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Reconstructing Minutiae and Orientation Fields Using Enhanced Feedback Paradigm

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***Abstract* - Latent fingerprints are partial impressions of the finger inadvertently left behind on the surface of objects when they are touched or handled. It is not usually visible to the naked eye but may be detected with some chemical and physical methods. In crime scenes and forensic evidence latent fingerprints play an important role. Similarly latent fingerprint matching also plays an important role in identifying suspects and criminals. In most latent fingerprint matching techniques orientation field reconstruction and alignment techniques are considered. The proposed work uses a robust reconstruction algorithm using minutiae features in enhanced feedback mechanism for automatic latent fingerprint matching to increase the authentication rate. The main contribution of this work is to reduce the spurious minutiae and improve the matching accuracy of automatic latent fingerprint matching.**

Keywords – Latent fingerprints; latent fingerprint matching; minutiae; enhanced feedback

1. INTRODUCTION

A fingerprint (Fig. 1) is an impression of the friction ridges left behind on the surface of an object when they are touched or handled. Each person has his own fingerprints with the permanent uniqueness. So fingerprints have being used for identification and forensic investigation for a long time. The ridges are the dark area of the fingerprint and the valleys are the white area that exists between the ridges. Friction ridges are created during foetal live and shape is genetically defined.Ridges remain the same all lifelong. Injuries such as superficial burns, abrasions, or cuts do not affect the underlying ridge structure and the original pattern is duplicated in any new skin that grows[5]. Ridges and valleys run in parallel; sometimes they bifurcate and sometimes they terminate.Many classifications are given to patterns that can arise in the ridges and some examples are given in the figure1.1. These points are also known as the minutiae of the fingerprint. Minutiae are also called as the discontinuities of the ridges. Minutiae include: Ridge ending/termination; Ridge bifurcation;Short ridge, or independent ridge;Island; Ridge enclosure; Spur; Crossover or bridge; Delta; andCore. Sir Francis Galton[1] first conceived the notion of uniqueness and individuality of the friction ridge patterns present on the palms of our hands and soles of our feet in the year 1892. The uniqueness of a fingerprint can be determined by the pattern of ridges and furrows as well as the minutiae points. Even identical twins having same face and genes are said to have different fingerprint.

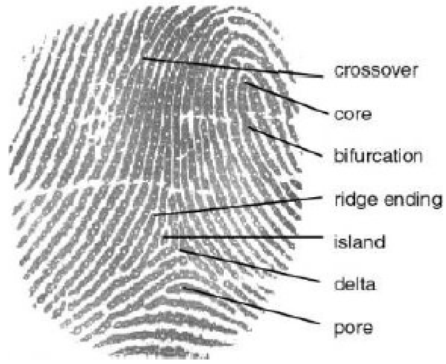

Figure 1: Fingerprint Image

Fingerprints can be broadly classified into three types (Fig. 2): (a) Rolled fingerprints which contain almost all of the ridge details and are captured by rolling a finger from “nail to nail” either on a paper or the platen of a scanner, (b) Plain/Slap fingerprints which are acquired by pressing the finger on a flat surface, and (c) Latent fingerprints which are partial impressions of the finger inadvertently left behind on the surface of objects when they are touched or handled. It is not usually visible to the naked eye but may be detected with some chemical[3] and physical methods[7][8].Latent prints, in particular, are of critical value in forensic applications because they are usually encountered at crime scenes and serve as crucial evidence in a court of law[1].

Rolled and plain impressions acquired under expert supervision[2]. They are mostly good quality fingerprints with sufficient amount of ridge patterns and clear ridge structures[6], and typically contain only minor background noise. Latents are partial images that are blurred, ugly with containing large distortion[3] and small area. Due to these characteristics, latents have significantly small number of minutiae points compared to plain and rolled fingerprints.

