# A DYNAMIC ENHANCEMENT METHOD FOR FINGERPRINT MATCHING

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**ABSTRACT**

*In this paper, we propose a technique a dynamic enhancement method for an adaptive fingerprint matching. Directional wavelet transform and Gabor filter are applied. The original fingerprint image is decomposed into approximation and detail sub-images. To each sub-dimension a directional filter: Gabor filter is applied for tuning up the image features. The filter parameter changes at every iteration. The filtered images are then used in the reconstruction phase. Changing in parameters of the filter not only resulted in the changing in line-end positions but also bifurcate positions. We investigated these changes. At some positions, the matching score can be made highest. There, the matching can be justified.*

*Keywords-Fingerprint enhancement; Wavelet transform; Gabor filter; Biometric.*

## 1. INTRODUCTION

Among all the biometrics, fingerprint-based identification is one of the most popular and reliable biometric techniques. This is because it holds many desirable features such as universality, permanence, collectability, and distinctiveness. Personal identification based on fingerprint matching is now popular in wide range of applications. Most automatic fingerprint identification systems are based in minutiae matching [1, 2, 3].

A fingerprint is the pattern of ridges and valleys on the surface of a fingerprint. Minutiae are local discontinuities in the fingerprint pattern. The most important ones are ridge ending and ridge bifurcation. Spurious ridge structure may change the individuality of input fingerprints. Ridges and valleys in a local neighborhood form a sinusoidal-shaped plane wave, which has a well-defined frequency and orientation. The main difficulty for feature extraction is that fingerprint quality is often too low, thus noise and contrast deficiency can produce false minutiae or hide valid ones. Even high quality images can also yield false minutiae, for example, when the person has cuts or scars in his/her fingers.

Minutiae-based matching relies on the set of the position of line-end and bifurcates. The consistency of these locations is very important. The wrong identifying these locations can affect the matching score such that the identification is not so successful. Our approach is to generate a set of valid locations to be considered by the matcher. These locations are changed slightly within a certain condition (for example, the locus lies in the same ridge). Under this approach some short-distance broken ridges can be joined and the fake lineends are made disappear. We do line-end extrapolation by configuring the filter parameters. While tuning up the filter parameter, the obtained binarized image can be processed for end point and bifurcate points where the matching can be performed consequently. This iterative method is shown in fig. 1. below.

The rest of this paper is organized as follows. In section II, the review the directional filtering that performed in the wavelet domain. Directional wavelet transform and Gabor filter are outlined. In section III, steps required in enhancement are given in brief. In section IV, to illustrate the performance of adaptive filtering we give some examples of filtered and binarized images. The paper is concluded in section IV. In this paper, we are not giving the details of fingerprint matching.

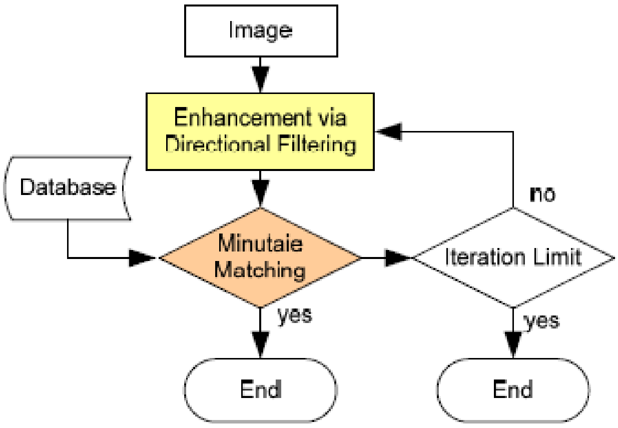


**Figure 1.** Iterative Enhament for adaptive matching

## 2. DIRECTIONAL FILTERING ENHANCEMENT

The main of an enhancement algorithm is to improve the clarity of ridge structures of fingerprint images in recoverable regions and to remove the unrecoverable regions.

In the fingerprint image, the pattern is related to the ridge direction. In principle, the enhancement can help visualizing the ridges. It is reasonable to use any type of directional filter in either single or multi-resolution analysis.

One of the most widely cited fingerprint enhancement using wavelet transform and Gabor filtering. This method uses wavelet transform for demising and increases the contrast between the ridge and background (valley) by using a map function to the wavelet coefficient set, and thereafter, the Gabor filter method can further enhance the ridge using the orientation and frequency information [4, 5, 6, 7,8].

In this work, a directional wavelet transform is applied to decompose the image into its orientation representation. Directional filtering (DF) is applied to each direction before image reconstruction. This is shown in Fig. 2 below. The Daubechies wavelet (db4) is used to decompose the fingerprint image before directional filtering. We reconstruct the fingerprint image by using the enhanced approximation image and detail images produced in decomposition.

