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Fingerprint Matching Algorithm Using Gabor, Median And Anisotropic Filters

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Abstract

In this paper an enhanced image-based matching algorithm is used to improve the matching accuracy and processing speed over poor quality images. It reduces the multispectral noises by using various filters. To enhance the images, using filtering techniques it can be categorized into isotropic and anisotropic according to the filter kernel. Isotropic filtering can properly preserve features on the input images but can hardly improve the quality of the images. On the other hand, anisotropic filtering can effectively remove noise from the image only when a reliable orientation is provided. For direct gray scale enhancement we used separately the median filter, gabor filter and anisotropic filters. Extract the minutiae from fingerprint images is the main important process in fingerprint enhancement. This can be done through local histogram equalization and image binarization. The comparison is based on a characterization criterion, usually used to evaluate the features discriminating ability. After that, the accuracy of the proposed approach is evaluated with Back Propagation Neural Network (BPNN). Extensive experiments prove that the fingerprint enhancement based on a novel features and BPNN algorithm gives better results in fingerprint matching than several other features and methods. Finally the results of the proposed method are evaluated on the FVC 2004 database. Experimental results achieved in three methods are compared with other methods and shows some improvement in matching process in terms of time required and efficiency.

Key words: Fingerprint image enhancement, Minutiae, Median filter, Gabor filter, Anisotropic filter.

1. Introduction

Fingerprints are today the biometric features most widely used for personal identification. In an automatic fingerprint verification system, the input includes a user identity (ID) and a fingerprint, and the output indicates whether the input fingerprint is consistent with the ID. The system simply compares the input fingerprint with the one addressed by the ID in the database. The performance of an automatic fingerprint verification system in terms of matching accuracy and computation speed depends mainly on methods of feature extraction and matching algorithm. Ridge termination and bifurcation, uniformly called minutiae, are the important characteristic features of fingerprint. Most minutiae-based methods suffer from several shortcomings, such as extracting minutiae from a poor-quality fingerprint image may result in low matching accuracy. In addition, these methods may not fully utilize the rich discriminatory information available in the fingerprints with high computational complexity [1].

Enhancement improves the clarity of the ridge structures to extract correct features. There are many filters for enhancement. For fingerprint images, enhancement using gabor, anisotropic, median are used with the proposed algorithm. The performance of minutiae based methods depends heavily on the quality of the fingerprint images [2]. The ridge structure in poor-quality fingerprint images is not always well defined and hence cannot be correctly detected. Therefore large errors in minutiae localization may be introduced [2]. Example of poor quality image is shown in figure 1. In order to ensure robust performance of a minutiae extraction algorithm, which can improve the clarity of the ridge structures, is necessary [2, 6].

Figure 1: Poor Quality Image

Matched filtering is a widely used image-processing operation in reducing image noise. Generally speaking, filtering techniques can be categorized as isotropic and anisotropic based on whether the filter kernel is orientation sensitive. The most commonly used isotropic filter is the median filter. Hong et al. [2] used Gabor filter banks to enhance fingerprint images and reported good performance. Gabor filter have both orientation and frequency-selective properties. Filtering, such as reducing image noises, smoothing, removing some forms of misfocus and motion blur, is in the front step of image processing. Since Hong [5] introduced the gabor filter to enhance fingerprint images, it has been adopted in many methods for fingerprint enhancement [6, 7, 8]. Figure 2 shows example images obtained by various filters. In anisotropic filter, another kind of structure-adaptive anisotropic filtering technique has been proposed by yang[9]. Instead of using local gradients as a means to controlling the anisotropism of filters, it uses both a local intensity orientation and a anisotropic measure to control the shape of the filter, adapter to fingerprint images. Instead of using both local ridge orientation and local frequency information, ridge orientation image by computing the gradients of pixels are used in our approach.

In this paper a we made comparative study by using median, gabor and anisotropic filters. The false acceptance rate and rejection rate can be calculated for three different filters. Figure 2 show example images obtained by various filters.

