

Detection of Fingerprint Alteration Using Scars, Minutiae Density and Ridge Discontinuity

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Abstract—A novel method for detecting altered fingerprints using scars, minutiae density and ridge discontinuity is proposed here. This paper mainly focuses on FFT enhancement for ridge discontinuity analysis and use of scars along with ridge discontinuity and minutiae density for alteration detection. The scar is detected by adaptive average filtering and thresholding. This method is found suitable for the detection of all types of alteration viz. obliteration, distortion and imitation.

Index Terms— Fingerprints alteration, obliteration, distortion, imitation, ridge orientation, minutiae density, scar, FFT, average filtering, SVM

1 INTRODUCTION

A number of biometric traits is in use worldwide and selection of trait depends on application. Over the last thirty years, fingerprint is the most widely used biometric trait for personal identification because of the fact that the pattern on fingerprint cannot change during the entire life time of the person [1]. One of the major threats to Fingerprint Automatic Identification System (AFIS) over the last few years is fake fingerprints and altered fingerprints. Fake fingerprints are made from glue or latex, on the other hand altered fingerprints are real fingerprints obtained by changing the ridge structure. The problem involving altered fingers falls under broader category of attacks known as biometric obfuscation. Obfuscation can be defined as a deliberate attempt by an individual to mask their identity from a biometric system by altering the biometric trait prior to its acquisition by the system [2]. By the subjective assessment of altered fingerprints, the alteration can be divided into three types. They are obliteration, distortion and imitation. Obliteration is performed by cutting, abrading, burning and poring strong chemicals into ridge pattern. Skin diseases also obliterate the fingerprint. Obliteration is again divided into scar and mutilation. Row 2 and 3 of figure 2 shows scar and mutilation respectively. Fingerprint can be distorted by changing the ridge structure by plastic surgery, in which portions of skin are removed from the finger and grafted back in different positions. Row 1 of figure 2 shows distortion type. Imitation type of alteration is obtained by performing surgical procedure in such a way that the altered region looks like natural fingerprint. Simulated fingerprint of imitation type is shown in row 4 of figure 2. These surgeries may involve transplantation of large area of skin from other parts of body such as fingers, palms, toes and soles. It is very difficult to detect imitation type of alteration because of its similarity with natural fingerprints. So the imitation detection is one of the major challenges for the researchers working in these fields.

Many researchers have attempted the detection of altered fingerprints. Jianjiang Feng, Anil K Jain and Arun K Ross developed an algorithm for detecting altered fingerprints. By decomposing the orientation field into singular fields and continuous field, high level features were extracted from continuous orientation fields and Support Vector Machine is used for classification [2]. Soweon Yoon, Jianjiang Feng and Anil K Jain have used orientation discontinuity and minutiae distribution for detecting altered fingerprints [3]. Orientation discontinuity is obtained by comparing global orientation fields and least square polynomial approximated orientation field of altered fingerprint.

In this paper we propose three features viz. ridge discontinuity, minutiae density and scar for detecting alteration.

2 PROPOSED METHOD

The proposed method uses combination of three features for fingerprint alteration detection. The features identified are Minutiae Density (MD), Ridge Discontinuity (RD) also known as Orientation Discontinuity (OD), and Scars (S). MD is extracted by Parzen window method as used in [3]. RD map is obtained by comparing original image with FFT enhanced image. Scar is detected by adaptive average filtering and thresholding. Average filtering is adaptive in the sense that window size of the filter is changed to account for dryness of the fingerprint image. Local histograms are created from extracted features. After concatenating the histograms, fed into SVM for classification [3].

3 CONSTRUCTION OF MINUTIAE DENSITY (MD)

A minutiae in the fingerprint indicates ridge characteristics such as ridge ending or ridge bifurcation. Almost all fingerprint recognition systems use minutiae for matching. Minutiae in altered fingerprints tend to form clusters in the altered region. For example, a scar generates a large number of ridge endings while minutiae in natural fingerprints are distributed rather uniformly. Altered region consists of large number of ridge endings than normal region [3]. Different steps used for extraction of minutiae are as follows.

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3.1 Fingerprint Enhancement

Enhancing the altered fingerprint by FFT [4], [5] gives some directional smoothing to the ridges. The image is divided into small processing blocks of 32×32 pixel size and FFT is performed according to the equation

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

For $u = 0, 1, 2, \dots, 31$ and $v = 0, 1, 2, \dots, 31$.