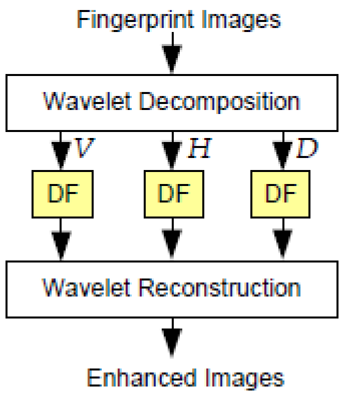


**Figure 2.** Fingerprint enhancement by mean of wavelet transform and directional filtering

### 2.1. Directional Wavelet Transform

The discrete wavelet transform of function f (x, y) of size M ×N is formulated as:

$$W_{\varphi}(j_0,m,n)=\frac{1}{\sqrt{MN}}\sum_{x=0}^{M-1}\sum_{y=0}^{N-1}f(x,y)\varphi_{j_0,m,n}(x,y) \tag{8}$$

$$W_{\psi}^{i}(j,m,n)=\frac{1}{\sqrt{MN}}\sum_{x=0}^{M-1}\sum_{y=0}^{N-1}f(x,y)\psi_{j,m,n}^{i}(x,y) \tag{9}$$

where i = {H,V ,D} , ψi (x, y) are directional wavelet, j0 is the starting scale of a scaling function ϕ(x, y) , and the Wϕ( j0 ,m,n) coefficients define the approximation of f (x, y) , at scale j0 . The Wψ( j,m,n) coefficients represent the horizontal, vertical and diagonal details for scales j ≥ j0 . Here j0 = 0 and select M + N = 2J so that j = 0,1, 2,.., J − 1 and m, n = 0,1, 2,..,(2J − 1). Then f (x, y) is obtained via the inverse discrete wavelet transform.

$$f(x,y)=\frac{1}{\sqrt{MN}}\sum_{m}\sum_{n}W_{\varphi}(j_0,m,n)\varphi_{j_0,m,n}(x,y)+\frac{1}{\sqrt{MN}}\sum_{i=H,V,D}\sum_{j=j_0}^{\infty}\sum_{m}\sum_{n}W_{\psi}^{i}(j,m,n)\psi_{j,m,n}^{i}(x,y), \tag{10}$$

As an example for one decomposition level the obtained decomposed images are shown below. The upper right subimage shows horizontal component. The lower left subimage shows vertical component while the lower right subimage shows the diagonal component respectively.

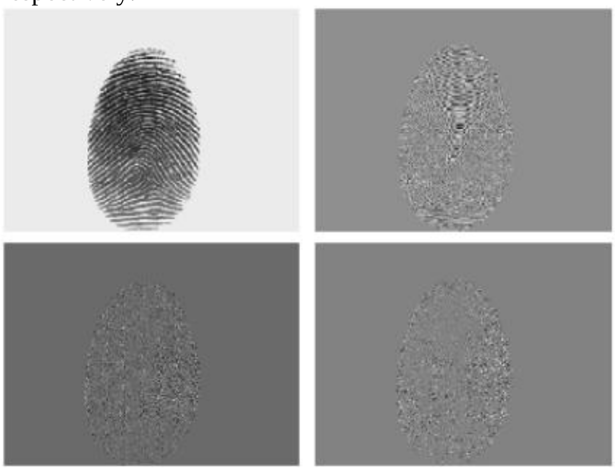

**Figure 3.** Wavelet transforms decomposition one level

### 2.2. Directional Filtering (Gabor Filter)

Gabor filter is employed to remove noise and preserve the ridge and valley structures. The sinusoidal-shaped waves of ridges and valleys vary slowly in a local constant orientation. Therefore, a band-pass filter that is tuned to the corresponding frequency and orientation can efficiently remove the undesired noise and preserve the true ridge and valley structures. The Gabor filter have both frequencyselective and orientation-selective properties and have optimal joint resolution in both spatial and frequency domains.

$$h(x,y:\phi,f)=\exp\left[-\frac{1}{2}\left(\frac{x_{\phi}^{2}+y_{\phi}^{2}}{\sigma_x^{2}+\sigma_y^{2}}\right)\right]\cos(2\pi f x_{\phi}) \tag{12}$$

where

$$\begin{bmatrix} x_{\phi} \\ y_{\phi} \end{bmatrix}=\begin{bmatrix} \sin\phi & \cos\phi \\ -\cos\phi & \sin\phi \end{bmatrix}\begin{bmatrix} x \\ y \end{bmatrix} \tag{13}$$

Where, φ is the orientation of the Gabor filter, f is the frequency of a sinusoidal plane wave, σx and σy are the standard deviations of the Gaussian envelope along x and y axes, respectively.

