Fingerprint Image Reconstruction from Minutiae

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 Abstract: For fingerprint matching the set of Minutiae is considered as the most distinct feature . Reconstruction techniques illustrates the need for securing fingerprint templates and its interoperability, and improving fingerprint fusion. Earlier it was considered that only minutiae set are not sufficient for reconstructing the fingerprint .However, the recent studies have proved that through Minutiae set it is possible to reconstruct the fingerprint. But still the matching accuracy between the original fingerprint image and its corresponding reconstructed image has some difference. This paper consists the prior knowledge about the ridge structures which is determined in terms of continuous phase patch and orientation patch dictionaries to improve the reconstruction. The orientation fields are reconstructed through orientation patch dictionary and ridge patterns are reconstructed with the help of continuous phase patch dictionary. Three public domain databases (FVC2002 DB1fiA, FVC2002 DB2fiA, and NIST SD4) are used to carry the experimental results that demonstrate that the proposed reconstruction algorithm outperforms the state-of-the-art reconstruction algorithms in terms of both:

Keywords: Fingerprint reconstruction, orientation patch dictionary, continuous phase patch dictionary, minutiae set, Binarization , AM-FM model.

I.   Introduction

Nowadays the crime is increasing, we have also seen crime happening all around, however, we can use the learning fingerprint project as one of the best tool to capture the fingerprints of various criminals and then we can easily identify the criminal. The developed application will ease the policeman to easily identify the desired criminal. The need for the paper based fingerprints will get eliminated. The application also gives a technical touch which would help automate the process of capturing and identifying the fingerprint. De-identifying a fingerprint image is necessary to mitigate concern related to data sharing and data misuse.

FINGERPRINTS are ridged and valley patterns present on the surface of human fingertips [1]. The purported uniqueness of fingerprints are characterized by three levels of features [1]. Global features, such as pattern type, ridge orientation and frequency fields, and singular points, are called level-1 features. Level-2 features mainly refer to minutia points in a local region; ridge endings and ridge bifurcations are the two most prominent types of minutiae. Level 3 features include all dimensional attributes on a very fine scale, such as width, shape, curvature and edge contours of the ridges, pores, incipient ridges, as well as other permanent details. Among these three types of features, the set of minutia points (called minutiae) is regarded as the most distinctive feature and is most commonly used in fingerprint matching systems. An international standard ISO/IEC 19794-2 [2] has been proposed for minutiae template representation for the purpose of interoperability of matching algorithms. FVC on Going [4], a well-known web-based automated evaluation platform for fingerprint recognition algorithms, has set up a benchmark to evaluate fingerprint matching algorithms using this standard minutiae template format. It was believed that it is not possible to reconstruct a fingerprint image given its extracted minutiae set. However, it has been demonstrated that it is indeed possible to reconstruct the fingerprint image from the minutiae; the reconstructed image can be matched to the original fingerprint image with a reasonably high accuracy [7][9].

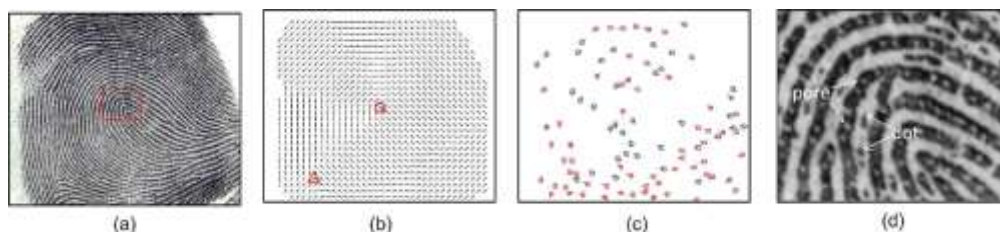(a)   (b)   (c)   (d)

Fig.1. Illustration of fingerprint features at three different levels. (a) A grayscale fingerprint image (NIST SD30,A002 01), (b) level 1 features: orientation field and singular points (core shown as a circle and delta shown as triangles), (c) level 2 features: ridge endings (red squares) and ridge bifurcations (blue circles) and (d) level 3 features: pores and dots.