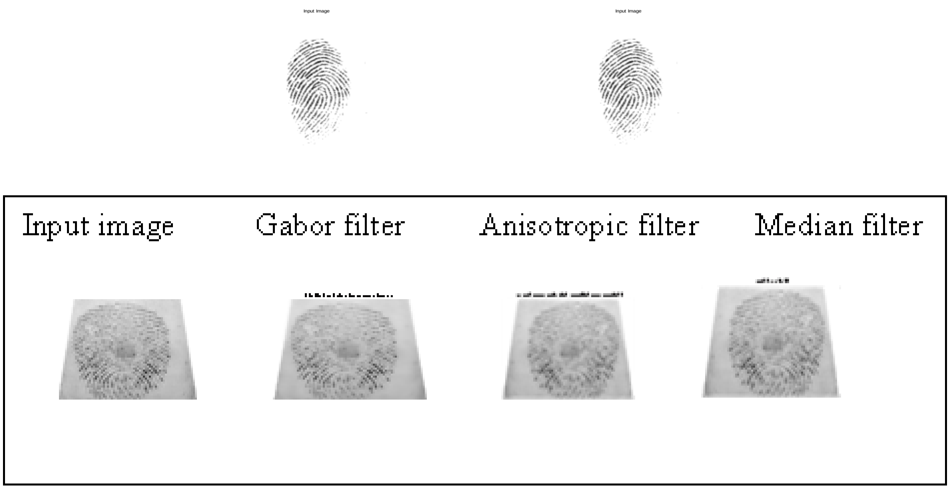

Figure 2: Images of several filters

2. Fingerprint image enhancement

Image processing techniques classically involved in typical preprocessing treatment like histogram equalization, normalization when applied to fingerprint images that can expand contrast or reduce some kind of noise. However, before any method is selected, it is initially important that the noise notion be properly defined. Dealing of such line pattern images, noise can be expressed as breaks in the directional flow of ridges. Moreover, the non-stationary property of fingerprint images suggests the use of contextual filters locally tuned. Such contextual information has to make in advance the textured nature of fingerprint images: on a block, the gray levels of the ridges and valleys constitute a sinusoidal form along the normal direction to the orientation field (see Figure 3).

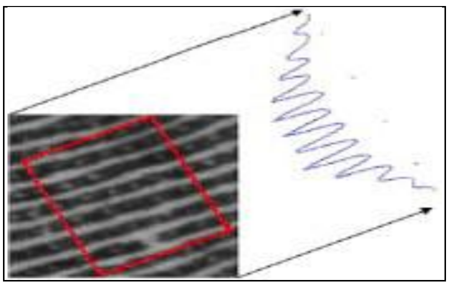

Figure 3: Sinusoidal form of an image

2.1 Median filtering

Median filter, the most prominently used impulse noise removing filter, provides better removal of impulse noise from corrupted images by replacing the individual pixels of the image, as the name suggests by the median value of the gray level. The median of a set of values is such that half of its values in the set are below the median value and half of them are above it and so it is the most acceptable value than any other image statistics value for replacing the impulse corrupted pixel of a noisy image for if there is an impulse in the set chosen to determine the median it will strictly lie at the ends of the set and the chance of identifying an impulse as a median to replace the image pixel is very less. A commonly used non-linear operator is the median, a special type of low-pass filter. The median filter takes an area of an image (3x3, 5x5, 7x7, etc.), sorts out all the pixel values in that area, and replaces the center pixel with the median value. The median filter does not require convolution. (If the neighborhood under consideration contains an even number of pixels, the averages of the two middle pixel values are used.) The best known order-statistics filter is the *median filter,* which replaces the value of a pixel by the median of the gray levels in the neighborhood of that pixel

The original value of the pixel is included in the computation of the median. Median filters are quite popular because, for certain types of random noise they provide excellent noise reduction capabilities, with considerably less blurring than linear smoothing filters of similar size. Figure 4.a and 4.b illustrates an example of how the median filter is calculated. The median filter is effective for removing impulse noise such as “salt and pepper noise” which is random occurrences of black and white pixels.

