhancement is a process which removes the unwanted noise or information from the input image, for further operations, depending on the type of application. Since the fingerprint images, acquired from sensors or other media are not always assured with perfect quality, the enhancement methods are needed, to increase the contrast between ridges and furrows and for connecting the false broken points of ridges due to different moisture condition on the skin etc.

The general purpose image enhancement techniques are not very useful due to the nonstationary nature of a fingerprint. In many cases, a single fingerprint image contains regions of good, medium, and poor quality, where the ridge pattern is very noisy and corrupted. When it uses a single filter convolution of the entire fingerprint image, it creates a significant number of spurious minutiae, a large number of genuine minutiae are missed and large error in the location (position and orientation) of minutiae are introduced. However, techniques such as gray-level smoothing, contrast stretching, histogram equalization can be used as pre-processing steps before a sophisticated fingerprint enhancement algorithm is applied. The estimation of orientation field plays an important role in the fingerprint enhancement. A good fingerprint enhancement technique obtains a relatively good estimate of orientation field, even if the quality of input fingerprint image is poor. Most of the fingerprint enhancement techniques use contextual filter or multi-resolution filter.

5.1.1 Directional Filter

Directional Filter is one of the enhancement technique which is familiar in multi-resolution enhancement method [85]. The Multi-resolution analysis has been proposed to remove noise from fingerprint image by decomposing the image into different frequency bands (or sub-images). This allows to compensate for different noise components at different scales: in particular, at higher levels (low and intermediate frequency bands) the rough ridge-valley flow is cleaned and gaps are closed, whereas at the lower levels (higher frequencies) the finer details are preserved. The enhanced image bands are then recombined to obtained the final image. Generally, in directional filter bank, the fingerprint image is divided into eight parts according to the orientation of the ridge structure. The eight orientations of fingerprint ridge flow structure is defined as shown in fig. 5.1.

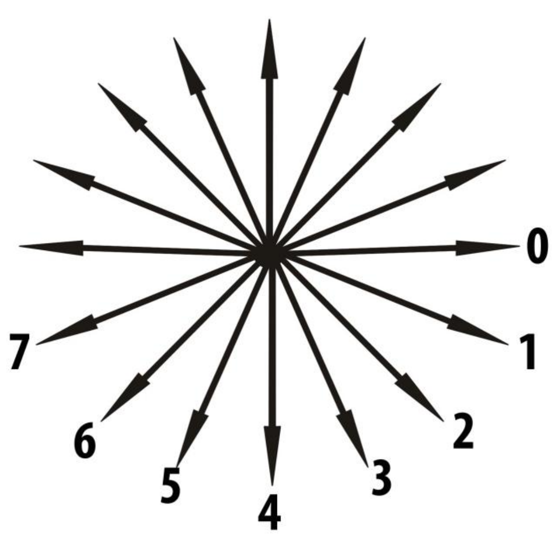


Fig 5.1. Orientation of fingerprint ridge flow

Some of the enhancement methods based on directional filters are Gabor filter [11,13,14], Short Time Fourier transformation (STFT) [52,88], Fast Fourier transformation (FFT) [10,86,89].

5.2 Proposed Fingerprint Enhancement

The enhancement algorithm used in this work is the combination of Fast Fourier Transformation (FFT) and Gaussian filter. A simple but effective fingerprint enhancement algorithm is found after adding Gaussian filter [87] to FFT developed by the Wuzhili[86]. These two enhancement methods are considered as primary enhancement and secondary enhancement. The FFT is used as a primary enhancement and Gaussian filter is used as a secondary enhancement.

5.2.1 Primary Enhancement

The primary enhancement is performed on the input fingerprint image to remove the noise from the ridge and furrow structure of the noisy fingerprint image. The primary enhancement using the Fourier transform technique is achieved by dividing the image into small processing blocks of size 32 x 32 pixels and the Fourier transformation is performed on each block according to the following equation (1):

$$F(u,v) = \sum_{x=0}^{M-1} \sum_{y=0}^{N-1} f(x,y) * \exp\left\{-j2\pi * \left(\frac{ux}{M} + \frac{vy}{N}\right)\right\} \; --- (1)$$

for u = 0,1,2,...,31 and v = 0,1,2,...,31.

The sub-divided blocks are enhanced by their dominant frequencies by multiplying the FFT of the block by its magnitude a set of times and the magnitude of the FFT is obtained as |F (u,v)|.