In this paper, our goal is to utilize a similar dictionary-based approach to improve the fingerprint reconstruction from a given minutiae set. Two dictionaries are constructed for fingerprint reconstruction: 1) Orientation patch dictionary and 2) Continuous phase patch dictionary. The proposed reconstruction algorithm has been evaluated on three different public domain databases, namely,FVC2002 DB1 A, FVC2002 DB2 A and NIST SD4, in terms of minutiae set accuracy with respect to the given minutiae set and matching performance of the reconstructed fingerprint. The superior performance of the proposed algorithm over [8] and [9] can be attributed to: 1) Use of prior knowledge of orientation pattern i.e., orientation patch dictionary, which provides better orientation field reconstruction, especially around singular points. 2) The sequential process which consists of (i) Reconstructing locally based on continuous phase patch dictionary, (ii) Stitching these patches to form a fingerprint image and (iii) Removing spurious minutiae. Instead of generating a continuous phase and then adding a spiral phase to the continuous phase globally, this procedure is able to better preserve the ridge structure. 3) Use of local ridge frequency around minutiae.

II. Literature Survey

1. L. Hong, Y. Wan, and A. Jain, Fingerprint image enhancement: Algorithm and performance evaluation, IEEE Trans. Pattern Anal. Mach. Intell., vol. 20, no. 8, pp. 777789, Aug. 1998.

The author proposed an algorithm to ensure that the performance of an automatic fingerprint identification/verification system will be robust with respect to the quality of input fingerprint images, it is essential to incorporate a fingerprint enhancement algorithm in the minutiae extraction module. We present a fast fingerprint enhancement algorithm, which can adaptively improve the clarity of ridge and valley structures of input fingerprint images based on the estimated local ridge orientation and frequency. We have evaluated the performance of the image enhancement algorithm using the goodness index of the extracted minutiae and the accuracy of an online fingerprint verification system. Experimental results show that incorporating the enhancement algorithm improves both the goodness index and the verification accuracy. They modeled ridges and valleys as a sinusoidal-shaped wave along the direction normal to the local ridge direction and extracted the amplitude, frequency, and variance of the sinusoid. Based on these parameters, they classify blocks as recoverable and unrecoverable.

2. C. J. Hill, Risk of masquerade arising from the storage of biometrics, B.S. Thesis, Dept. Comput. SCI., Austral. Nat. Univ., Canberra, ACT, Australia, 2001.

In this paper the orientation field was reconstructed from the singular points (core and delta) using the zero-pole model. However, the orientation field in fingerprints cannot simply be accounted for by singular points only. The author proposed ridge pattern reconstruction only generates a partial skeleton of the fingerprint, which is obtained by drawing a sequence of splints passing through the minutiae.

3. A. Ross, J. Shah, and A. K. Jain, From template to image: Reconstructing fingerprints from minutiae points, IEEE Trans. Pattern Anal. Mach. Intell., vol. 29, no. 4, pp. 544560, Apr. 2007. 15

The authors proposed to estimate the orientation field by selecting well-structured tri- angles from the minutia set and computing the orientation values within each triangle by interpolation. This method fails to estimate the orientations where minutiae are not enough.

4. R. Cappelli, D. Maio, A. Lumini, and D. Maltoni, Fingerprint image reconstruction from standard templates, IEEE Trans. Pattern Anal. Mach. Intell., vol. 29, no. 9, pp. 14891503, Sep. 2007.

This work proposes a novel approach to reconstruct fingerprint images from the standard templates and investigates to what extent the reconstructed images are similar to the original ones (that is, those the templates were extracted from). The efficacy of the reconstruction technique has been assessed by estimating the success chances of a masquerade attack against nine different fingerprint recognition algorithms. The experimental results show that the reconstructed images are very realistic and that, although it is unlikely that they can fool a human expert, there is a high chance to deceive state-of-the-art commercial fingerprint recognition systems.

5. F. Chen, J. Zhou, and C. Yang, Reconstructing orientation field from fingerprint minutiae to improve minutiae-matching accuracy, IEEE Trans. Inf. Forensics Security, vol. 18, no. 7, pp. 19061912, Jul. 2009.

The author has proposed a novel fingerprint reconstruction algorithm to reconstruct the phase image, which was then converted into the grayscale image. They proposed a reconstruction technique due utilizes which the fingerprints orientation from the minutiae, and it in the matching stage for the improvement of the systems performance. To add some virtual minutiae and use Delaunay triangulation.

