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TWO STAGE FRAMEWORK FOR ALTERED FINGERPRINT MATCHING

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Abstract

Fingerprint alteration is the process of masking one's identity from personal identification systems especially in boarder control security systems. Failure of matching the altered fingerprint of the criminals against the watch list of fingerprints can help them to break the security system. This fact leads to the need of a method for altered fingerprint matching. This paper presents a two stage method for altered fingerprint matching. In first stage, approximated global ridge orientation field of altered fingerprint is matched against the orientation field of its unaltered mate. If this matching is successful, fingerprints go to second stage. Second stage starts with the selection of unaltered region from the altered FP and same region from the unaltered mates. Matching in this stage is performed by extraction of ridge texture and ridge frequency from the selected region of interest. Euclidian distance is used in both stages to compute the matching score.

Keywords:

Matching, Ridge Orientation, Ridge Texture, Ridge Frequency, Wavelet Transform

1. INTRODUCTION

Fingerprint alteration is a major threat to boarder control security systems [1]. Altered fingerprint (FP) is entirely different from fake fingerprints. Fake fingerprints are made from latex or glue for imitating the normal fingerprints so that the matching become successful and they can break the security system. Different ways of making altered fingerprints are abrasion and cutting with blades, poring chemicals and transplantation of ridge structure by surgery. Based on these, altered fingerprints are classified into three types [1], [2], obliteration, distortion and imitation. Processes like abrasion and cutting with blades and poring chemicals leads to obliteration. It is again divided into scar and mutilation. Even though the distortion and imitation are produced by surgery, they are different in terms of area of transplantation. Imitation contains large area transplanted from palm print or leg print. Distortion contains small area transplanted from different portion of the same fingerprints. Fingerprint recognition is basically divided into three types [3]. They are correlation based, minutiae based and texture features based techniques [3]. In correlation based techniques, two FP images are superimposed and the correlation between corresponding pixels is computed for different alignments [4-8]. Ridge endings and bifurcation is known as minutiae features and is unique for each FP. Minutiae-based matching consists of finding the alignment between the template and the input minutiae feature sets that result in the maximum number of minutiae pairings [9-14]. In non minutiae based matching, features of the ridge pattern like local orientation, frequency, ridge shape and texture information and number, type and position of singularities are used [15-17]. Successful matching of altered fingerprint (FP) is essential since it helps to find the criminals and also prevents the breaking of fingerprint based security system. Altered FP matching can be done in two ways. First method needs the reconstruction or restoration of altered region and matching is performed in the same way as the normal FP matching. In second method, matching can be done by using the features in the unaltered region. These two methods fails when whole region of the fingerprint is altered. Proposed method is a hybrid one since it uses the reconstructed ridge orientation and features in the unaltered region. Matching of imitation type altered FP is not possible since reconstruction of altered region is not possible. Separation of unaltered region from the altered region is also difficult. Matching of Z-type distortion is possible because altered region can be reconstructed. Soweon Yoon and Anil K. Jain have performed the matching of 'Z' cut type of distortion by the restoration of minutiae distribution in the altered region [18]. Proposed method belongs to texture feature based technique.

Rest of the paper is organized as follows. Proposed method starts from section 2. Section 3 explains approximation of ridge orientation field of altered FP and alignment. Matching score computation using orientation field is given in section 4. Region of Interest extraction is given in section 5. Section 6 explains the ridge frequency extraction. Section 7 explains matching score computation from ridge frequency and ridge texture images. Results and discussion is given in section 8 and conclusion is given in section 9.

2. PROPOSED METHOD

The method uses three features namely Ridge Orientation Field (ROF), Ridge Texture (RT) and Ridge Frequency (RF). Last two features are extracted from the unaltered region of the altered FP. The computation of a single matching score from these three features is not possible since automatic selection of unaltered region from the altered FP is not possible in one to many matching. FP images from different fingers may sometimes appear similar in terms of global structure such as local ridge orientation [3]. Thus the proposed method is implemented in two stages. First stage utilizes the approximated ridge orientation to compute the matching score in terms of Euclidian distance and if this matching is successful, the FP goes to next stage. Second stage is used to confirm the successful matching of the first stage by using RT and FR in the unaltered region. A matching is declared as successful, if genuine match occurs in both the stage. Fig.1 shows the block diagram of the proposed method.