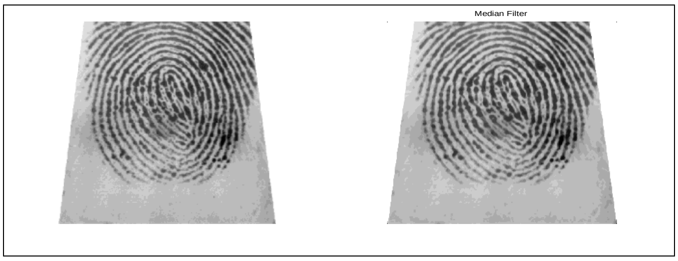

Figure 4: (a) Input image (b) Filtered image

2.2 Gabor filtering

Gabor filters have both frequency selective and orientation selective properties. Gabor filters can remove noise and preserve the true ridge and valley structures thus showing good performance. Gabor filters have been applied to the problem of fingerprint image enhancement in [8]. Gabor filters are band-pass filters with adjustable frequency, orientation, and bandwidth parameters. A gabor function is a sinusoidal waveform that is modulated by a rotated gaussian envelope, and has the following form in the spatial domain:

$$G(x, y, \theta, \sigma) = \exp\{\frac{x'2 + y'2}{2\sigma 2}\}\cos(2\pi fx')$$

x'= xcosθ-ysinθ y'= xsinθ+ycosθ (1)

Where *f* is the sinusoidal frequency along the direction .s is the standard deviation of the Gaussian envelope. In our experiments, we set the filter frequency to the average ridge frequency (1/K) , where *K* is the inter-ridge average distance. The normalized fingerprint is then convolved with a bank of filters tuned with the dominant orientation in each *WxW* image block. Orientation field is obtained by the mean square orientation estimation algorithm.

2.3. Anisotropic filtering

In this section we have used a new enhancement method based on anisotropic filtering. The goal is to use the local intensity orientation to control the shape of the filter. The filter kernel applied to each point *x*0 is defined as following:

$$G\theta\{x, y\} = \left\{\exp\left(\frac{-(u-mean)2}{2\sigma 2}\right)\right\}1\sqrt{2\pi\sigma 2\}}\ \exp\{\frac{-(v-mean)2}{2\sigma 2})\ \frac{1}{\sqrt{2\pi\sigma 2\}}}$$

$$u = x\cos\theta - y\sin\theta, v = x\sin\theta + y\cos\theta \qquad (2)$$

The shape of the kernel is controlled through mean and σ. This formula which is a modulation of a gaussian and it is derived, behaves as a pass-band filter in the given direction. By modifying the filter with a scale

c=-2 as follows:

h_θ =c*$g_{\sigma(}$x, y) (3)

We obtain better results than the classical anisotropic filtering proposed in [9] when applied to fingerprint images. For certain directions, these filters are represented by images represented in figure 5.

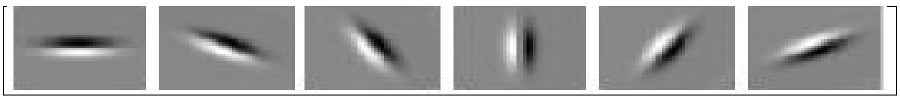

Figure 5 : Controlling anisotropy in different directions

3. Proposed algorithm

The proposed algorithm contains two main steps: preprocessing with STFT analysis and enhancement.

Step 1
STFT analysis

1. For each overlapping block in an image, generate and reconstruct a ridge orientation image by computing gradients of pixels in a block, a ridge frequency image by obtaining the FFT value of the block, and an energy image by summing the power of FFT value;
2. Smooth the orientation image using vector average to yield a smoothed orientation image, and generate a coherence image for bandwidth using the smoothed orientation image;
3. Generate a region mask by thresholding the energy image

Step 2
Enhancement

4. For each overlapping block in the image,
a. Generate the angular filter Fa centered on the orientation in the smoothed orientation image with a bandwidth inversely proportional to coherence image;
b. Generate the angular filter Fa centered on frequency image;
c. Filter the block in the FFT domain, F =F*Fa
d. Generate the enhanced block by Fast Fourier Transform FFT (F);

5. Reconstruct the enhanced image by composing enhanced blocks, and yield the final contrast enhanced image with the region mask.

4. Minutiae detection process
In this phase, the detection of minutiae from the acquired fingerprint is performed. The set of the detected minutiae corresponding to ridge bifurcation and ridge ending, respectively are found out through binarization-based method and contrast enhancement.

4.1 A binarization –based method
In some binarization–based approaches the binarization and thinning process are preceded by a smoothing operation. Moayer [4] used a smoothing operation based on convolution with a Gaussian 5x5 pixels mask, in order to regularize the starting image. We propose an enhancement process, which combines filters and noise reduction technique for pre and post processing as well. The proposed scheme is based on adaptive histogram equalization for contrast expansion, followed by median, gabor, anisotropic for noise reduction. The binarization process is applied using an adaptive threshold based on the local intensity mean. Then a timing process is carried out through the algorithm presented by Baruch, which provides good results on finger prints. Finally morphological filtering is applied to eliminate artifacts in noisy regions and to fill some gaps in valid ridgelines.