The enhanced block is obtained according to equation (2)

$$g(x,y) = F^{-1}\{F(u,v) * |F(u,v)|^{K}\} \; --- (2)$$

where ‘k’ is an experimentally determined constant (k=0.45 is taken for experimentation). While having a higher ‘k’ value improves the appearance of the ridges, by filling up small holes in ridges and having a too high “k” value can result in false joining of ridges. Thus a termination might become a bifurcation. The inverse transform is given in equation (3).

$$f(x,y) = \frac{1}{MN} \sum_{x=0}^{M-1} \sum_{y=0}^{N-1} F\,(u,v) * \exp\left\{j2\pi * \left(\frac{ux}{M} + \frac{vy}{N}\right)\right\} --- (3)$$

for x = 0, 1, 2, ..., 31 and y = 0, 1, 2, ..., 31.

The enhanced image due to Fourier Transformation has the improved ridge structure by connecting some falsely broken points on the ridge and removing some spurious connection between the ridges. However, the alignment of the ridges in the sub-blocks of the images may lead to some spurious connection which can be removed in the secondary enhancement stage.

5.2.2 Secondary enhancement

A Secondary enhancement is performed using a two dimensional Gaussian filter given in equation (4).

$$f(x,y) = e^{-\frac{x^2+y^2}{2\sigma^2})} --- (4)$$

where σ is the standard deviation. A large value of σ produces a flatter curve and a small value leads to a “pointier” curve. In this study, the value of σ is 1.5 as shown in figure 5.2.

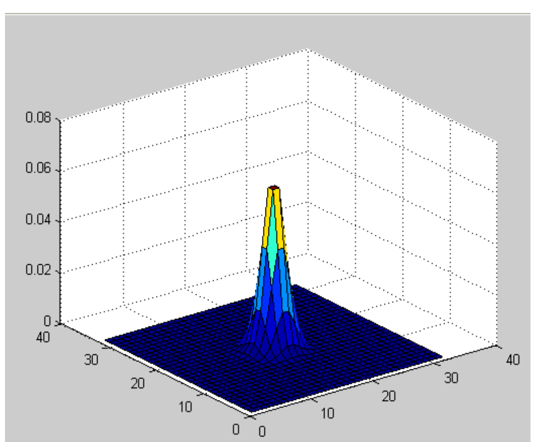
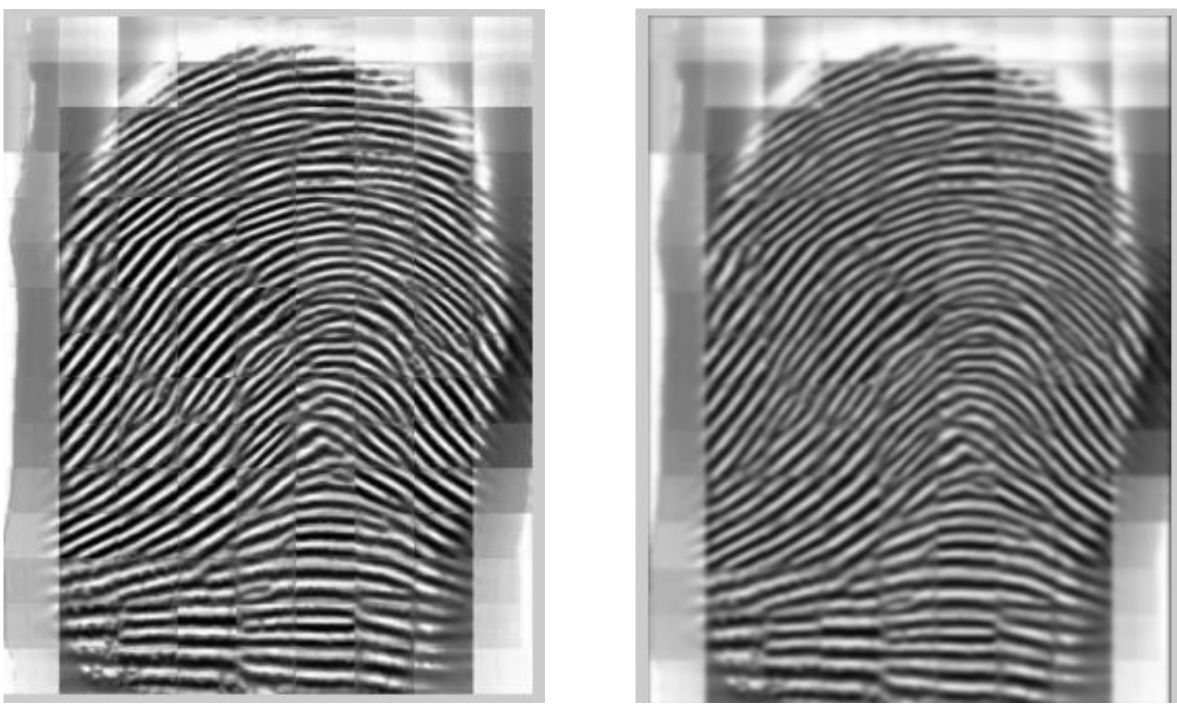