In order to enhance a specific block by its dominant frequency the FFT of the block is multiplied by its magnitude a set of times. Where the magnitude of the original

FFT = $\text{abs}(F(u,v)) = |F(u,v)|$.

Thus the enhanced block is obtained by

$$g(x,y) = F^{-1} \{ F(u,v) \times |F(u,v)|^K \} \quad (2)$$

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

$$f(x,y) = \frac{1}{MN} \sum_{x=0}^{M-1} \sum_{y=0}^{N-1} F(u,v) \times \exp \left\{ -j2\pi \times \left(\frac{ux}{M} + \frac{vy}{N} \right) \right\} \quad (3)$$

For $x = 0, 1, 2, \dots, 31$ and $y = 0, 1, 2, \dots, 31$.

The K in equation (2) is an experimentally determined constant, which we choose $K=0.3$. Higher value of " K " improves the appearance of the ridges by filling up small holes in ridges, but very higher value of ' K ' can result in false joining of ridges. Thus a termination might become a bifurcation.

3.2 Binarization.

Image Binarization is a process which transforms the 8bit gray image to a 1-bit image with 0-value for ridges and 1 value for furrows. After the operation, ridges in the fingerprint are highlighted with black color while furrows are white. Otsu's method is used for finding the optimum threshold for binarization.

3.3 Thinning

It is a morphological operation that successively erodes away the foreground pixels until they are one pixel wide [1]. The application of the thinning algorithm to a fingerprint image preserves the connectivity of the ridge structures while forming a skeletonized version of the binary image. This skeleton image is then used in the subsequent extraction of minutiae.

3.4 Minutiae extraction

In 3 × 3 window, if the central pixel is 0 and has exactly 3 zero-value neighbors, then the central pixel is a ridge branch or bifurcation. If it has only one zero-value neighbor, then the central pixel is a ridge ending or termination [1]. Fig.1 below illustrates this method. Zero in the figure corresponds to ridges and one corresponds to valleys.

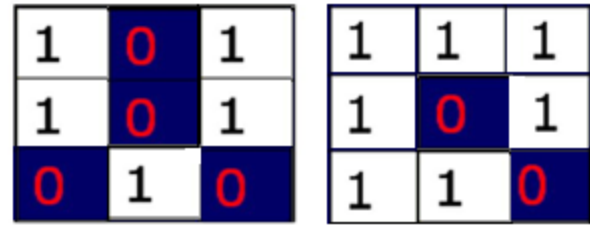


Fig.1 (a) Bifurcation

(b) Ridge ending

3.5 Minutiae density map (MD)

After extracting minutiae, MD map is constructed by using the Parzen window method with uniform kernel function [3]. Let S_m be the set of minutiae of the fingerprint.

Where $S_m = \{x | x = (x,y) \text{ is the position of minutiae}\}$

Then, the MD map from S_m is constructed as follows. Initial density map $M_d(x, y)$ is given by

$$M_d(x, y) = \sum_{x_0 \in S_m} K_r(x - x_0) \quad (4)$$

Where $K_r(x-x_0)$ is a uniform kernel function centered at $(x-x_0)$ with radius r . ($r = 40$ pixels). Then $M_d(x, y)$ is smoothed by a Gaussian filter of size 30×30 pixels with standard deviation of 10 pixels. After smoothing, $M_d(x, y)$ is transformed to lie in the interval $[0, 1]$. Figure 2 shows the Minutiae Density map (MD) obtained by above steps. It has corresponding changes with respect to increase in the density of ridge endings and bifurcations. In Fig.2, imitation type has very low density of minutiae than other types. It shows that alteration creates large number of ridge endings and bifurcations than normal region.

4 EXTRACTION OF RIDGE DISCONTINUITY

Ridge orientation of altered fingerprint is discontinuous in the altered region. The obliteration type of alteration again can be divided into two, scar and mutilation type as shown in rows 2 and 3 of figure2. It is evident that both of the images contain RD at the altered region. Similarly, ridges are discontinuous at the boundary of the altered region of distortion and imitation type shown in row 1 and 4 respectively of figure 2. This is the reason that RD is an important feature for detecting fingerprint alteration. Different steps used for finding RD are given below:

4.1 Ridge orientation measurement

Orientation will give us the path or direction of ridge flow in a fingerprint image and its value at every pixel will vary between zero and π [1]. Good quality fingerprints have a smooth orientation field except near the singular points (e.g., core and delta). Based on this fact, many orientation field models have been developed by combining the global orientation field model for the continuous flow field of the fingerprint with the

local orientation field model around the singular points [6], [7], [8], [9]