We used the selective feature of the filter to tune up the filter characteristic that affect the enhancement result. Illustrate in Fig 4. below, the filter with different standard derivation.

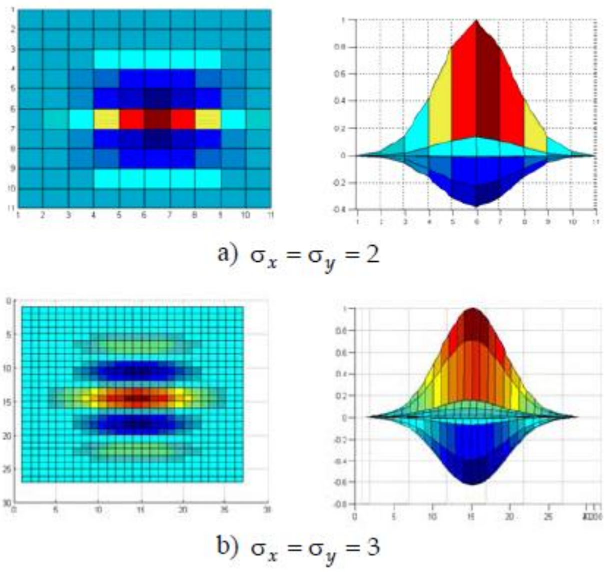


**Figure 4.** Gabor filter's shape at different stand derivations

## 3. FINGERPRINT ENHANCEMENT PROCESS

There several steps in the enhancement. The main objective is trying to remove noise and tuning the direction of the ridges. Field smoothing is the heart of field direction tuning. The subsequent directional filer works on this tuned orientation. The detail process is as follows.

### 3.1. Normalization

The processing of fingerprint normalization can reduce the variance in gray-level values along ridges and valleys by means of adjust the gray-level values to the predefined constant mean and variance. And normalization can remove the influences of sensor noise and gray-level deformation.

### 3.2. Ridge Frequency Estimation

In a gray scale image, repeated ridges and valley appearance of fingerprint patterns can be viewed as a sinusoidal shape with some particular frequency. We can approximate ridge frequency of the fingerprint image by dividing it into blocks (for instance, 5 × 5 pixels). An oriented window (oriented in the direction orthogonal to the local ridge orientation) is used to approximate this sinusoid. The inverse of the average distance between the numbers of peaks encountered is the local frequency of that block. In our case, the ridge frequency of 0.10-0.12 was measured. The obtained frequency is used in the directional filtering step.

### 3.3. Wavelet Decomposition

In this paper, we select Daubechies to implement the decomposition for its sufficient information in sub-image approximation. Theoretically, we can decompose the image into sub-images at any level. However, too low resolution is not suitable because an excessive down sampling of the signal can destroy the orientation characteristic of the ridge structure. We used only one decomposition level in this experiment.

### 3.4. Orientation Field Estimation

Since directional filtering is a direction-sensitive filter. We have to estimate the local orientation before applying the filter. Before such an attempt we apply 2D Low Pass Weiner filter (block of 5 × 5 ) to the image as a purpose of noise reduction with some effect of directional filtering.

Let φ(i, j) be defined as the orientation field of a finger print image. φ(i, j) represents the local ridge at pixel (i, j) . In general local ridge is specified for a block rather than for every pixel. Thus, an image is divided in to a set of nonoverlapping blocks, size of w ×w . Each bock holds a single orientation. A procedure proposed for orientation estimation is summarized below [2].

Divide the input image into consecutive (nonoverlapping) blocks size of w ×w . We used w = 16 .

Compute the x and y magnitude of the gradients ( , ) x ∂ u v and ( , ) y ∂ u v , at each pixel (i, j) . The local orientation of each block centered at pixel (i, j) can be estimated by:

$$\phi(i,j) = \tfrac{1}{2}\tan^{-1}\left(\frac{V_y(i,j)}{V_x(i,j)}\right) \qquad (11)$$

Where, φ(i, j) is the least square estimate of the local ridge orientation of the block centered at pixel (i, j) and

$$V_x(i,j) = \sum_{u=i-w/2}^{i+w/2} \sum_{v=j-w/2}^{j+w/2} 2\partial_x(u,v)\partial_y(u,v), \qquad (12)$$

$$V_y(i,j) = \sum_{u=i-w/2}^{i+w/2} \sum_{v=j-w/2}^{j+w/2} 2\partial_x^2(u,v)\partial_y^2(u,v), \qquad (13)$$

### 3.5. The Filter and Image Reconstruction

The Gabor filter with selectable standard derivation detailed in the previous section is used at this step. After modifying the approximated sub-image with directional filter, we can reconstruct the final fingerprint image.

