A REVIEW ON LATENT FINGERPRINT RECONSTRUCTION METHODS

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Abstract - *Fingerprints are the most important means of identification of an individual due to its uniqueness, permanence, acceptability and collectability. And the minutiae-based representation is the widely accepted fingerprint representation method. However, a constraint was taken into account that the minutiae points are entirely insufficient for the latent fingerprint reconstruction. Latent fingerprints are fingerprint impressions left at crime scenes by criminals that have been used as primary evidence in criminal investigations. The quality of latent fingerprints is typically poor, with complicated background noise, distortion, and a limited fingerprint region. As a result, image enhancement is required for the reliable identification. A lot of research is being done to automate all of the major processes in the latent fingerprint identification process. The performance of several state-of-the-art latent fingerprint identification systems, on the other hand, is far from satisfactory. The existence of noise, distortion, little information, and a big database make designing a latent fingerprint identification system extremely difficult. The purpose of this paper is to make a comparative analysis of existing latent fingerprint reconstruction methods.*

Key Words: **Minutiae, Latent fingerprint, fingerprint reconstruction, image enhancement, fingerprint identification system.**

1. INTRODUCTION

Fingerprint recognition is one of the most effective method for the identifying an individual. This is used to confirm the identity of a person by comparing the fingerprint impression of two fingerprints. Even with the new emerging techniques in the field of biometrics, fingerprints have the most reliable physiological traits due to their uniqueness, permanence, collectability and acceptability. Thus, it is used in many applications today in the field of criminology, banking etc.

Fingerprints are the valley and ridge patterns on the surface of human fingertips. The uniqueness of fingerprints is characterized by three levels of features such as level-1, level-2 and level-3. Level-1 features are considered as macro level features which include pattern type, ridge orientation and frequency fields, and singular points. Level-2 features refer to the local features that include minutia points in a local region such as ridge endings and ridge bifurcations. And level 3 features consist of all dimensional attributes at a very fine scale, such as width, shape, curvature and edge contours of ridges, pores, as well as other permanent details.

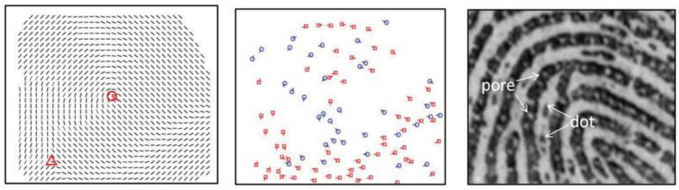
The minutiae (set of minutia points) are the most effective feature among these three types of characteristics and is most typically utilized in fingerprint matching and recognition systems. It was believed that it is not possible to reconstruct a fingerprint image from its extracted minutiae set. However, it has been demonstrated that it is possible to reconstruct the fingerprint image in this way and the reconstructed image can be matched to the original fingerprint image with a reasonable high accuracy. The goal of fingerprint reconstruction from a set of minutiae is for the rebuilt fingerprint to look like the original.

The existing fingerprint reconstruction methods consist of two major steps:

i) Orientation field reconstruction and

ii) Ridge pattern reconstruction.

Only when the reconstructed image matches the original fingerprint image on the minutiae points is considered as the successful fingerprint reconstruction.



(a) (b) (c)

Fig-1: Illustration of fingerprint features. (a) level 1 features: orientation field and singular points, (b) level 2 features: ridge endings (red squares) and ridge bifurcations (blue circles) and (c) level 3 features: pores and dots.

2. REVIEW OF PAPERS

Liu *et al.* [1] proposed a deep convolutional neural network architecture with the nested UNets for automatic segmentation and enhancement of latent fingerprints. For that synthetically generated latent fingerprints are used as the training dataset. Then, a nested UNets is proposed to transform low quality latent image into segmentation mask and high-quality images through pixels-to-pixels and end-to-end training. Finally, the test latent fingerprints are segmented and enhanced with the deep nested UNets to improve the image quality. By combining the local and global losses the enhancement network is optimized, which not only helps to reconstruct the global structure, but also enhance the local ridge details of latent fingerprints. The experimental results and comparison were carried out on NIST SD27 and IIITD-MOLF latent fingerprint databases.

Agarwal *et al.* [2] introduced the usefulness of pores, that is, level 3 features besides minutiae in latent fingerprint matching. An algorithm based on Lindeberg's automatic scale selection method is proposed for pores extraction in latent fingerprint images. The fusion of minutiae and pores at score level is used to re-rank the minutiae based latent fingerprint matcher. The performance of the proposed algorithm and pores utility are evaluated by observing and comparing the latent recognition accuracy obtained for minutiae matching and matching after fusion. Both pores and minutiae are automatically extracted in latent and reference fingerprints. The experimental results indicated that the fusion improves the latent fingerprint recognition rate in comparison to the minutiae matching.

Horapong *et al.* [3] introduced a novel framework for latent fingerprint enhancement. It uses a progressive feedback mechanism incorporated with a new learning model for anomalous fingerprint pattern detection. In this paper a progressive feedback mechanism is developed for handling automatic latent fingerprint enhancement and introduced an automatic initial block localization method, which can indicate multiple initial locations. This method helps to reduce the risk of initial start at the wrong location resulting in error propagation. Then, trained the proposed spectral autoencoder by a large set of enhanced spectral patches of high-quality fingerprints. This spectral autoencoder helps to detect the anomalous fingerprint patterns from outputs of the progressive feedback mechanism. The error locations are then detected and sent back for re-enhancement in the next iteration. This learning model provides a superior scheme for error detection and error correction of the proposed framework.

