Research on the Robust Fingerprint Image Enhancement Based on Fractional Algorithm

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Abstract
In this paper, the author researched on the robust fingerprint image enhancement based on fractional algorithm. We discusses the prior work carried out in literature for the enhancement of the fingerprint images and reviews the theory of Poincare Index method used for finding core location in proposed fractional algorithm using a combination of Diffusion Coherence Filter. Then we describe the Non-linear Diffusion process and the spatial domain Gabor filtering principle respectively. The proposed algorithm is described in detail and finally section and we presents the results of our experiments.
Keywords: ROBUST FINGERPRINT IMAGE ENHANCEMENT, FRACTIONAL ALGORITHM, FINGERPRINT IMAGE

1. Introduction

With the city expanding and increasingly well-developed transportation network in modern society, urban population is increasing rapidly and showing more and more mobility. How to identify ID simply and effectively for such a large-scale population is an important issue that government must take into account. In addition, with the high development of computer and network technology, information security has shown the unprecedented importance. Biometric identification is necessary to ensure information system security. Finance, national security, justice, e-commerce applications will require accurate identification and authentication. Automated Fingerprint Identification System (AFIS) is drawing more and more attention for its easy-to-use, friendly interface and low prices. There were a lot of fingerprint recognition products, but most of them could lose efficacy considering the balance of accuracy and real-time requirement. Yun's [1] paper mainly described the Automated Fingerprint Identification System around two key technologies: fingerprint enhancement and matching. According to the shortcoming of the past algorithms, the paper improved algorithms of the fingerprint enhancement and matching. After performance analysis and comparison, the new algorithm showed better ability. He's paper [2] introduced the history of fingerprint recognition technology, the status quo and development trend. After analyzing the advancement and shortcomings of the previous enhancement algorithms, the adaptive fingerprint enhancement algorithm based on frequency domain and the hybrid filter fingerprint enhancement method were presented. Two algorithms were all based on the fingerprint image characteristics in the frequency domain and spatial domain. The filter was designed according to the turn of the fingerprint ridge pattern. Experiment shows that the algorithms are better than past algorithms. A fingerprint recognition algorithm based on hybrid ant colony was presented. When the fingerprint had a small deformation, fingerprint matching algorithm only confirmed translation, rotation and scale parameters. Ant colony algorithm was a very good optimization algorithm, but the basic ant colony algorithm had the problems of long-time consumption and easily getting into the local optimum. So the simulated annealing algorithm was used to accelerate the optimization of the fingerprint. The annealing and backfire procedure could increase the diversity of solutions to avoid a local optimal solution. A novel algorithm for fingerprint recognition based on RANSAC strategy was presented. The local characteristic of the fingerprint was used to find the coarse matching points. Then the RANSAC algorithm was used to match the fingerprints. In the process of fingerprint matching, compensation method is used to eliminate the impact non-linear deformation.

Kim's paper [3] takes plenty of research materials about fingerprint recognition both at home and abroad for reference and analysis. And technologies like image processing, pattern recognition and machining learning are also employed for this research. In-depth studies are made in areas of fingerprint image segmentation, fingerprint image enhancement, fingerprint core point extraction and fingerprint matching. Some useful results are yielded in both fields of theory and practice. Vieira discussed [4] the fingerprint image segmentation. Features of fingerprint image are analyzed in three different aspects. According to the mean and variance of pixel gray value in local area, clarity of fingerprint ridges and symmetry of local ridges, intra-consistency, extra-consistency and local ridge conformity have been defined. Foreground and background of fingerprint image is differentiated by utilizing multiply features. The experimental results show that the proposed method can segment fingerprint image in an effective way, especially for the regions between foreground and background. Moreover the computation cost is relatively small.