6. E. Liu, H. Zhao, L. Pang, K. Cao, J. Liang, and J. Tian, Method for fingerprint orientation field reconstruction from minutia template, Electron. Let., vol. 47, no. 2, pp. 98100, Jan. 2011.

The paper proposes a Gaussian weighted method for fingerprint orientation field reconstruction from the minutia template only. In the method, prior information about ridgeflow characteristics is considered to more accurately model the ridge orientation. Experimental results show that our method can obtain an accurate orientation field in terms of the accuracy of the orientation field based fingerprint classification and the performance of the orientation descriptor based fingerprint matching.

7. J. Feng and A. K. Jain, Fingerprint reconstruction: From minutiae to phase, IEEE Trans. Pattern Anal. Mach. Intell., vol. 33, no. 2, pp. 209223, Feb. 2011.

Feng and Jain utilized the amplitude and frequency modulated (AM-FM) model to reconstruct fingerprint, where the phrase, consisting of continuous phase and spiral phase (corresponding to minutiae), completely determines the ridge structure and minutiae. Continuous phase reconstruction is therefore a critical step in the AM-FM model based fingerprint reconstruction. The continuous phase was obtained by a piecewise planar model. However, the piecewise planar model introduced many spurious minutiae and resulted in visible blocking effects during the continuation phase reconstruction. The algorithm predicts an orientation value for each block by using the nearest minutia in each of the eight sectors.

8. S. Li and A. C. Kot, An improved scheme for full fingerprint reconstruction, IEEE Trans. Inf. Forensics Security, vol. 7, no. 6, pp. 19061912, Dec. 2012.

Li and Kot reconstructed continuous phase from a binary ridge pattern generated using Gabor filtering with the reconstructed orientation field and predefined ridge frequency; the continuous phase was obtained by subtracting spiral phase from the phase of the binary ridge pattern. While this approach ensures that no spirals will appear in the continuous phase, the continuous phase after removing all spirals may be quite different from the desired one in terms of ridge flow and ridge frequency.

9. J. Feng, J. Zhou, and A. K. Jain, Orientation field estimation for latent fingerprint enhancement, IEEE Trans. Pattern Anal. Mach. Intell., vol. 54,no. 4, pp. 925940, Apr. 2013.

Feng et al. Proposed a dictionary of orientation patches to estimate the orientation field in the manually marked ROI. An essential component of this lights-out capability is to develop a fully automatic latent feature extraction module. This is highly desirable to (i) increase the throughput of latent matching systems, (ii) improves repeatability of latent feature extraction and, (iii) increase the compatibility between features extracted in the talents and features extracted in the reference prints by an AFIS. However, Cappelli algorithm was developed for plain or rolled fingerprint. The authors were the first to propose the use of a dictionary for fingerprint orientation field estimation. However, their dictionary was based on orientation patches and they ignored the ridge structure information. This is the main reason their method was not very successful for segmentation and frequency field estimation. In this section, we present the proposed ridge structure dictionary learning.

10. K. Cao, E. Liu, and A. K. Jain, Segmentation and enhancement of latent fingerprints: A coarse to fine ridge structure dictionary, IEEE Trans. Pattern Anal. Mach. Intell., vol. 36, no. 9, pp. 18471859, Sep. 2014.

