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Multi Feature Based Fingerprint Recognition With Score Fusion

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Abstract

Fingerprint is one of the widely used biometric authentication system for secured transactions. In this work, a novel fingerprint recognition system is proposed using score level fusion to yield high recognition accuracy with limited training data. Two fingerprint patterns seem to be same but they do not have unique minutiae points. Noise factors like moist, scars affect the recognition accuracy in the extraction of local features like Minutiae and Core Points. To handle spurious minutiae type of problems, in this proposed work similarity scores computed from Minutiae and Core Point methods are fused. Initially, Fingerprint enhancement is done in both spatial and frequency domains, then Minutiae and Core Point extraction will be done. Computed Scores are fused using Z-Score method. Recognition accuracy of proposed method is 96.4%, 94.5% on Vignan's Fingerprint Recognition (VFR) and Fingerprint Verification Competition (FVC) databases respectively and it is better in comparison with the existing methods.

Keywords: Fingerprint, Gabor Filters, FFT, Minutiae Points, Core Points, Fusion.

Introduction

In recent scenario fingerprint is one of the familiar biometric trait most widely used for personal authentication. A human fingertip is made up of ridges and furrows combination of such ridges and furrows generates distinctive patterns called fingerprints. Ridges are the dark lines whereas valleys are the white spaces held among ridges held in the fingerprint image pattern. Fingerprint is unique, and remains unchanged during the life i.e., immutable. With those characteristics fingerprints are widely used for person identification in forensic applications.

Region of the ridge pattern where the fingerprint is made visually prominent called singularities. Fingerprint singularities [7, 9] are categorized into core and delta features those are widely used to distinguish fingerprints from one another. Detailed analysis of the fingerprint depicts some anomalies held in the fingerprint pattern called ridge endings, bifurcations, crossovers, short ridges, etc. These set of local features of fingerprints form minutiae, used for manual or automatic fingerprint identification.

An enhanced or smoothed quality fingerprint may contain 80 to 120 minutiae points [10] but some poor quality images may have different number of minutiae. Noise factors like moist areas, scars and skin conditions will affect the quality of the image. Fingerprint image enhancement is carried out in both frequency and spatial domains. Clarity of Fingerprint ridge pattern is enhanced by the removal of noise in the enhancement step of automatic fingerprint recognition [11].

Related Work

A. Image Enhancement

The quality of fingerprints relies on acquisition strategies and that effect the performance of minutiae and core point extraction. Hong et al. presented a fast fingerprint enhancement algorithm based on local ridge structure by enhancing the ridge and valley structures. They evaluated the performance of their work based on goodness index of the extracted minutiae and verification accuracy.

Zorita et al.[14] presented a method for automatic fingerprint recognition in two steps. In the first step, local characteristics of fingerprints called minutiae are extracted then in the second step, fingerprints are matched with templates in test database. Keun et al. proposed directional filter bank based enhancement algorithm which decomposed the input image into directional sub-band images and those are reconstructed to form a synthesized enhance image. Experiment results proven that the proposed method has yielded high PSNR values and preserved the spatial characteristics at local features like minutiae and singular points. Sen et al. enhanced the quality of image around singular point using filters. Initially they have identified singular point area and then designed a new filter to enhance this area.

B.Minutiae Based Recognition

In Jiang et al. [19]and Yau et al.[10] proposed a new fingerprint matching algorithm. It matches the minutiae points of a fingerprint image by using its local and global features. The local features of minutiae includes rotation and translation invariant feature of minutiae. The global features determine the uniqueness. This matching algorithm is useful for online processing because it is having high processing speed. Gu et al. and Jain et al. [7, 8] proposed a hybrid matching algorithm. They matched minutiae points and texture information of fingerprint. Results have shown that combination of minutiae matching along with texture information improved the matching performance. Eckert et al.[3] extracted rotation, translation and distortion invariant minutiae points.

In Luo et al. proposed modified minutiae based fingerprint matching algorithm based on algorithm proposed by Jain et al. [9, 11]. The algorithm distinguishes the two images from different fingers. It is more robust to deformation. The experimental results were good when evaluated on scanned fingerprint images. Andrew K Hrechak [1] proposed a structural matching algorithm. In their work they used local structure of minutiae to describe the characteristics of minutiae.