2. Basic Theory on Robust Fingerprint Image Enhancement

Fingerprint image enhancement is analyzed in Carsten's paper [5]. An improved Gabor filter based method for fingerprint image enhancement is proposed. Traditional Gabor filter based method uses a fixed filtering region, while a more reasonable and effective region selecting strategy is devised on the basis of frequency and orientation of local ridge in this dissertation. A fast implementation of Gabor filter is also employed for the symmetry of Gabor filter. The experimental results show that the proposed method is effective and the computation cost is reduced. Method for fingerprint core point detection is investigated in Hartwig's paper [6]. A fingerprint core point detecting algorithm by using Supported Vector Machine (SVM) and tangent complex filter is proposed. In terms of ridge distribution in core point region and non-core point region, feature vector is constructed. Then SVM is used to form the classification model, and the candidate region in which core point exists can be predicted. Since the ridge around core point is homo-symmetry, a complex filter is designed on the basis of tangent function. By comparing traditional complex filter, tangent complex filter can depict ridges around core point more suitable. Hence fingerprint core point is localized with high resolution. The experimental results show that the proposed method can compute the position and orientation of fingerprint core point precisely. Moreover, the computation cost is also reduced [7]. With the existence of distortion in fingerprint images, the position of ridges can be changed to some extent. Khan [8] designs a fingerprint matching method based on excluding elastic distortion. First adjacent feature union (AFU) is defined according to neighbor minutiae. Then reference minutiae pair is obtained by comparing AFUs between template and query fingerprints. Reference minutiae pair is used for fingerprint alignment. Ridge frequency and orientation between reference minutiae and query minutiae are used to construct the distortion model. The position and direction of query minutiae are adjusted according to corresponding distortion model. Then matching producer is carried out by adopting minutiae after adjustment. Experimental results show that our proposed method can reduce the effect of distortion in fingerprint image, and has high robustness. Traditional fingerprint matching methods based on single reference minutiae can be affected by partly obtained fingerprint images and inevitable noises. Local feature unit (LFU) is constructed by use of minutia and its neighbor ridges. Potential matched minutiae set (PMS) is obtained by comparing LFUs of template and query fingerprints. True matched minutiae set (TMS) are obtained by purifying PMS. Minutiae in TMS are used as multi-reference points. The remaining minutiae are compared according to the distance from minutiae to TMS. The experimental results show the multi-reference points fingerprint matching algorithm is more effective and efficient than the single reference point fingerprint matching algorithm.

Thus it is clear from the above discussion that fingerprint which is a complex structure of oriented patterns need an effective enhancement processing of the image before the features can be reliably extracted from it. In this chapter we present our robust method for the enhancement of fingerprint images is using a combination of Non-linear coherence diffusion and spatial domain Gabor filtering to overcome the deficiencies found out in these methods if used separately. The algorithm is applied on FVC 2002 databases and the experimental results are compared with that of the Diffusion-based and Gabor filter-based methods. Diffusion filtering is used to model the diffusion process and is an iterative technique of spatial filtering in which image intensities in a local neighborhood are considered to find out new intensity values. The type of diffusion in which the filter coefficients remain constant throughout the image is called the linear diffusion whereas the one in which the filter coefficients change in response to differential structures within the image is known as the nonlinear diffusion. Coherence-enhancing filtering is a regularized nonlinear diffusion that carries out the image smoothing in the direction of pixels located in close proximity with similar intensity values. The type of diffusion in which the diffusivity function does not remain constant and allows more smoothing parallel to image edges but less smoothing perpendicular to it is known as edge-enhancing anisotropic diffusion. The term anisotropic has been used due to the fact that the flux and gradient vectors no longer remain parallel throughout the image. In order to include directional information in addition to the edge contrast, the diffusivity function generates a matrix tensor that includes orientation information about underlying edges. In edge-enhancing anisotropic diffusion, the diffusivity tensor is written as given by equations. The diffusion process is speeded up in the direction of minimum rate of gradient change, while it is impeded in the direction of maximum rate of gradient change. Thus the image will be smoothed in a direction parallel to edges and not across edges, which preserves its shape and locality.

3. Proposed Fractional Algorithm: Fingerprint Image Enhancement using Coherence Diffusion Filter and Gabor Filter

The fingerprint image enhancement algorithms using diffusion method and Gabor-filtering do not give satisfactory results for the whole image area. The diffusion method gives better results in the region of image with high curvature ridges that is in the core point surrounding region but produce unsatisfactory results for cut and broken ridges. Whereas the Gabor filter enhancement method can enhance the cut and broken ridge areas in the uniform ridge-valley region of the image but gives distorted image results for the high curvature region of the image surrounding the core point. The local fractional algorithm can be expressed as following:

$$f^{(\alpha)}(x0) = \left.\frac{df(x)}{dx^{\alpha}}\right|_{x=x_0} = \lim_{\delta x \to 0} \frac{\Delta^{\alpha}(f(x) - f(x_0))}{(x-x_0)^{\alpha}} \quad (1)$$

for $0 < a \le 1$ where

$$\Delta^{\alpha}(f(x) - f(x_0)) \cong \Gamma(1+\alpha) \lim_{x\to\infty} \Delta(f(x) - f(x_0)) \quad (2)$$

And local fractional integral of $f(x)$ defined by Eq.3.

$${}_aI_b^{(\alpha)} f(t) = \frac{1}{\Gamma(1+\alpha)} \int_a^b f(t)(dt)^{\alpha} = \frac{1}{\Gamma(1+\alpha)} \lim_{\Delta t\to 0} \sum_{j=0}^{j=N-1} f(t_j)(\Delta t_j)^{\alpha} \quad (3)$$

With $\Delta t_j = t_{j+1} - t_j$ and $\Delta t = \max\{\Delta t_1, \Delta t_2, \cdots, \Delta t_j, \cdots\}$, where for $j = 1, 2, \cdots, N-1$, $[t_j, t_{j+1}]$ is a partition of the interval $[a,b]$ and $t_0 = a$, $t_N = b$.

