Comparison of Ridge Discontinuity Analysis Methods of Altered Fingerprints

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Abstract - Ridge discontinuity is an important feature in altered fingerprint detection. This paper compares two methods of ridge discontinuity analysis; polynomial approximation of orientation and Fast Fourier Transform (FFT) enhancement based method. Altered fingerprints are detected using these methods and result is compared using Receive Operating Characteristics (ROC) curve analysis. Altered fingerprint database used for comparison comprises of real and synthetically altered fingerprints. The result shows that FFT based method gives better performance.

Keywords – Comparison, Ridge Discontinuity, Altered fingerprint, Detection, FFT.

1. INTRODUCTION

Fingerprint alteration is the deliberate attempt by the criminals and illegal immigrants with an aim of negative recognition. Altered (affected) fingerprint (FP) is entirely different from fake fingerprints. Different process used for making altered fingerprints are abrasion and cutting with blades, poring chemicals and transplantation of ridge structure by surgery [1],[2]. With respect to different processes of alteration, altered fingerprints are classified into three types [1], [2], obliteration, distortion and imitation. Mechanical and chemical means, like scratching and cutting with blades and knifes and dropping chemicals leads to obliteration. Scar and mutilation are two types obliteration. Distortion and imitation is produced by surgery. Imitation contains large area transplanted from palm print or leg print by plastic surgery. Techniques have been developed for fingerprint alteration detection by the analysis of curvature histogram of continuous orientation field [1], orientation discontinuity and minutiae (ridge ending and bifurcation) distribution [2] and fingerprint orientation reliability map which has peaks in the singular point locations [3]. John H. Ellingsgaard developed a method for fingerprint alteration detection using the analysis of singular point density and minutiae distribution at local level [4]**.**

The method used for the analysis of features used in altered Fingerprint (FP) detection has great impact in overall detection results. Ridge discontinuity (RD) or orientation discontinuity gives important information about the alteration. In fact, different process of alteration creates broken ridges and leads to RD in the affected ridge region. This paper compares two methods of RD analysis on altered FP detection. Compared is done based on ROC curve analysis. First method is based on Fast Fourier Transform enhancement of altered FP proposed by us in [5]. In this method, RD is obtained by the comparison of the orientation field before and after the Fourier Transform enhancement. Next method is based on two variable polynomial approximation of ridge orientation given in [2]. They found the RD by taking difference between the 6th degree bivariate polynomial approximated ridge orientation and the original orientation of the altered FP.

The remaining part of the paper is organized as follows. Section 2 explains the ridge orientation estimation using gradient method. Section 3 and 4 gives RD analysis based on polynomial approximation and FFT enhancement respectively. Alteration detection by RD is given in section 5.Comparative result and conclusion is given in section 6 and 7 respectively.

2. RIDGE ORIENTATION DETECTION BASED ON GRADIENT METHOD

Orientation of altered FP is determined using gradient based method [6] described as follows. If we denote the gradient of an image at a point (x, y) as [Gx(x,y), Gy(x,y)] , then Gx and Gy gives the variation of intensity in x and y directions respectively. The principal axis of variation of gradients in x direction, diagonal directions and y direction is obtained as

$$G_{xx} = G_x * G_x \quad (1)$$

$$G_{xy} = G_x * G_y \quad (2)$$

$$G_{yy} = G_y * G_y \quad (3)$$

Then the sine and cosine of doubled orientation is obtained as

$$\sin 2\theta = G_{xy} / \sqrt{[(G_{xy})^2 + (G_{xx} - G_{yy})^2]} \quad (4)$$

$$\cos 2\theta = (G_{xy} - G_{yy}) / \sqrt{[(G_{xy})^2 + (G_{xx} - G_{yy})^2]} \quad (5)$$

where θ is the orientation angle at pixel (x, y). After obtaining the sine and cosine of doubled orientation, the orientation $\theta_{org}(x, y)$ is obtained as

$$\theta_{org} (x, y) = pi/2 + \text{atan2}(\sin 2\theta, \cos 2\theta)/2, \quad (6)$$

where θ_{org} denotes the orientation of altered fingerprint.