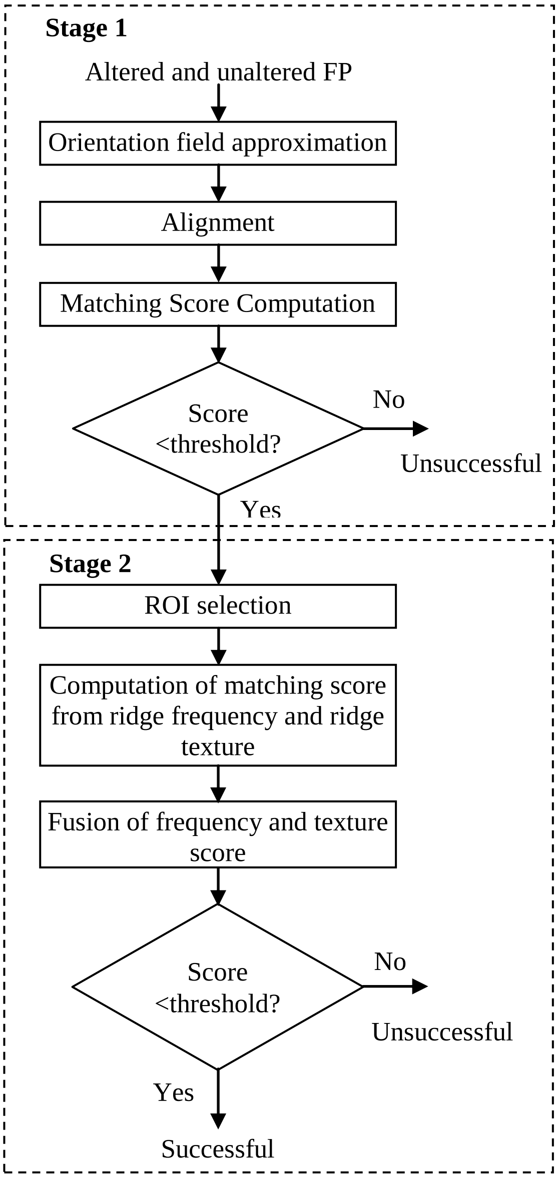


Fig.1. Block diagram of the proposed method

3. ORIENTATION FIELD APPROXIMATION OF ALTERED FP

Local ridge orientation at a pixel [x, y] is the angle θ_{xy} that the fingerprint ridges form with the horizontal axis [3] which may vary between 0 and 180. The position of core and delta points are unavailable in case of altered FP if it is situated in the altered region. Thus the global ridge orientation of the altered FP I approximated by wavelet transform is used for matching. Initial orientation of altered FP is found by gradient based method [3]. Then it is transformed into a continuous complex function. Denoting $\theta(x, y)$ as orientation field and $U(x, y)$ as transformed function the mapping can be described as,

$$U = RE + iIM = cos2\theta + i\ sin2\theta \quad (1)$$

where, RE and IM denote respectively the real and imaginary part of complex function $U(x, y)$ and is obtained as follows. The gradient $G(x, y)$ at a point (x, y) of a gray scale image is a two dimensional vector $[G_x(x, y), G_y(x, y)]$ where G_x and G_y are the derivatives of image at point (x, y) with respect to x and y directions respectively. Then

$$IM = sin2\theta = G_{xy} / \sqrt{[(G_{xy})^2 + (G_{xx} - G_{yy})^2]} \quad (2)$$

$$RE = cos2\theta = (G_{xy} - G_{yy}) / \sqrt{[(G_{xy})^2 + (G_{xx} - G_{yy})^2]} \quad (3)$$

where, G_{xx}, G_{xy} and G_{yy} are given as

$$G_{xx} = G_x * G_x \quad (4)$$

$$G_{xy} = G_x * G_y \quad (5)$$

$$G_{yy} = G_y * G_y \quad (6)$$

The above mapping is a one to one transformation and $\theta(x, y)$ can be easily reconstructed from the values of $RE(x, y)$ and $IM(x, y)$ using the Eq.(7) given below.