4.2 Contrast enhancement

Histogram equalization defines a mapping of gray level p into gray level q such that the distribution gray levels q is uniform [3]. This mapping stretches contrast (expands the range of gray level) for gray level near histogram maxima. Since contrast is expanded for most of the images pixel, the transformation improves the delectability of many images features.

The probability density function of pixel intensity level r_2 is given by:

$$p_r(r_k) = n_k \tag{4}$$

Where $0 \leq r_k \leq 1$, k=0,1,…..255, n_k is the number of pixels at intensity level r_k and n is the total number of pixels. The histogram is derived by plotting $p_r(r_k)$ against r_k. A new intensity s_k of level k is defined as:

$$s_k = \sum_{j=0}^{k} \frac{n_j}{n} = \sum_{j=0}^{k} p_r(r_j) \tag{5}$$

We apply histogram equalization locally by using local windows of 11x11 pixels. This results in expanding the contrast locally, and changing the intensity of each pixel according to its local neighborhood.

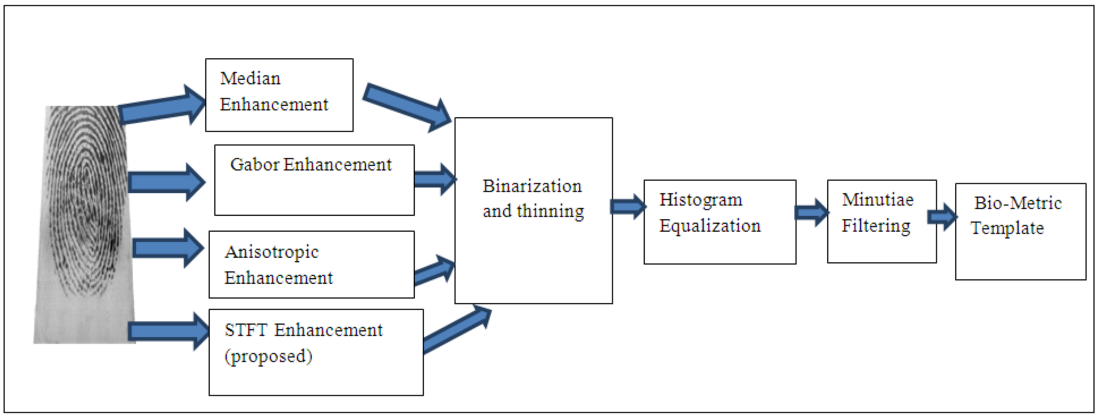

Figure 6: Stages for fingerprint matching

5. Result analysis

In the following Table 1 we took the images from FVC2004db2101_7. By applying the three filters we got the best result using gabor filter and the PSNR value achieved are high compared to other work. The ratio between the maximum possible power of a signal and the power of corrupting noise that affects the fidelity of its representation is called peak signal to noise ratio (PSNR). To get high accuracy the value of PSNR lies around 21 to 40.We got the highest accuracy rate 67.23 in contrast enhancement using gabor filter.

Image: FVC2004 db2101_7

Table 1: Result table

S. No	Filtering Technique	Enhancement	PSNR	Structured Similarity	Normalized MSE	Normalized Correlation	Structured Content
1	Median Filter	Contrast	48.9137	6.8361e+003	6.7517	6.7517	0.72
2	Median Filter	Histogram	57.5392	8.6322	0.4915	0.0025	1.00
3	Median Filter	Negative	36	3.6194e+004	17.6931	0.0032	0.60
4	Gabor Filter	Contrast	67.2366	2.9400e+003	4.5489	2.4529e-004	1.00
5	Gabor Filter	Histogram	59.6703	0.1185	0.7727	0.0028	1.00
6	Gabor Filter	Negative	43	3.1775e+004	16.0300	9.8876e-005	0.67
7	Anisotropic	Contrast	53.4108	5.557e+004	6.2674	0.0019	1.00
8	Anisotropic	Histogram	53.9251	0.1309	0.8297	8.3718e-004	1.00
9	Anisotropic	Negative	35	3.6272e+004	17.6361	6.4983e-004	0.59