If $f(x)$ is defined on the real line $-\infty < x < \infty$, its local fractional Hilbert transform, denoted by $f_x^{H,\alpha}(x)$ is defined by

$$H_{\alpha}\{f(t)\} = \hat{f}_H^{\alpha}(x) = \frac{1}{\Gamma(1+\alpha)} \int_R \frac{f(t)}{(t-x)^{\alpha}}(dt)^{\alpha} \quad (4)$$

Where x is real and the integral is treated as a Canchy principal value, that is,

$$\frac{1}{\Gamma(1+\alpha)} \int_R \frac{f(t)}{(t-x)^{\alpha}}(dt)^{\alpha} = \lim_{\varepsilon\to 0}\left[\frac{1}{\Gamma(1+\alpha)} \int_{-\infty}^{x-\varepsilon} \frac{f(t)}{(t-x)^{\alpha}}(dt)^{\alpha} + \frac{1}{\Gamma(1+\alpha)} \int_{x+\varepsilon}^{\infty} \frac{f(t)}{(t-x)^{\alpha}}(dt)^{\alpha}\right] \quad (5)$$

To obtain the inverse local fractional Hilbert transform, write again Eq. (4) as

$$\hat{f}_H^{\alpha}(x) = \frac{1}{\Gamma(1+\alpha)} \int_{-\infty}^{\infty} \frac{f(t)}{(t-x)^{\alpha}}(dt)^{\alpha} = \frac{1}{\Gamma(1+\alpha)} \int_{-\infty}^{\infty} f(t)g(x-t)(dt)^{\alpha} = f(x) * g(x), \quad (6)$$

The proposed algorithm overcomes the shortcoming of both cited algorithms and enhances the fingerprint image in all areas of ridge-valley pattern including the core point. It enhances the core region without any distortion, improves the clarity between ridges and valleys, removes the gap between the broken and the scratched ridges and increases the number of correct features which are required to be used in matching algorithms for fingerprint recognition. The algorithm is described in detail as follows.

Step 1:Determine the core point of the image to be enhanced by using the Poincare index method, as explained in the Figure 1 shows the results of applying the method to images from FVC 2002 databases.

Step 2: Select the ridge high-curvature region R, of dimensions 60X60 pixels surrounding the core point location found in step 1 .Figure 2 shows region R1 of FVC 2002 database images shown in figure 1.

Figure 1. The results of applying the method to images from FVC 2002 databases

Figure 2. The region R1 of FVC 2002 database images shown in figure 1

Step 3: Apply the Diffusion Coherence method of image enhancement, as explained in Section 2, to the selected region R1 determined in step 2.

Step 4: Apply the 2D Spatial-domain Gabor-Filtering method to the remaining region RZ of the input image. In this method, we employ a novel overlapping blocks technique to remove the blocking artifacts which have been found in the enhanced images obtained by using the method of Ref. [6]. The overlapping block technique is explained as given below.

(a) After we get the filtered block of N X N pixels by employing the Gabon-filter, then only the top left quarter of the filtered block is considered as the final enhanced image's part, instead of the whole block.

(b) The block is forwarded by N/2 pixels (Figure 3) and the process of enhancement is repeated again for next N X N pixels block.

(c) At the end of the horizontal row, the block is incremented by N/2 pixels in the vertical direction as shown in Figure 4 and the process step 4 (a) to step 4 (b) is repeated.

(d) The enhancement is ended when the last bottom right N X N pixels block is reached in the image.

Step 5: Merge the image regions R1 and R2 obtained in step 3 and step 4 to get the final enhanced image.

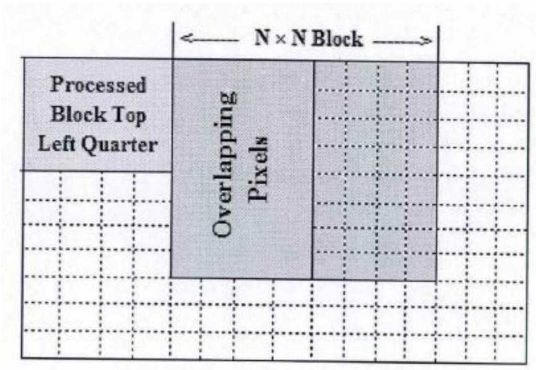


Figure 3. Processed Block Quarter and the Overlapping Pixels in the Horizontal Direction