C. Core Point Based Recognition

F. Benhammadi et.al.,[4] proposed fingerprint matching algorithm based on global alignment of the core point neighborhoods of minutiae features. In general, minutiae features are distributed in different fingerprint regions. Kunal Goyal and Rutvik Malekar [11] proposed an algorithm that uses SIFT points which are present on the fingerprint image. These SIFT points are used to detect the core point. It eliminates the noisy and spurious points. So the possibility of detecting false core point is eliminated. B.Karuna kumar and Dr. K.Satya Prasad [2] proposed a hybrid core point localization algorithm. In this method field orientation is estimated then filtering techniques are applied to extract the core point.

Proposed Method

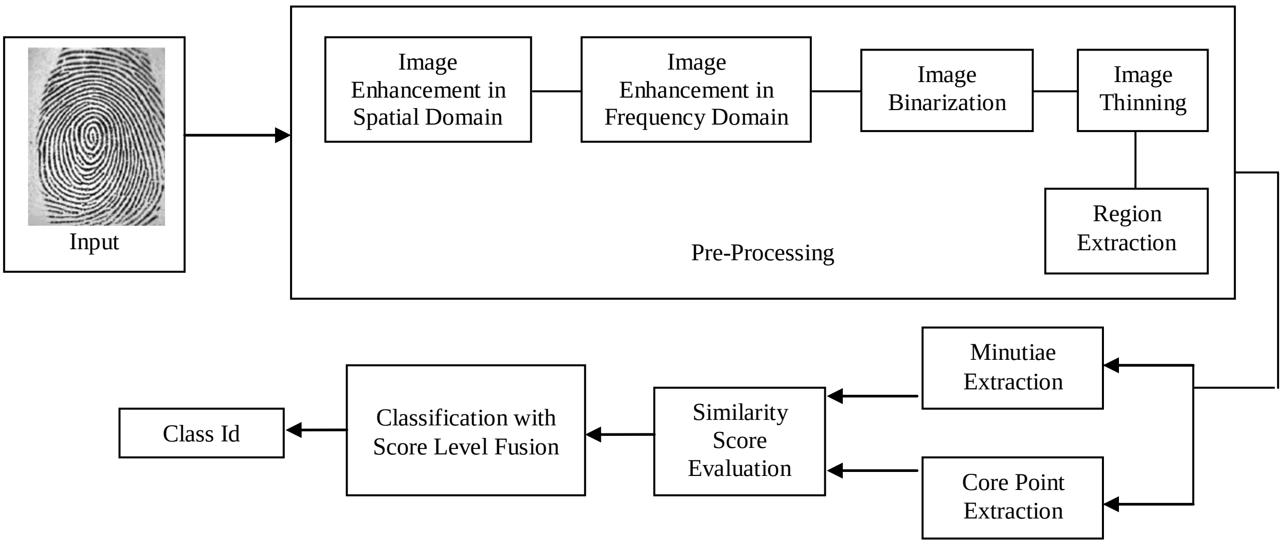

Figure 1: Architecture of The Proposed Method

Image Enhancement In Spatial Domain

In spatial domain, image enhancement is directly applied on pixels. In the proposed method, Histogram equalization [2, 4, 6] is used to enhance the quality of the image. Pixel gray level distribution is computed with Histogram equalization. To improve the contrast of the finger print image, pixel values are normalized in the range from 0 to 255 with Histogram equalization.

Image Enhancement In Frequency Domain

Fourier Transform used to convert an image to frequency domain from spatial domain. In frequency domain, Gabor Kernels are used to reduce noise thereby enhance the quality of the image. To get back the image into spatial domain, Inverse Fourier Transform is used. Selective, orientation and optimal joint resolution [5,12] properties are hold by Gabor filters in both spatial and frequency domains. Gabor filters are appropriate to remove noise and also essential to maintain original ridge/valley patterns. In block wise local orientation angle and frequency were calculated with filtering. Once ridge orientation and frequency information are calculated, those are used to build even symmetric Gabor filter. Gabor filters are having 5 scales and 8 orientations, i.e., in total 40 kernels.