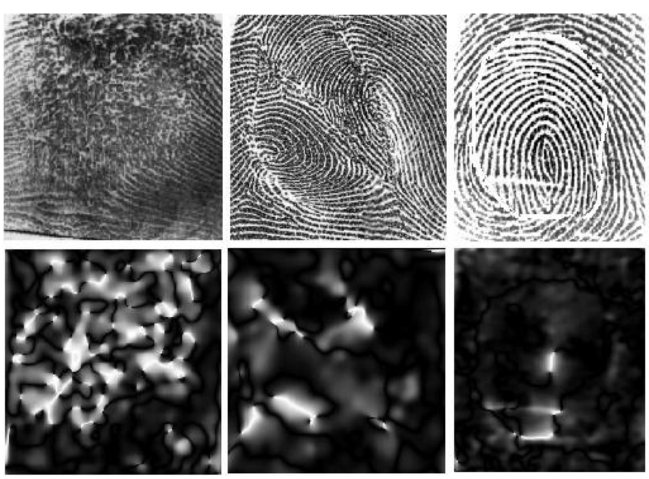
3. RD ANALYSIS BY POLYNOMIAL APPROXIMATION

This section explains the RD obtained by polynomial approximation of orientation of altered FP proposed in [2]. They decomposed the sine and cosine of doubled orientation using 6^{th} degree two variable polynomial as given below.

$$\text{Sin}2\theta(x, y) = [1\ x\ y\ x^2\ xy\ y^2 \ldots x^6 \ldots y^6]\ [a_1\ a_2\ a_3 \ldots . a_{28}]^T \quad (7)$$

$$\cos 2\theta(x, y) = [1\ x\ y\ x^2\ xy\ y^2 \ldots x^6 \ldots y^6]\ [b_1\ b_2\ b_3 \ldots . b_{28}]^T \quad (8)$$

where a and b are coefficients of polynomial. T denotes transpose. In order to represent a 6^{th} degree two variable polynomial, 28 coefficients are needed. To find out these coefficients, least square polynomial approximation is used. After finding the coefficients, the orientation θ_{rec} is reconstructed from the approximated $\sin 2\theta(x, y)$ and $\cos 2\theta(x, y)$ using equation (6).



(a) (b) (c)

Fig. 1. Ridge Discontinuity (a) obliteration type, (b) distortion type and (c) imitation type.

The RD is obtained by taking the difference between θ_{org} (orientation of the altered FP) and reconstructed orientation θ_{rec} according to the equation given below .

$$RD(i, j) = \min (|\theta_{org} (i, j) - \theta_{rec} (i, j)|,$$

$$\pi - | \theta_{org} (i, j) - \theta_{rec} (i, j)|) / \pi/2 \quad (9)$$

Figure 1 shows the RD obtained from three different types altered FP by the polynomial approximation based method.

4. RD ANALYSIS BY FFT ENHANCEMENT

RD analysis by FFT enhancement proposed by us in [5] is explained in this section. After finding the ridge orientation by gradient based method, the altered fingerprint is enhanced by FFT [7], [8]. In this method, the image is first transformed into frequency domain. For enhancement, every frequency components are multiplied by some power of its magnitude. Altered FP image is initially divided into 32x32 processing blocks. Then Fast Fourier Transform is performed on each block so that each block is converted into frequency domain.

The equation used for performing FFT is given as

$$F(u,v)= \sum_{x=0}^{M-1} \sum_{y=0}^{N-1} f(x,y) \times \exp\left\{-j2\pi \times \left\langle \frac{ux}{M} + \frac{vy}{N} \right\rangle\right\} \quad (10)$$

For u = 0, 1, 2... M-1 and v = 0, 1, 2...N-1, where M, N is the size of the image block.

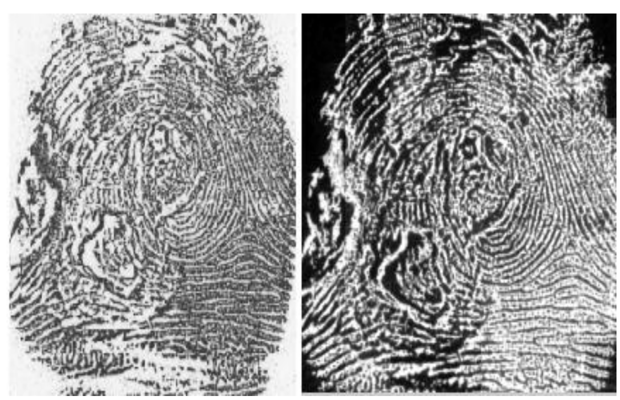


Fig.2. Altered FP (a) before enhancement (b) After enhancement.

Then enhancement is done by multiplying the frequency components by K times of its magnitude . The value of K is selected by iteration.

Thus the enhanced block is obtained by

$$g(x,y)= \mathrm{IFFT}\{F(u,v)\times|F(u,v)|^K)\} \tag{11}$$

Where $F^{-1}(u, v)$ is obtained by

$$f(x,y)=\frac{1}{MN}\sum_{u=0}^{M-1}\sum_{v=0}^{N-1} F(u,v)\times \exp\left\{j2\pi\times\left(\frac{ux}{M}+\frac{vy}{N}\right)\right\} \tag{12}$$

For $x = 0, 1, 2... M-1$ and $y = 0, 1, 2... N-1$.

Value of K is selected as 0.3. Higher values of K fills up small holes in ridges and as value of K increases beyond a certain limits produce false joining of ridges. The altered FP from NIST SD14 database before and after the enhancement is shown in figure 2.