Figure 5.2 Two-dimensional Gaussian with σ = 1.5

5.3. Necessity of Secondary Enhancement After Primary Enhancement.

After reconstruction of images from FFT, the image of each block is enhanced like a sine wave with different direction. So, the ridge and furrow alignment of many blocks were found mismatch and this will create the “hairy” structures which lead to spurious ridge bifurcations and ridge endings in the post processing stage. In order to make smoother and better results from this misalignment, a low pass filter is required. A typical fingerprint image after FFT enhancement and Gaussian filter is shown in figure 5.3.



a) After FFT enhancement b) After FFT and Gaussian Filter enhancement

Figure 5.3 Enhancement Image

The closed view of missed alignment of some blocks after FFT enhancement is shown in figure 5.4.

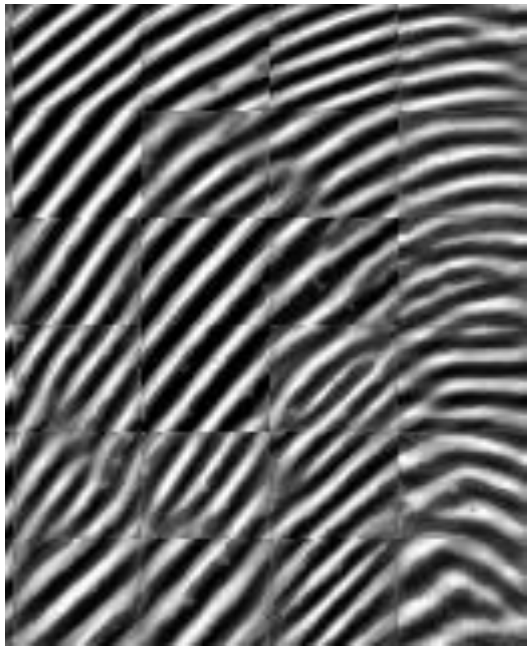
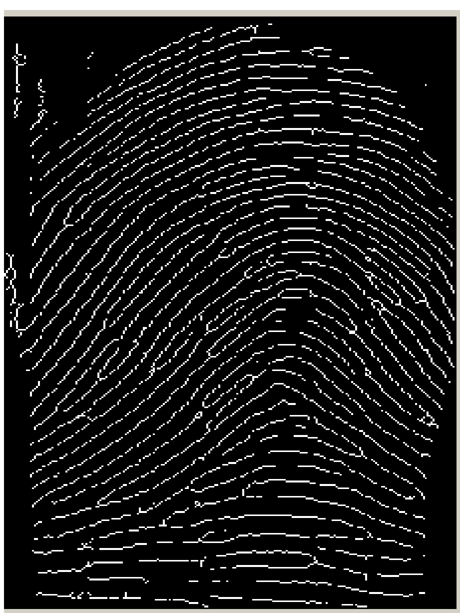
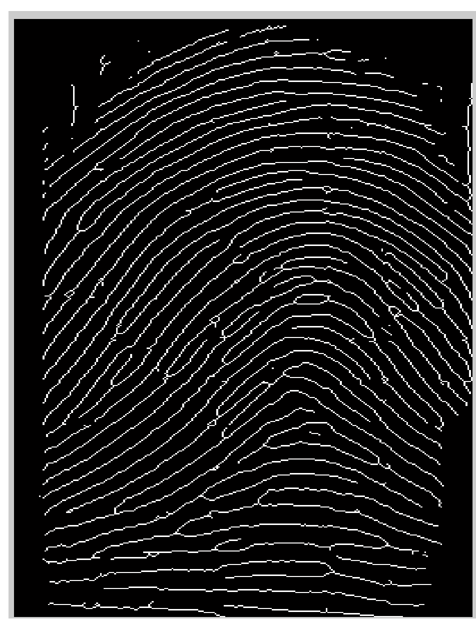


Figure 5.4 A 32 x 32 block pixel of 4 X 6

Another advantage of using Gaussian filter after FFT is found in the fingerprint ridge thinning. The artificial ridge gap after thinning process without Gaussian filter is shown in fig. 5.5(A).