6. Back propagation Neural Network (BPNN)

A back-propagation algorithm is one of the many different learning algorithms that can be applied for neural network training. It belongs to a category of so called learning with the teacher. For every input vector x that is presented to the neural network there is predefined desired response of the network in a vector t (the teacher). The desired output of the neural network is then compared with the real output by computing an error e of vector t and neural network output vector y. The correction of the weights in the neural network is done by propagating the error e backward from the output layer towards the input layer, therefore the name of the algorithm. The back-propagation algorithm is carried out in the following steps:

1. Select a training pair from the training set; apply the input vector to the network input.
2. Calculate the output of the network.
3. Calculate the error between the network output and the desired output (the target vector from the training pair)
4. Adjust the weights of the network in a way that minimizes the error.
5. Repeat the steps 1 through 4 for each vector in the training set until the error for the entire set is acceptably low. [10]

The performance evaluation protocol used in FVC2004 is adopted in these experiments. We introduce many performance indicators of fingerprint verification such as False Acceptance Rate (FAR), which is the rate that an imposter fingerprint is incorrectly accepted as a genuine claims, equivalent to the probability that an unauthorized person is incorrectly accepted as authorized person, False Reject Rate (FRR), .which is the rate that a genuine fingerprint is incorrectly rejected as an imposter claims, equivalent to the probability that the system does not detect an authorized person. Equal Error Rate (EER),it is the rate at which both accept and reject rates are identical. The EER is used as a performance indicator. Genuine acceptance rate (GAR), which is the rate that a genuine fingerprint is correctly accepted as genuine.

The GAR, FAR and FRR are defined as follows:

$$GAR = \frac{\text{Number of accepted genuine finger}}{\text{Total number of genuine finger}} * 100$$

$$FAR = \frac{\text{Number of accepted imposter finger}}{\text{Total number of imposter finger}} * 100$$

$$FRR = \frac{\text{Number of rejected genuine finger}}{\text{Total number of genuine finger}} * 100$$

The Equal Error Rate (EER), False Reject Rate (FRR) and False Accept Rate (FAR) are computed on the four databases of FVC 2004 and the accepted fingerprint match (genuine) and rejected fingerprint match (impostor) were performed. For genuine fingerprint match, each test fingerprint of each person was compared with the template fingerprint of the same person. For impostor fingerprint match, the test fingerprint of each person was compared with the template fingerprint of other persons. We can find that the average EER (%) values of Back Propagation Neural Network (BPNN) match over four databases with the three different filters with our proposed method. We obtained the best average EER(%)of matching with gabor filter is 3.18%.The computation speed of the proposed algorithm is also much faster than others by showing nearly 0.92 s, for each fingerprint enrollment and matching, while the best of others shows 1.31 s. For very low quality and severely distorted images as those in FVC2004 databases, each database consists of 800 fingerprint images (100 persons, 8 fingerprints per person). The proposed algorithm still shows better performance than others.

Equal Error Rate

Table 2: Proposed method with the supervised Back Propagation Neural Network (BPNN) over the four databases, using the comparison of the Equal Error Rate EER (%).

Database	FVC 2004 DB1	FVC 2004 DB2	FVC 2004 DB3	FVC 2004 DB4	Average (EER %)
Matching with our proposed method					
Gabor filter	3.32	3.48	2.89	3.06	3.18
Median filter	3.59	3.87	3.52	3.39	3.59
Anisotropic filter	4.08	3.55	3.63	3.49	3.68

7. Conclusion

In this paper, we have proposed an improved feature for fingerprint identification. The minutiae extraction problem we have also reported that the main difficulty is due to the image quality. With an aim of obtaining robust minutiae template, a strategy of fusion enters the three methods has been proposed. The proposed algorithm basically uses moment features invariant to scale, position and rotation to increase the matching accuracy with a low computational load. It further pursues an improved performance by using the alignment and rotation after a sophisticated, reliable detection of a reference point. Having invariant characteristics in the proposed algorithm can significantly improve the performance for input images under various conditions. The computation speed of the proposed algorithm is also much faster than others. For very low quality and severely distorted images as those in FVC2004 Databases, the proposed algorithm still shows better performance than others.

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