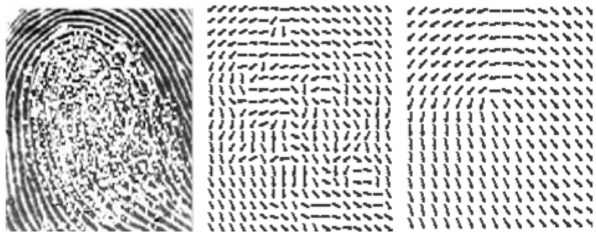
$$\theta(i, j) = pi/2 + atan2(sin2\theta, cos2\theta)/2, \quad (7)$$

After transforming the orientation into complex function, $sin2\theta(x,y)$ and $cos2\theta(x,y)$ is decomposed to 6^{th} level using orthogonal wavelet using the equation given in Eq.(8) and Eq.(9).

$$w_\phi(j_0, m, n) = \frac{1}{\sqrt{MN}} \sum_{x=0}^{M-1} \sum_{y=0}^{N-1} f(x,y).\phi_{j_0,m,n}(x,y) \quad (8)$$

$$w_\psi^i(j, m, n) = \frac{1}{\sqrt{MN}} \sum_{x=0}^{M-1} \sum_{y=0}^{N-1} f(x,y).\psi^i_{j,m,n}(x,y) \quad (9)$$

where, $i = \{H, V, D\}$, j_0 is an arbitrary starting scale, $w_\phi(j_0, m, n)$ define the approximation coefficients and $w_\psi^i(j,m,n)$ defines the detailed coefficients in horizontal, vertical and diagonal directions. Reconstruction of $sin2\theta(x, Y)$ and $cos2\theta(x, y)$ is performed according to Eq.(8) by keeping $w_\psi^i(j,m,n)$ to zero in every stage.



(a) (b) (c)

Fig.2. Synthetically altered FP, orientation and reconstructed orientation in (a), (b) and (c) respectively

Then the approximation coefficients are reconstructed back to get the approximated $sin2\theta(x,y)$ and $cos2\theta(x,y)$ by keeping $w_\psi^i(j,m,n)$ as zero at every stage in Eq.(10). Then the approximated orientation is found using Eq.(7). Synthetically altered FP, its orientation and reconstructed orientation are shown in Fig.2.

$$f_{rec}(x,y) = \frac{1}{\sqrt{MN}} \sum_m \sum_n w_\phi(j_0,m,n)\phi_{j_0,m,n}(x,y) + \frac{1}{\sqrt{MN}} \sum_{i=H,V,D} \sum_{j=j_0}^{\infty} \sum_m \sum_n w_\psi^i(j,m,n)\psi^i_{j.m.n}(x,y) \quad (10)$$

Ridge orientation of unaltered fingerprints is also found by same method. Ridge orientation estimated as explained above is used for performing the alignment of altered and its unaltered mate. This is performed by rotating the FP image in such a way that the ridges points to the vertical direction. Fig.3(a) shows the altered FP rotated in anticlockwise direction and *s* its unaltered mate rotated in clockwise direction. Fig.3(b) shows the two fingerprints after performing the alignment. Ridge direction of both altered and unaltered mates point to the vertical direction. Alignment prevents the unsuccessful matching of the FP due to rotation.

(a). Before Alignment

(b). After Alignment

Fig.3. Altered and its unaltered mate

4. ORIENTATION BASED MATCHING SCORE

Matching score is computed as follows [19]. Let the reconstructed orientation of altered FP and orientation of its unaltered mates are denoted as A and B respectively. Take 'Ω' as the common area of intersection from two orientation fields and *N* as the total number of points in **Ω**. Then matching score between two orientation fields *A* and *B* is computed as follows.

$$s(A,B)=\frac{1}{N}\sum_{(i,j)\in\Omega}\delta(i,j) \tag{11}$$

In Eq.(9), $\delta(i, j)$ is the difference between the orientation values at the point, (i, j) in *A* and *B* which is given as

$$\delta(i,j) = \delta0(i, j),\ \text{if}\ \delta0(i, j) \leq \pi/2 \tag{12}$$

$$\delta(i,j) = \pi - \delta0(I ,j),\ \text{otherwise} \tag{13}$$

and $\delta0(i, j)$ is defined as

$$\delta0(i, j) = |\theta A(i, j) - \theta B(i, j)| \tag{14}$$

where, $\theta A(i,j)$ and $\theta B(i,j)$ are the direction of point, (i,j) in image *A* and *B*. If the matching score $s(A,B)$ is higher than a certain threshold, two orientation fields are said to be matched.