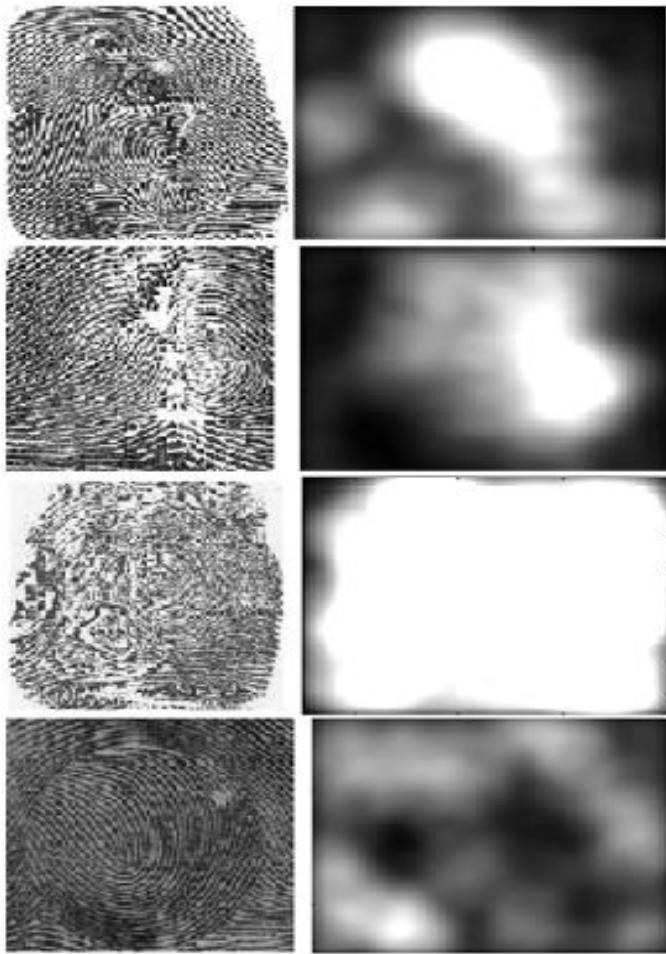


Fig.2 MD maps. Row1: distortion type, row 2: scar type, row 3: mutilation, row 5: imitation.

We have not considered the orientation around core and delta. So the orientation is known as global ridge orientation field. Gradient based method is used for finding global ridge orientation of fingerprint images [1]. Ridge orientation measurement consists of following tasks.

A. Gradients Measurement: The gradient $G(x, y)$ at a point (x, y) of an 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. Gradient of Gaussian is used for this purpose.

B. Local orientation: Local orientation is estimated by finding the principal axis of variation of gradients around a window of size $w \times w$ (19×19) centered at each pixel and are denoted as G_{xx} , G_{yy} and G_{xy} .

C. Direction of Gradients: Direction of gradient is obtained as $\sin 2\theta$ and $\cos 2\theta$. 2θ is used instead of θ to discount the circularity of angles.

$$A = \sqrt{((G_{xy})^2 + (G_{xx} - G_{yy})^2)} \quad (5)$$

$$\sin 2\theta = \frac{G_{xy}}{A} \quad (6)$$

$$\cos 2\theta = \frac{(G_{xx} - G_{yy})}{A} \quad (7)$$

D. Orientation Angle: Ridge orientation at each pixel is obtained as

$$\theta(i, j) = \pi/2 + \text{atan2}(\sin 2\theta, \cos 2\theta)/2 \quad (8)$$

4.2 Ridge Discontinuity

After finding the ridge orientation field, the altered image is enhanced by FFT given in section 3.1. The ridge orientation field defined as $\theta^{\wedge}(i, j)$ of the FFT enhanced image is obtained by same steps as explained in ridge orientation measurement. The difference between observed orientation field and FFT enhanced orientation field gives the orientation discontinuity map. The error map is obtained by the equation

$$\mathcal{E}(i, j) = \min(|\theta(i, j) - \theta^{\wedge}(i, j)|, \pi - |\theta(i, j) - \theta^{\wedge}(i, j)|) / \pi/2 \quad (9)$$

Fig.3 shows the altered fingerprint and RD map obtained by equation (9). From the RD map, it is clear that ridge discontinuity is zero everywhere except at altered region. RD is very less in imitation type of alteration.