Fingerprint matching[3] means finding most appropriate similar fingerprint to query fingerprint. A fingerprint matching system computes a match score between two fingerprints, which should be high for fingerprints from the same finger and low for those from different fingers. Fingerprint matching has been successfully used by law enforcement for more than a century. Latent fingerprint matching means match the latent image with a set of rolled and plain prints. Latent prints are typically of poor quality[4] with complex background noise which makes feature extraction and matching of latents a significantly challenging problem.

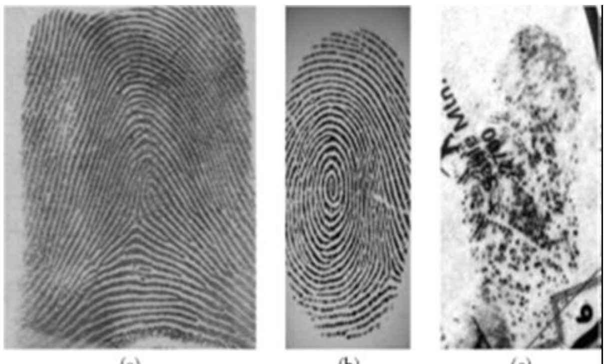

Figure 2: Three types of fingerprint images. (a) rolled, (b) plain and (c) latent fingerprints

In this paper, a robust reconstruction algorithm is proposed in enhanced feedback[1][4] mechanism to reconstruct the minutiae features from orientation field and the reconstructed latent fingerprint image ensure that the candidate list retrieved after matching with rolled and plain prints are accurate. The proposed system helps to recover from spurious minutiae produced during the refinement of latent image.This system also helps to reduce the fault percentage rate in matching.

The remaining paper is organized as follows: Section 2 discuss about the ACE-V[6][9] process for manual latent fingerprint matching and the limitations of human experts in latent fingerprint analysis. This section also focuses on the common concept of automatic latent fingerprint matching. In Section 3, the proposed system has been described which includes system architecture and reconstruction algorithm. Section 4 summarizes the contents of this paper.

2. RELATED WORKS

There exist a number of techniques to match the latent fingerprint with rolled and plain fingerprints by manually and automatically. Latent prints are typically of poor quality[4] with complex background noise which makes feature extraction and matching of latents a significantly challenging problem.

In manual matching of latent prints, latent fingerprint examiners usually follow the Analysis, Comparison, Evaluation and Verification (ACE-V) methodology [6]. This basically, is a four step process:-

Analysis: The preliminary step involves analyzing the latent image to ascertain if the latent is of sufficient value for processing and manually marking features such as minutiae, orientation field and ridge frequency. This is usually done by observing the latent image in isolation.

Comparison: This consists of comparing the latent image to the rolled and plain image in terms of their features, and assessing the degree of similarity/dissimilarity between latent and rolled and plain.

Evaluation: The latent examiner determines the strength of the evidence between the latent and rolled and plain based on the assessed degree of similarity/dissimilarity between the latent and rolled and plain in the comparison step.

Verification: A second latent examiner independently evaluates the latent- rolled and plain pair to validate the results of the first latent examiner.

The ACE-V procedure is a tedious and time consuming process for the latent examiner as it may involve a large number of fingerprint comparisons between different rolled and plain fingerprint pairs. This results in one of the following five outcomes: as suggested in [1] [4]

1) The latent examiner correctly matches the latent fingerprint to its true mated rolled and plain from the candidate list.
2) The examiner erroneously matches the latent fingerprint to rolled and plain fingerprint from the candidate list (which is not the true mate).
3) The examiner correctly excludes anrolled and plain fingerprint from the candidate list (which is not the true mate) to be the possible mate of the latent fingerprint.
4) The examiner erroneously excludes the true mated rolled and plain fingerprint of the latent fingerprint from the candidate list to be the possible mate of the latent.
5) The examiner deems the matching result to be inconclusive because he is unable to find any candidate rolled and plain that is sufficiently similar to the latent print. Note that while outcome 2) is an erroneous match and outcome 4) an erroneous exclusion, outcome 5) is a reject in the sense that the true mate does not exist in the background database[1].