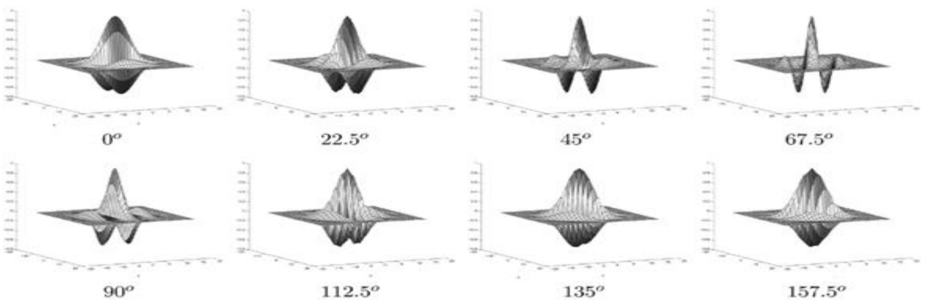

Figure 2: Eight Gabor Orientations

Image Binarization

To extract the local features like minutiae and core points from a fingerprint image. In Image Binarization, the gray color image is converted into binary image. Gray color image have 256 gray levels (0-255) were as binary image has 2 levels (0-1). In the binarized image, pixels are having only 0 and 1 intensity values. Here 0 represents Black and 1 represents White pixels-values to define ridges and valleys respectively. In Local adaptive threshold binarization method, pixel intensity values are transformed to 1 if it more than the mean intensity value. Binarization improves the extraction of minutiae points from the noised fingerprint images also.

Thinning

Thinning is a process that transforms the binary fingerprint pattern to a connected skeleton of unit width. A sub image or mask is moved on an image, to examine the center pixel based on neighboring pixels. With thinning, binary image became skeletonized. In the proposed work, Morphological operators such as open, close etc., are used for thinning. This thinning preserves the connectivity of the ridge structure and results skeleton of the fingerprint image. This skeleton image is used for further feature extraction procedures called minutia & core point extraction.

Minutiae Extraction

Minutiae is a local feature, and the position of minutiae doesn’t change over time. Minutiae are defined as a combination of Termination and Bifurcation points.

Termination points are located at the ridge ending and Bifurcation points are located at branch of a ridge. On the thinned fingerprint ridge, termination and bifurcation points are identified based on neighboring pixels. The process of minutiae marking is done by using the concept of crossing number (CN). In a 3x3 window, if central pixel is 1 and has exactly three 1 neighbors then the central pixel is a ridge branch or bifurcation. In a 3x3 window, if the central pixel of mask is 1 and it has only one 1 value as a neighbor then the central pixel is defined as ridge ending or termination. 3x3 windows are used to identify the bifurcation and termination points as defined in Fig 3 and Fig 4 respectively.

0	0	1
1	1	0
0	0	1

1	0	1
0	1	0
0	1	0

1	0	0
0	1	1
1	0	0

0	1	0
0	1	0
1	0	1

Figure 3: Masks For Detecting Bifurcation Points

0	0	0
1	1	0
0	0	0

0	0	0
0	1	0
0	1	0

0	0	0
0	1	1
0	0	0

0	1	0
0	1	0
0	0	0

Figure 4: Masks For Detecting Termination Points

Region of Interest Extraction

Image segmentation is used to locate objects and boundaries similar to the lines and curves held in fingerprint images. The features available at the Region of Interest (ROI) are useful to recognize the individual. The image area without effective ridges and furrows holds background information. ROI extraction can be done using two Morphological methods called OPEN and CLOSE. OPEN operation can enhance quality of the image by removing background noise and CLOSE operation shrink the image by eliminating the small cavities.

False Minutiae Removal

Some artifacts will lead spurious minutiae in preprocessing stage. These spurious or false minutiae will affect the accuracy of matching in classification stage. A threshold ‘D’ is chosen for identification of false minutiae. So the elimination of false minutiae is important and the procedure to remove false minutiae is done based on the distance between bifurcation and termination is less than D. If two minutiae are held in the same ridge then both of them are removed. The computed distance between two bifurcation points on a same ridge is less than D then those two points will be eliminated. If no termination points are located in between two termination points then two minutiae are considered as false minutiae over a broken ridge and those are removed.

Core Point Extraction

Core point is defined as convex ridges with the maximum curvature. To identify the core point of an image, ridge orientation field estimation is necessary.

Ridge Orientation Estimation

The Ridge orientation is used to estimate the orientation of each pixel in a finger print image. It helps to determine the overall ridge flow in a fingerprint. The process of orientation field estimation is done by a moving window at all pixels on raw image. The window is moved in 16 equally spaced directions and then the projections are calculated along y direction. The projection with maximum variance is fixed as the orientation of the pixel. This process is continuously done to obtain the values for all pixels. For every pixel (x, y) co-ordinates are noted along with orientation angle. This orientation estimation is one of the important methodologies to calculate the core point.