### 3.6. Binarization and Features Detection

The enhanced image is then thinned and binarized to ease endpoint and bifurcate detection. Since the main concept of minutiae matching is based on the availability and consistency of line-end and bifurcate appear on the fingerprint, correct detection of these features is important key.

## 4. EXPERIMENT AND RESULTS

In this experiment we used few samples of downloaded DB1_A of FVC-2004. Figure 5 demonstrates the filtering capability of the proposed technique. The original image is at quite good quality. Ridges are disconnected across the pattern. Theses disconnections are not so severe that ridge reconnection can be made by the filtering process. Stared from 1, the standard derivation of the filter was increased up to 4. At each change, line-ending position and bifurcate position are recorded and counted. Number of points decreased as the image looked better. The quality of enhanced image seems stable after σx = σy = 3 . Figure 6 demonstrate the filtering of a very poor original image. A portion of the image was taken and fed through the enhancement process. Obviously, the filtering has great affected the quality improvement. The movement of the lineending point can be clearly observed. Number of line-end point and bifurcate point varies in an interval but with a trend of decline when standard derivation of the filter increases.

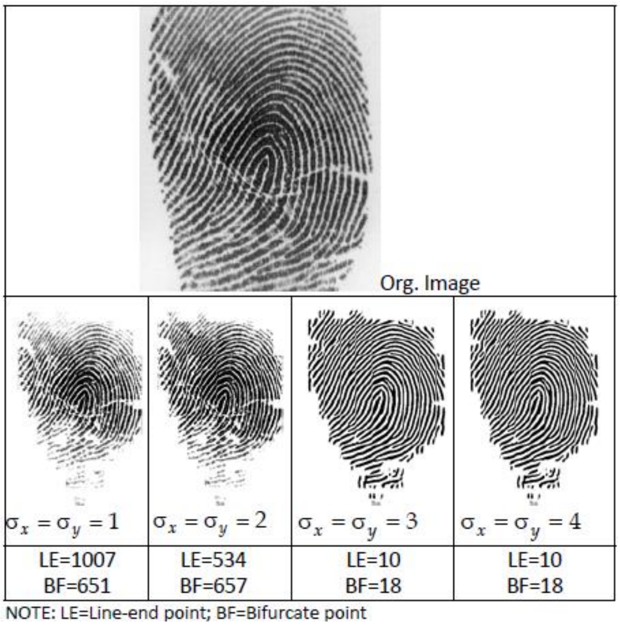


**Figure 5.** Images after enhancement (good image with some cuts)

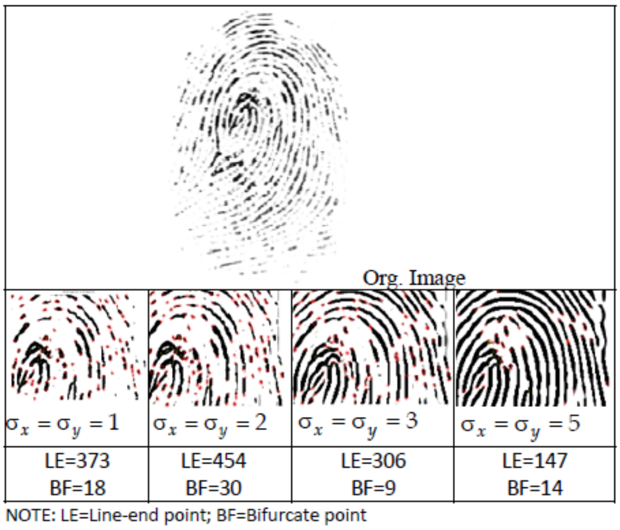


**Figure 6.** Image after enhancement (Very poor quality image)

## 5. CONCLUSION

In this paper, we propose a dynamic fingerprint matching method by the making the directional filter to be an adaptive one. Adaptive filtering has employed wavelet transform and Gabor filter. The performance to the Gabor filter is tuned by changing its standard derivation ( σx and σy ). Toward our notice, the filter can play a good impact when its standard derivation is 2-3. After 5, the image is not much improved. According to the filter's parameter changing, the line-ending position tends to change accordingly. In some cases, bifurcate can be recovered. These changes can result in minutiae matching score. At some proper positions of these minutiae, the fingerprint pattern can be matched. Hence, our effort is believed to improve the successful rate of fingerprint matching.

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