5. SELECTION OF REGION OF INTEREST

Region of interest (ROI) is the unaltered region selected from the altered FP. Before the ROI extraction, alignment is made as explained in section 3. Similar region is also selected from the entire normal fingerprint in the database consisting of unaltered mates. Fig.1 shows the synthetically altered FP and its unaltered mate along with other normal fingerprints. Unaltered region belongs to bottom of the altered FP and hence similar region with same size is selected from normal fingerprints as shown in Fig.4(b-d). Selection of unaltered area is performed with respect to position of the altered region. If the alteration is at the bottom region, then the top end region of fingerprint is selected. See Fig.5.

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

Fig.4. Region of interest marked as rectangle in altered and unaltered fingerprints. (a). Synthetically altered FP, (b). Unaltered mate, (c) & (d). Unaltered FP in the database

Fig.5. ROI selected from altered FP

6. RIDGE FREQUENCY EXTRACTION

The local ridge frequency (or density) f_{xy} at point $[x, y]$ is the number of ridges per unit length along a hypothetical segment centred at $[x, y]$ and orthogonal to the local ridge orientation. A frequency image **F**, analogous to the orientation image **D**, can be defined if the frequency is estimated at discrete positions and arranged into a matrix. The local ridge frequency varies across different fingers, and may also vary across different regions of the same fingerprint [3]. Hong, Wan, and Jain proposed a method to estimate ridge frequency [20] and is used in this paper. In order to find the frequency f_{ij} at a point (x_i, y_j), a rectangular window of size 32 × 32 centered at (x_i, y_j) is considered. Then the window is rotated in such a way that the ridges points in the vertical direction. After the rotation, the gray levels in the each column are accumulated to obtain *x*-signature. Then f_{ij} is determined as the inverse of the average distance between two consecutive peaks of the x-signature. This is shown in Fig.6. Thus f_{ij} at (x_i,y_j) is given by $f_{ij} = 4/(s_1+s_2+s_3+s_4)$. Extracted frequency is shown in Fig.7.

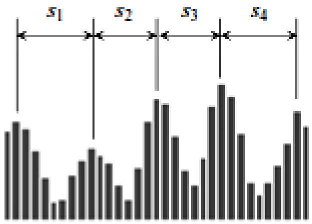


Fig.6. x-signature

(a) (b)

Fig.7(a).Fingerprint, (b).Ridge frequency image

7. MATCHING SCORE COMPUTATION FROM RIDGE FREQENCY AND RIDGE TEXTURE

Ridge frequency image for both altered FP and normal FP is obtained as explained in section 2. These images are decomposed up to level 4 using Haar wavelet [21], [22], [23] and the mean of approximation coefficients at the 4th level and detailed coefficients at all the levels are found. The Matching score is obtained by finding the Euclidian distance between these two feature vectors as in Eq.(15) as follows.

$$ERF = \sqrt{\sum_{N=1}^{13}\left(mRF\_AFP(N) - mFP\_NFP(N)\right)^2} \qquad (15)$$

where, ERF is Euclidian distance for ridge frequency, mRF_AFP(N) and mFP_NFP(N) is the mean of the coefficients of ridge frequency image of altered FP and normal FP respectively. *N* varies from 1 to 13.

The ROI from altered and normal FP is decomposed to fourth level by Haar wavelet to find out ridge texture feature vectors. Procedure followed is same as explained for ridge frequency and the parameter for this is given in Eq.(16).

$$ERT = \sqrt{\sum_{N=1}^{13}\left(mRT\_AFP(N) - mFN\_NFP(N)\right)^2} \qquad (16)$$

where, ERT is Euclidian distance for ridge texture, mRT_AFP(N) and mFN_NFP(N) is the mean of the coefficients of ridge texture image of altered FP and normal FP respectively. Matching scores obtained by comparing ridge frequency features and ridge textures are combined to get a single matching score. In order to do this, we have used weighted sum rule [16]. Final matching score EFS is generated as in Eq.(17) follows.

$$EFS = \alpha.ERF + (1-\alpha)ERT \qquad (17)$$

where, α varies between 0 and 1. The value of ERT is very high as compared to ERF. Thus α is taken as 0.98 to normalize ERT to a value in between 0 and 1.

8. RESULTS AND DISCUSSION

An altered FP database consisting of 70 synthetically altered fingerprints is used for the experiments. Normal fingerprints obtained from FVC 2000 and FVC 2004 database is used for creating synthetically altered fingerprints. Each group in this database consists of 8 impressions of 10 fingers and is captured by optical and capacitive sensors. The resolution of each fingerprint is 500dpi. Synthetically altered obliteration of different area is created by making scar and scratches in the image.