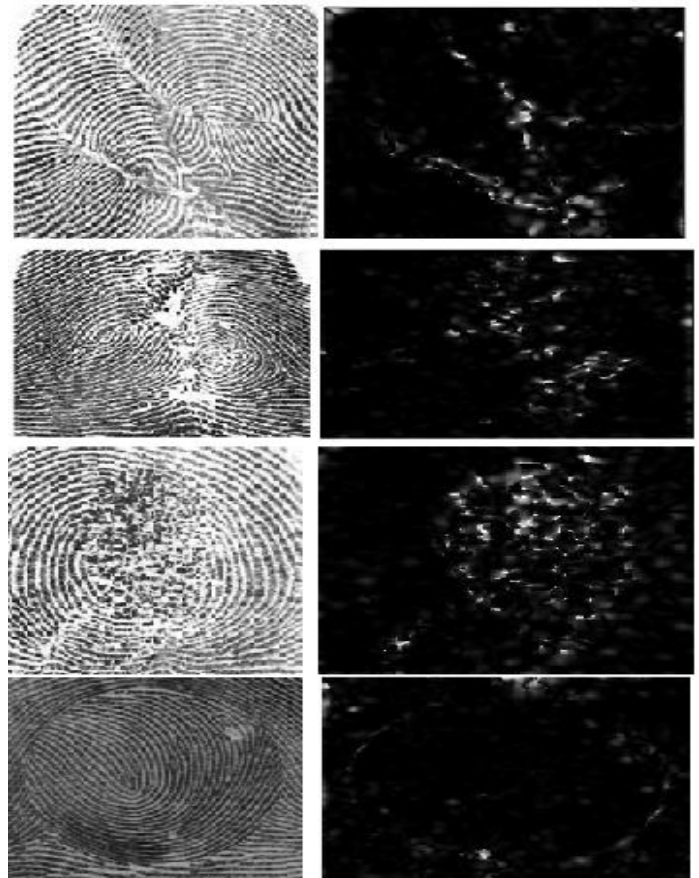


Fig.3 RD maps. Row1: distortion type, row 2: scar type, row 3: mutilation, row 5: imitation.

5 ANALYSIS OF SCARS

Apart from the long cuts in the scar, the absence of ridges and valleys in a fingerprint is also known as scar. Scar is an important feature in scar type of obliteration. Other types of alteration except imitation and highly mutilated fingerprint also consist of absence of ridges and valleys. Row 2 in figure 4 shows an image with scars. Scars often appear along the cuts on the ridges and it gives important information about alteration. Scar is present in obliteration and distortion type of alteration. The scar in the distortion should span small amount of area than obliteration type of alteration. Average filtering for scar detecton is given in [10]. In this work, we made the filtering adaptive with respect to the the dryness of the fingerprint. Following steps are performed for scar detection.

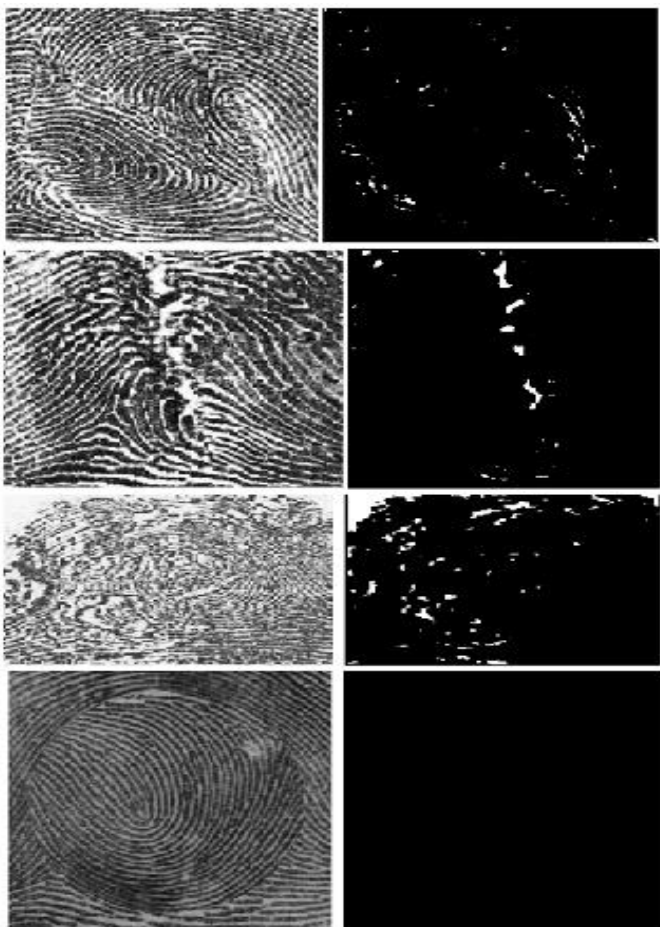


Fig.4 altered fingerprint and detected scar Row1: distortiontype, row 2: scar type, row 3: mutilation, row 5: imitation (scar is not present).