After the FFT enhancement of altered FP, the ridge orientation θ_{en} of enhanced FP is found using the gradient based method as explained in section 2. Thus the Ridge Discontinuity is found by equation (9) by substituting θ_{en} instead of θ_{rec}. RD obtained by FFT enhancement for varies types of altered FP is shown in figure 3.

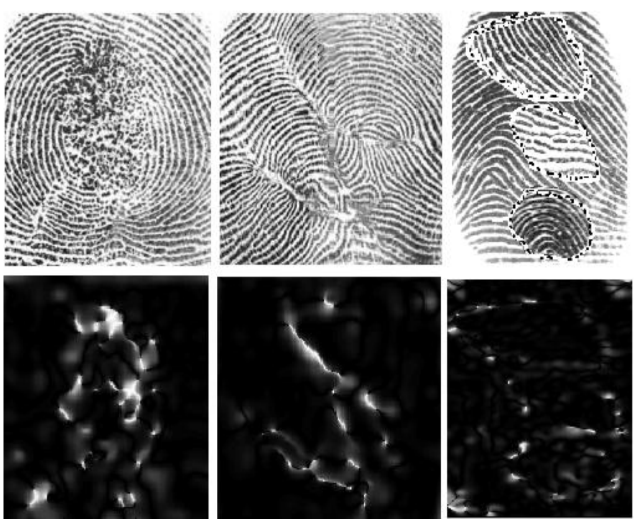


Fig. 3. Ridge Discontinuity (a) obliteration type, (b) distortion type and (c) imitation type.

5. ALTERATION DETECTION BY RD

We have detected the altered FP using two ridge discontinuity analysis method for comparison. Detection of affected or altered FP is done by creating feature vectors from the RD map [2]. The RD obtained by two methods is divided into 9 cells and local histogram of the each cell is computed. These local histograms are combined to create feature vectors and are fed into Support Vector Machine (SVM) for classification.

6. RESULTS

A database consisting of normal and altered FP images of 100 numbers is used for the performance comparison of the two RD analysis methods. Altered FP database consists of both real and synthetically altered FP with all types of alterations. The synthetically altered FP is created from normal FP obtained from FVC 2000 and 2004. Altered FP database contains all type of alterations.

Receiver Operating Characteristics (ROC) curve is plotted between True Positive Rate (TPR) and False Positive Rate (FAR). The positive class is assigned for altered or affected FP. Detection of affected FP as affected one is fall into TPR and detecting normal FP as affected one into FPR. **Figure 4 shows the ROC curve.**

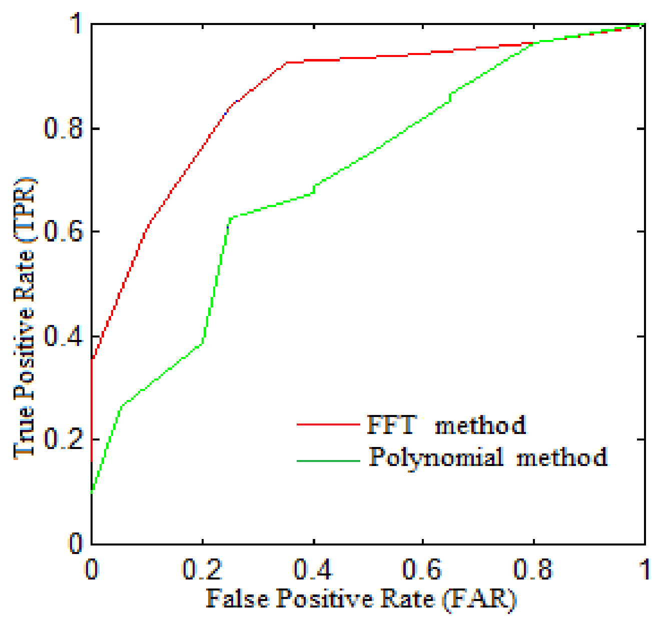


Fig.4. ROC curve Analysis

Table-1: Table Heading

Method	TPR in %	FAR in %	Area Under Curve (AUC)
FFT	82	30	0.865
Polynomial	63	30	0.70562

The table 1 shows the TPR and FPR of the two ridge discontinuity analysis methods for the optimum classification. FFT based ridge discontinuity analysis has produced 82% of TPR and polynomial based method produced 63% of TPR. The Area Under Curve (AUC) for FFT based method and polynomial method is 0.865 and 0.70562 respectively. These results show that the performance of FFT based method is better as compared to polynomial based method. Both the method produced 30% of FPR.

7. CONCLUSION

Two RD analysis methods are compared based on performance on altered FP detection. One is based on polynomial approximation and other is proposed by us based on Fast Fourier Transform enhancement. Testing of both methods on affected FP and normal FP database, concluded that proposed method gives better performance.

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