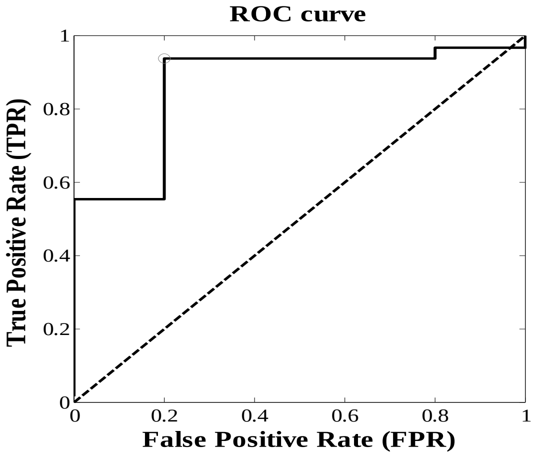


Fig.8. ROC curve for the matching scores in first stage

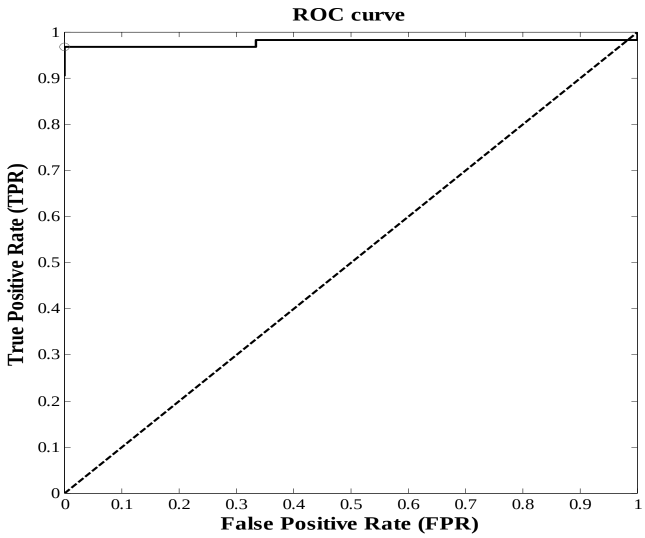


Fig.9. ROC curve for matching scores in second stage

Matching scores are obtained as follows. In one to many matching, one altered FP is matched against all the unaltered FP. The actual mates with matching scores less than a threshold belongs to Genuine match and greater than threshold belongs to false non match. Different FP mates having scores less than threshold is considered as false match. The ROC (Receiver Operating Characteristics Curve) curve between Genuine

Acceptance Rate (GAR) and False Acceptance Rate (FAR) for each stage is plotted. ROC curve gives the performance of the matching system for different threshold. Given the matching score, it computes the GAR and FAR for different thresholds and plot the graph. ROC curve for first stage is shown in Fig.8 and second stage is shown in Fig.9. The threshold that gives maximum matching results is marked as circle. These cut-off point for best GAR and FAR is 0.2213 and 0.0520 for first and second stage respectively.

The Table.1 shows the GAR and FAR of the proposed method for the optimum threshold found by ROC curves. Two fingerprints image are considered as from same fingertip only when the value of $s(A, B)$ and EFS are less than 0.2213 and 0.0520 respectively. Different FP mates with matching score less than above mentioned threshold in both stages are considered for FAR. True FP mates with both matching score less than above mentioned threshold is taken for GAR. The second stage reduced the FAR produced at the first stage.

Table.1. GAR and FAR for the thresholds 0.2213 and 0.0520

No. of altered of FP	GAR in %	FAR in %
Altered FP(70)	87.14	0

This method is tested on another database of synthetically altered fingerprints. These fingerprints are created by normal fingerprints obtained from casia fingerprint database. The Table.2 shows the results of matching.

Table.2. GAR and FAR for the testing database

GAR in %	FAR in %
90	3.33

9. CONCLUSION

This paper presents a two stage method to match obliteration type of altered fingerprint with its unaltered mates. Reconstructed orientation is used in the first stage. In second stage ridge frequency and ridge texture in the unaltered region of the altered FP is used for matching. As the number of FP images to be matched increases, the manual ROI selection becomes difficult. The two stage matching reduces this difficulty. Results show that this method is suitable for altered FP matching.

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