5.1 Histogram equalization

The first step in the scar detection is the normalization of the fingerprint image so that it has a prespecified mean and variance. This results in maximum span of the gray scale variation in the image, with the help of spreading of the histogram of the image across the entire spectrum. This is done by histogram equalization.

5.2 Adaptive Average filtering

The averaging filter preserves the sharp edges in the image. Thus the image is convolved with average filter in the spatial domain to accentuate the present scars. The dryness on the fingerprint will affect the preservation of scars in the fingerprint. This difficulty is solved by changing the window size by setting a threshold for mean and standard deviation for the pixel intensity of the image. Thus the filter is adapted to the dryness of the fingerprint. The mean and standard deviation varies for wet, dry and normal fingerprint images. We set a window size of 3×3 , 5×5 and 7×7 for wet, normal and dry fingerprints respectively.

5.3 Thresholding

Thresholding is used for segmenting the scars from the filtered fingerprint image. Fig.4 shows the segmented scars from the altered fingerprint images. It is clear from the figure that scars are present at the altered regions except imitation type. Scar is not present for highly mutilated type of alteration. This is shown in figure 5 below.

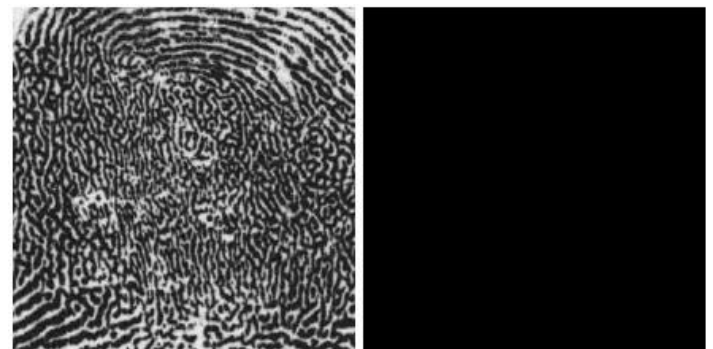


Fig.5 highly mutilated image and detected scar. Scar is not present.

6 FEATURE ECTRACTION AND CLASSIFICATION

Support Vector machine is used for classification. The feature vectors from the ridge discontinuity map, minutiae density map and scar is constructed by local histograms in 3×3 cells. After combining all these features by concatenating local histograms in each cell is fed into SVM for classification [1].

7 EXPERIMENTS AND RESULTS

A database of 60 altered fingerprint images consisting of all types of alteration obtained from the database of [2] and [3] is used for the experiments. Imitation type in the database is obtained by synthetic alteration. Normal fingerprint images are obtained from [11]. By subjective assessment, all images are categorised into obliteration, distortion and imitation. Simulation is performed for all types of alteration. Ridge discontinuity, minutiae density and scar are extracted from altered and normal fingerprint and local histograms are created from the extracted features. These histograms are concatenated

to form feature vectors. Some of the images from the database are used for training the support vector machine. Finally the feature vectors are fed into SVM for classification. Table 1 shows the percentage of detection for different types of alterations. Detection rate for imitation type is very less.

Table 1. Result of altered fingerprint detection.

Type of Alteration	% of Detection
Obliteration(scar & mutilation)	87
Distortion	100
Imitation	33

8 CONCLUSION

In this paper, we developed a method for detecting altered fingerprints. Altered fingerprints consist of three features, Ridge Discontinuity (RD), Non uniform Minutiae Density (MD), and absence of ridges and valleys known as Scars(S). All these features are extracted and constructed the feature vectors for feeding into SVM. FFT is used for constructing RD map. Scars are detected by average filtering and thresholding. Parzen window method is used for constructing MD map. From the results, it is concluded that detection of obliteration and distortion is possible by using three features. Detection of imitation type needs further verification on real altered fingerprints. Normal fingerprints sometimes have the natural scar. Thus there is a need of method for separating scar of altered altered fingerprint from that of natural fingerprints.

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