According to the author Latent fingerprint matching has played a critical role in identifying suspects and criminals. The author compared to rolled and plain fingerprint matching, latent identification accuracy is significantly lower due to complex background noise, poor ride quality and overlapping structured noise in latent images. To reduce this mark-up cost and to improve the consistency in feature mark-up, fully automatic and highly accurate (lights-out capability) latent matching algorithms are needed. In this paper, a dictionary-based approach is proposed for automatic latent segmentation and enhancement towards the goal of achieving lights-out latent identification systems. The algorithm can be further improved along the following aspects: 1) a robust patch quality definition, especially for dry fingerprint images, where the ridges are broken. 2) A better definition of confidence measure for the segmentation and enhancement results. 3) Improve the computational efficiency of the algorithm. The proposed algorithm outperforms the state-of-the art segmentation and enhancement algorithms and boosts the performance of a state-of-the-art commercial latent matcher.
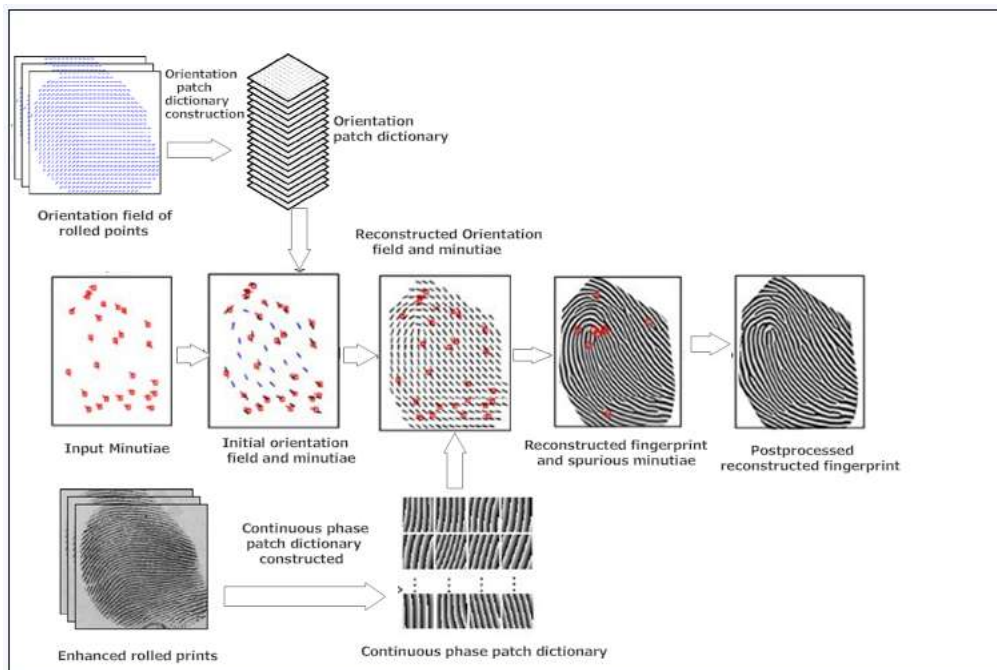
III. SYSTEM ARCHITECTURE

Fig 2: System Architecture

The system buildings and structure design above clearly makes certain definition clear, from the minutiae input (input) to the reconstructed fingerprint (output) image. The minutiae set is passed as the input to the design. For this given input the system takes into view two types of dictionaries, i.e. Orientation patch dictionaries continuous phase patch dictionaries. Orientation patch dictionaries is responsible for reconstructing the adjustment area of the fingerprint and the continuous phase patch dictionaries reconstructs the line of joining designs of the fingerprint.

These two reconstructed images are then merged together to form a reconstructed fingerprint. But this newly made fingerprint generate false minutiae. For this reason the image refinement process is done to it and we reconstruct a completely error free reconstructed image of the fingerprint from the given minutiae put.

It was thought that it is not possible to reconstruction fingerprint images from given minutiae. Yet it has been made clear that it is in fact possible to reconstruction the fingerprint image from the minutiae. The purpose of fingerprint reconstruction from a given minutiae set is to make the reconstructed fingerprint be like to the original fingerprint. To reconstruction the fingerprint image we use before knowledge. As the image of the fingerprint is to be reconstructed from the minutiae set, firstly it is important to get out the minutiae from the input fingerprint and then store the fingerprint minutiae into the knowledge. Then the minutiae put of the fingerprint is taken into account as the input to reconstruction the picture. Two cases of the dictionaries needed for the reconstruction as a before knowledge are: Orientation patch dictionary and continuous phase patch dictionary. Orientation patch dictionaries reconstructs Orientation fields, and Continuous phase patch dictionary is used to produce line of joining designs i.e. the ridge patterns. In the supporters step, the adjustment fields of the fingerprint will be made again using an Orientation patch dictionaries in company with fingerprint is reconstructed with the public organization continuous phase patch dictionaries. The reconstructed fingerprint image will still have within false minutiae. To remove this spurious minutiae some post processing is performed to the reconstructed image. These minutiae will be got moved from one position to another using the image refinement process. AM-FM design to be copied is sent in name for in the refinement way. After the completion of the image refinement process the reconstructed image will be free from spurious minutiae points which results in high accurate reconstructed fingerprint image.