(A) Skeleton image without gaussian filter



(B) Skeleton Image with gaussian filter

Figure 5.5 Skeleton image with and without secondary enhancement

This artificial ridge gap will compromise the accuracy of the whole fingerprint recognition system as it will create a number of ridge ending. By using Gaussian filter after FFT enhancement, almost all the artificial ridge gap is not seen in the fig. 5.5(B).

5.4 Minutiae Extraction

In this section, minutiae extraction method is discussed which used the crossing number (CN) defined by Rutovitz [33] and widely used by many authors [9, 22, 26, 28]. For a pixel ***P*** in the snap shot of an image is shown, the crossing number is calculated using the equation 5.

$$\begin{bmatrix} P_4 & P_3 & P_2 \\ P_5 & P & P_1 \\ P_6 & P_7 & P_8 \end{bmatrix}$$

(A snap shot of an image in the 3X3 matrix form)

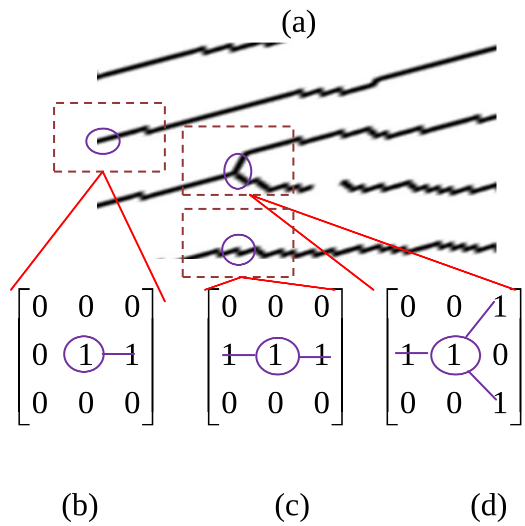
$$CN = \frac{1}{2}\sum_{I=1}^{8} |P_I - P_{I+1}| \qquad (5)$$

where, P_i is the neighbourhood of P with binary value of either 0 or 1.

The CN value using Equation 1 can have values ranging from 0 to 4, which shows the properties of point P providing P=1 as shown in Fig. 3. The properties of CN are as follows:

i. when CN=0, ***P*** is known as Isolated point.
ii. when CN=1, ***P*** is known as Ending point.
iii. when CN=2, ***P*** is known as Connecting point.
iv. when CN=3, ***P*** is known as Bifurcation point.
v. when CN=4, ***P*** is known as Crossing point.

The occurrence of isolated points and crossing points are treated as false points, so these points are filtered using morphological function in post-processing stage.



(a)Skeleton Image (b)Ending point (CN=1) (c)Connective point(CN=2) (d)Bifurcation point (CN=3)

Fig 5.6: Illustration of crossing number properties.

5.5 Purifying Minutiae

The possible occurrence of the false minutiae has been explained by different authors [22, 29, 34]. The minutiae extracted in the above section may include many spurious minutiae and may degrade the accuracy of the matching system, if they are considered as genuine minutiae.

The procedure for the identification for the false minutiae and the removal of the same is given below by assuming a threshold distance D as the average inter ridge width representing the average distance between the two parallel neighbor ridges.

a) In the fingerprint pattern, the bifurcation and termination are considered in the same ridge and the distance between the two is less than the threshold distance D then the bifurcation and termination are removed.

b) By identifying the two bifurcations (if any) on the same ridge with an inter distance less than the threshold distance, the two bifurcations will be removed.

c) If a false minutiae due to any two terminations are identified with the following conditions:

(i) Two terminations are within the distance D and their directions are coincident with a small angle variation and

(ii) No other termination is located between the two terminations, then the identified false minutiae, by the broken ridge due to two terminations, are removed. The two terminations located in a short ridge with a distance less than D are identified and removed.

5.6 The Different Stages of Preprocessing and Post processing

Other than the fingerprint enhancement, minutiae extraction and purification, the remaining stages used morphological function available in the MATLAB. The different level of preprocessing and post processing stages is shown in fig. 5.7.

Preprocessing	**Post processing**
a) Normalization	a) Remove bridge
b) Primary enhancement	b) Remove spur
c) Secondary enhancement	c) Minutiae extraction
d) Binarization	d) Purification
e) Thinning	

Figure 5.7. A preprocessing and post processing stages

5.7 Chapter Summary

In this chapter, we proposed an improved fingerprint enhancement algorithm for preprocessing stage of fingerprint recognition system. The advantages of the improved fingerprint enhancement technique over the existence FFT fingerprint enhancement are discussed. The different stages of preprocessing and post processing stages are also discussed in this chapter.