Fingerprint image is needed to be segmented from background based on the variance estimation. Background is usually characterized by small variance. Estimate the orientation field for an enhanced image. This operation is done locally for each pixel of image by moving a frame of 2 x 2 size. Compute gradient and magnitude M of the orientation field. For a fixed a magnitude value, a logical matrix L is defined

L(i, j) = 1 if M(i, ,j) > Mt

= 0 otherwise

Logical matrix L is thinned to find ridges ending. If the thinned binary image has an ending point in the current pixel then result is a logical matrix T whose element T(i, j) is set to 1. The elements of matrix T set to 1 are all candidates to final core point.

Fusion of Minutiae & Core Point Features

Similarity scores evaluated with Minutiae & Core Point feature vectors are fused with Z score Fusion. By considering the challenges with individual Minutiae and Core point methods, in this work fusion is proposed.

$$S = \frac{V - V_{mean}}{V_{std}}$$

Where $V_{mean}=(V_1+V_2)/2$ and V_{std}=Standard Deviation (V_1, V_2). V_1 and V_2 are the similarity scores achieved with Minutiae and Core Point methods respectively.

Experimental Results

In this work, the performance of proposed method is evaluated on Vignan's Fingerprint Recognition (VFR) Database, which was generated by using NITGEN (NTG-HFDU14(A)) device. Students and Employees' of Vignan's University are served as volunteers for the generation of VFR database. The proposed method is applied on sample image of VFR database and various stages of samples are shown in Fig. .

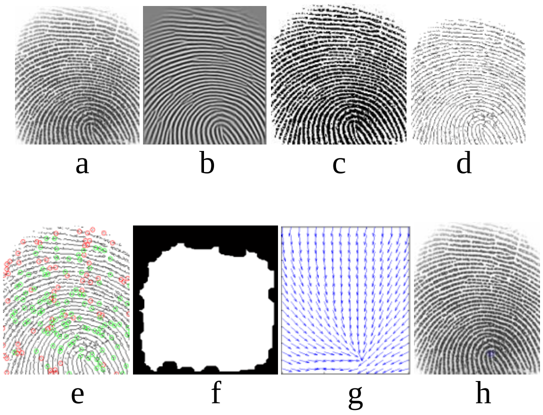

Figure 5: a. Original image b. Enhanced image c. Binarized image d. Thinned image e. Bifurcation points f. ROI extraction g. Oriention field estimation h. Core point identification.

VFR database consists of 110 male and female subjects with 8 samples and having 300 dpi resolution. Subjects' age varied from 17 years to 65 years. Each sample of size 260*300 and database consists of 880 samples. Samples were collected during different atmospheric conditions. The sample images of VFR database are as follows:

Figure 6: Sample Images of VFR Database

The proposed method is evaluated on VFR [17] database by considering 2 samples for training and remaining 6 samples are used for performance evaluation. The performance of proposed method is compared with other existing methods and recognition rates are tabulated in Table 1. Recognition rates of proposed method on VFR database with 2 training samples has outperformed other existing methods like Local feature based and pattern based methods.

Table 1: Recognition Rates of Proposed Method with VFR Database

Method	**Recognition Rate with 2 Training Samples**	**Recognition Rate with 3 Training Samples**
Gabor+ 2D-DTW	88.9	91.5
Minutiae Based Method	93.9	96.2
Core Point Based Method	91.5	94.1
Proposed Method	96.4	97.7

The proposed method is also evaluated on FVC 2002 [13] database. FVC 2002 database consists of 4 different datasets. Each dataset consists of 110 classes, and each class consists of 8 samples. Proposed method is evaluated on dataset 1 whose size is 388*374 pixels with 500dpi. Results of the proposed method with 2 and 3 training samples are shown in Table 2.

Table 2: Recognition Rates of Proposed Method with FVC 2002 Database

Method	**Recognition Rate with 2 Training Samples**	**Recognition Rate with 3 Training Samples**
Gabor+ 2D- DTW	86.3	91.4
Minutiae Based Method	91.2	94.8
Core Point Based Method	89.3	92.8
Proposed Method	94.5	96.4

Conclusion

Fingerprint recognition is one of the widely used biometric authentication method in several application areas with low recognition rates and speed. In this work, fingerprint images are enhanced in both spatial and frequency domains. Local features like Minutiae and Core Point extracted then similarity scores are evaluated with those methods. Z Score method is used to fuse both scores, based on that score performance evaluation is done on VFR and FVC-2002 Databases. The proposed method yields good results when limited samples are available for training the model.

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