Gupta *et al.* [4] proposed a novel technique which considers the minutiae density and the orientation field direction for the reconstruction of fingerprint. The public domain databases Fingerprint Verification Competition 2002 (FVC2002) and Fingerprint Verification Competition 2004 (FVC2004) have been used for the experimental results and to validate the suggested methods for the fingerprint reconstruction and enhancement. Both DB_1 and DB_2 databases are used here. The prior knowledge of the ridge structure is used in the algorithm for the improvement of the ridge structure. Two types of dictionaries are used in this method; orientation based and continuous phase-based dictionaries. These dictionaries are used for obtaining the orientation field from the obtained minutiae set. The continuous phase-based dictionary is used for the reconstruction of the ridge pattern. The ridge frequency field used in this proposed method can be either fixed priori or reconstructed image from the ridge frequency around minutiae. By this method the reconstructed fingerprint images do not contain many spurious minutiae in the background and the results for the latent fingerprints are as accurate as they are for the normal data sets. In Type-I attack TAR of 97.95% and 94.05% is obtained on FVC2002 and FVC2004 databases respectively.

Manickam *et al.* [5] proposed an enhancement and matching of latent fingerprint method using Scale Invariant Feature Transformation (SIFT). It consists of two phases: (i) Latent fingerprint contrast enhancement using intuitionistic type-2 fuzzy set (ii) Extract the SIFT feature points from the latent fingerprints. Then the proposed algorithm is performed with *n*- number of images and scores are calculated by using Euclidean distance. This method was implemented using public domain fingerprint database such as FVC-2004 and IIIT-latent fingerprint. And the experimental results shows that the matching result obtained is better when compared to minutiae points.

Bajahzar *et al.* [6] proposed a method to minimize the size of fingerprint images and retain the reference points. The method is divided into three parts, the first part is about digital image preprocessing for eliminating the noise, improve the image, convert it into a binary image, detect the skeleton and locate the reference point. The second part concerns about the detection of critical points by the Douglas-Peucker method. And the final part presents the methodology for the fingerprint curves reconstruction using the fractal interpolation curves. The experimental result shows that the relative error is between 2.007% and 5.627% and the mean squared error (MSE) is between 0.126 and 0.009 at a small number of iterations. For a greater number of iterations, the ER is between 0.415% and 1.64% and MSE is between 0.000124 and 0.0167. This clearly indicates that the interpolated curves and the original curves are virtually identical and exceedingly similar to each other.

Cao *et al.* [7] proposed a ConvNet (convolutional neural networks) based approach for the estimation of latent orientation field. This idea is to identify the orientation field of a latent patch which is one of a set of representative orientation patterns. For this, 128 representative orientation patterns are learnt from a large number of orientation fields and 10000 fingerprint patches are selected to train the ConvNet for each orientation pattern. Experiment was carried out on NIST SD27 latent database.

Feng *et al.* [8] utilized the amplitude and frequency modulated (AM-FM) model for fingerprint reconstruction. The phase, which includes a continuous phase and a spiral phase (which corresponds to minutiae), totally defines the minutiae and ridge structure in this method. In the AM-FM model-based fingerprint reconstruction, continuous phase reconstruction is a crucial step. Moreover, the continuous phase was obtained by a piecewise planar model. The piecewise planar model, on the other hand, included numerous erroneous details into the reconstructed image, resulting in noticeable blocking effects. The TAR obtained here is 94.12% at 0.1% FAR on FVC2002 DB1_A and 99.7% rank-1 identification rate on NIST SD4 in the case of Type-I attack. Considering Type-II attack TAR is 45.89% at 0.1% FAR on FVC2002 DB1_A and 65.75% rank-1 identification rate on NIST SD4.

Ross *et al.* [9] proposed fingerprint reconstruction from minutiae points. Here the selected minutiae triplets in the template are used for the orientation field estimation. Then, with minutiae and border points, a streamline is traced. Linear Integral Convolution (LIC) is used to impart texture-like appearance to the ridges. Finally, the image is smoothened for obtaining wider ridges. But this algorithm can generate only a partial fingerprint. The performance of this reconstruction algorithm was tested by matching 2000 reconstructed fingerprints against the 2000 original fingerprints in NIST SD4. Type -I attack rate of 23% was reported here.

Cappelli *et al.* [10] introduced a method to reconstruct the grayscale image from minutiae directly. The orientation field is estimated by a modified zero-pole model. Then Gabor filtering is iteratively performed from minutiae on an image initialized by the local minutiae pattern. Then the reconstructed image is made more realistic by a rendering step. Here the performance is evaluated based on True Accept Rate (TAR) and False Accept Rate (FAR). An average TAR of 81.49% at 0% FAR was obtained in matching 120 reconstructed fingerprints against the 120 original fingerprints in FVC2002 DB_1. But this algorithm generates many spurious minutiae in the reconstructed images.

Hill [11] proposed a fingerprint reconstruction method in which a skeleton image is reconstructed from the minutiae which is then converted into grayscale image. Here the orientation field is generated based on singular points. The zero-pole method is suggested for the estimation of orientation field and partial skeleton reconstruction method for ridge pattern recognition. The main disadvantage of this method is that it only generates a partial skeleton image of the fingerprint.

3. CONCLUSION

Fingerprint reconstruction aims to recreate the original fingerprint image from a set of input minutiae. The fingerprint images are reconstruction from a given minutiae set is being studied for three main reasons: (i) for securing minutiae templates, (ii) to increase the interoperability of fingerprint templates generated by various sensor and algorithm combinations, (iii) to improve fingerprint synthesis. Despite of significant improvements in reconstruction techniques over the last ten years, there is still a matching performance gap between the reconstructed and original fingerprint images. This paper is the summary of different latent fingerprint reconstruction methods.

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