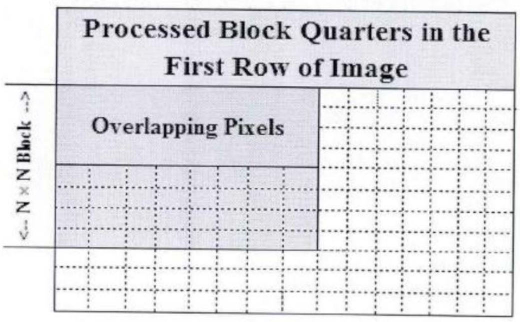


Figure 4. Processed Block Quarter and the Overlapping Pixels in the Vertical Direction

The proposed enhancement algorithm is tested on the FVC 2002 Databases DB1, DB2, DB3 and DB4. Each of these databases contains 80 fingerprint images from 10 participants with 8 images per finger. DB 1 images are of good quality, DB3 images are of low quality where as DBZ and DB4 images are of moderate quality.

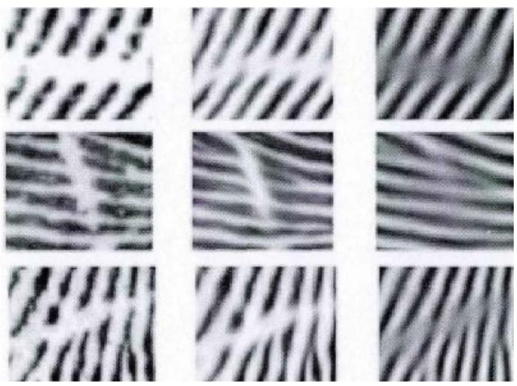
Figure 5 shows the results of our experiments. Column (a) shows the images from FVC 2002 databases, column (b) shows these images enhanced by Diffusion Coherence Method, column (c) shows the same images enhanced by using the Gabor-filter Method and finally column (d) shows the images enhanced by the Proposed Method. It is obvious that the images enhanced by the proposed method are better than those enhanced by the diffusion method and Gabor filter method.

The diffusion Method gives good image enhancement in the core region but gives poor results for the broken ridges as shown in the magnified view in Figure 6.

On the other hand the Gabor-filter method provides good enhancement for the uniform ridge-valley areas and enhances well the broken ridges but its result near the high curvature region of core point is distorted and has unwanted blocking effects as is apparent in the magnified view of core region shown in the Figure 7.

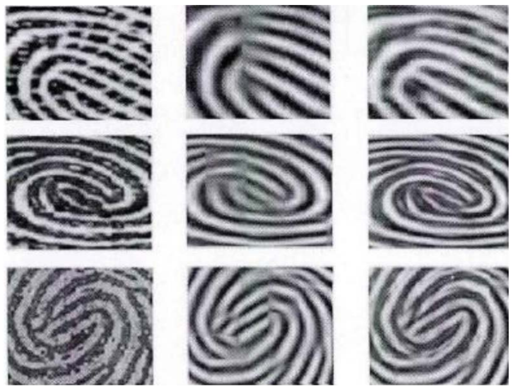
(a) (b) (c) (d)

Figure 5. (a) The images from FVC 2002 databases, column
(b) These images enhanced by Diffusion Coherence Method, column
(c) The same images enhanced by using the Gabor-filter Method and finally column
(d) The images enhanced by the Proposed Method



(a) (b) (c)

Figure 6. (a) Original Image; (b) Enhancement by CDM; (c) Enhancement by Fractional Method



(a) (b) (c)

Figure 7. (a) Original Image; (b) Enhancement by GM; (c) Enhancement by Fractional Method

The images enhanced by the proposed method have clear distinction between ridges and valleys in all area of the image and are ready to be processed by feature extraction module. These enhanced images can further be used for fingerprint classification and matching algorithms in the fingerprint recognition system which will ultimately improve the overall performance of the system.

Conclusions

In this paper, the author researched on the robust fingerprint image enhancement based on fractional algorithm. An improved Gabor filter based method for fingerprint image enhancement is proposed. Traditional Gabor filter based method uses a fixed filtering region, while a more reasonable and effective region selecting strategy is devised on the basis of frequency and orientation of local ridge in this dissertation. A fast implementation of Gabor filter is also employed for the symmetry of Gabor filter. The experimental results show that the proposed method is effective and the computation cost is reduced. The images enhanced by the proposed method have clear distinction between ridges and valleys in all area of the image and are ready to be processed by feature extraction module.

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An Improved Multi-query Optimization Algorithm in Wireless Sensor Networks

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Abstract

Wireless sensor networks (WSNs) is a data-centric network, the traditional query algorithm becomes difficult in dealing with the query efficiency and energy consumption. How to reduce the energy consumption of sensor