3.1 Algorithm:

The aim to reconstruct a fingerprint image is to reconstruct an image from the minutiae set. A dictionary based approach is proposed in this paper. We introduce two dictionaries: 1) Orientation patch dictionary and 2) Continuous phase patch dictionary. In *n* number of minutiae each set contains the location and direction of each minutiae. For the input of fingerprint minutiae set, the orientation patch dictionary is used to reconstruct the orientation field, and continuous phase dictionary helps to reconstruct the ridge pattern. But still it introduces spurious sets, which are removed by the global AM-FM model.

1. Orientation Patch Dictionary: The orientation patch dictionary for latent enhancement , is implied as a prior concept. The Orientation patch dictionary is made up of number of orientation patches. A high Quality fingerprint image is selected for construction of orientation patches.

2. Continuous Phase Patch Dictionary: Number of Phase patches are constructed in Continuous phase patch dictionary. For a selected fingerprint the Gabor filtering is applied to enhance the fingerprint and frequency field is calculated and also orientation field are obtained. Then the orientation patches are selected and if the quality of selected patch is larger than the predefined patch in training set, then it is replaced. The similar patches forms the cluster. The minutiae points are eliminated using this method which forms continuous phase patch dictionary.

3. Orientation Field Reconstruction: The image is divided in blocks which will not overlap each other. Simply the orientation are replaced by its corresponding minutiae directions. A concept of Orientation density is introduced to select precisely representative orientation patch. The reconstructed orientation field may differ then orientation in the block of minutiae set. A Gaussian filtering method is proposed to secure the orientation around minutiae.

4. Fingerprint Reconstruction: Based on the reconstructed orientation fields the ridge frequency fields are reconstructed. It utilizes the continuous phase patch dictionary for ridge field reconstruction. Global optimization is obtained for fingerprint image. The closest sub dictionary is selected from the continuous phase patch dictionary based on similarity. The similarity is checked between the initial image and continuous phase patch. The continuous phase patch and spirals are combined and computation is performed from the minutiae in a patch for adding minutiae. The dissimilarity term is computed between initial fingerprint and reconstructed patch. The compatibility is also important to measure the compatibility between two neighboring reconstructed fingerprint patch. However, it may generate few spurious set in the reconstructed image.

5. Fingerprint image enhancement: The reconstructed image still contains spurious values. To remove the spurious set AM-FM model is proposed. AM-FM model represents the hologram image i.e. the image consisting of 2D pattern. The discontinuity is removed by adding or subtracting co-ordinate and changing the discontinuity segment. As the discontinuity segments are removed Gabor Filtering is applied to smoothen the fingerprint region.

IV. Conclusion

The goal of fingerprint reconstruction is to multiply the original fingerprint image from an input minutiae set. On that point are basically three primary reasons for studying the problem of fingerprint image reconstruction from a given minutiae set: (i) to demonstrate the demand for securing minutiae template, (ii) to improve the interoperability of fingerprint templates generated by different combinations of sensors and algorithms, (iii) to improve fingerprint synthesis. Despite a substantial advance in the performance of reconstruction algorithms over the past ten years, in that location is still a discrepancy between the reconstructed fingerprint image and original fingerprint image (from which the minutiae template was extracted) in terms of mating performance. In this report, we propose a reconstruction algorithm that uses prior knowledge of the fingerprint ridge structure to improve the reconstructed fingerprint image. The prior knowledge is interpreted in terms of two kinds of dictionaries, orientation patch and continuous phase patch dictionaries. The orientation patch dictionary is used to restore the orientation field from the given minutiae set, while the continuous phase patch dictionary is used to reconstruct the ridge pattern. Although the reconstructed fingerprints, as indicated in Fig. 13, are very close to the original fingerprints from which the minutiae were extracted in terms of orientation field, ridge frequency field and minutiae distribution, it is nevertheless hard to fool a human expert because the reconstructed fingerprints are ideal fingerprints (without any disturbance) and cause the synthetic appearance. Future work will investigate to make the reconstructed fingerprints more realistic. The suggested method for orientation field reconstruction only considers the local orientation pattern. The role of global orientation prior knowledge as well as singular points may further improve the ridge orientation reconstruction. The ridge frequency field used in this paper can be either a fixed priori or reconstructed from the ridge frequency around minutiae. Future studies will investigate frequency field reconstruction directly from the minutiae position and management.

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