In automatic latent fingerprint matching, a latent probe image is collected and pre-processes that image using both segmentation and enhancement. Next step is the feature extraction after pre-processing. And finally match the latent to the rolled and plain background database which is already have extracted features from rolled and plains and generate a match score. This approach is called bottom–up data approach[1][4]. The bottom-up approach basically builds a system from several sub-systems or components. There is a sequential "bottom-up" data flow from pre-processing and feature extraction to matching and match score computation. However, the basic assumption in the bottom-up systems is that if all the individual sub-systems are functioning well, the system as a whole would function well too.

3. PROPOSED SYSTEM

The idea of enhanced feedback in latent fingerprint matching is to incorporate a data flow between the matching module and feature extraction module and reconstructs the orientation field and minutiae. The systemic ways to use information in rolled and plain prints for refining latent features, e.g., ridge orientation and frequency, and use them to develop a feedback[1][4] paradigm and reconstructs the fingerprint image using minutiae features which could be integrated into a latent matcher to improve its matching accuracy. This enhanced

feedback is particularly useful because features extracted from the latent are often unreliable due to their poor quality. Matching latent images based on the initially extracted set of features without any prior information[4] is prone to error. Additional data flow provided by the enhanced feedback allows the matching system to use the hypothesized rolled and plain mates to refine initially extracted features from the latent and reconstructs the minutiae features improve the matching accuracy.
The advantages of this mechanism over existing mechanisms to latent fingerprint reconstruction are: A complete latent fingerprint having minutiae features can be reconstructed by ridge orientation field and the reconstructed fingerprint contains very few spurious minutiae.

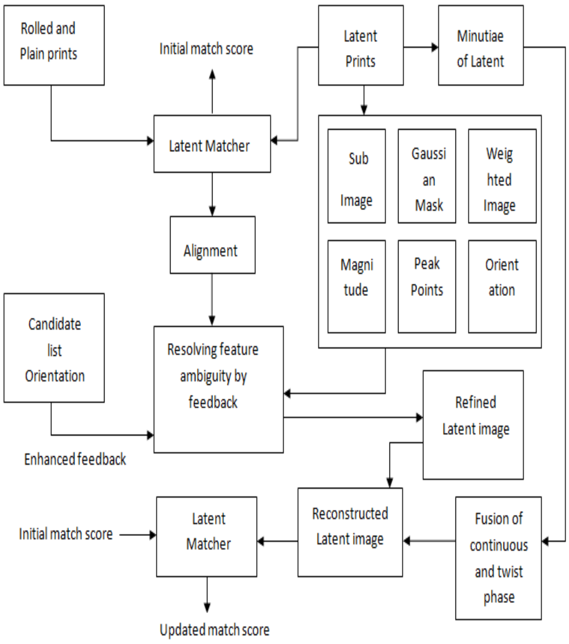

Figure 3: System Architectural Diagram Representation

The bottom–up mode[1] latent matcher is used in initial matching and alignment[2]. The manually marked minutiae in the latent image and automatically extracted minutiae from the rolled and plain image are fed as input to the latent matcher to obtain the initial match score. The latent is then aligned to the rolled and plain images using the scaling, rotation and translation parameters. Descriptor Based Hough Transform[2] alignment algorithm is used to align fingerprints.Using the bottom–up matcher generate an initial match score between the latent and rolled and plain, then a candidate list (top k candidates) is generated based on the initial match score.
Two different types of local features are computed for the rolled and plain image, namely ridge orientation and ridge frequency. Ridge orientation[1][4] represents the local direction of the ridge-valley structure. Ridge frequency[1][4] is the reciprocal of the ridge distance in the direction perpendicular to local ridge orientation. Given an rolled and plain image, its ridge skeleton image is first extracted in the dictionary construction phase. The skeleton image[4] is then divided into 16 by 16 pixel blocks. Ridge orientation and ridge frequency are then computed for each block in the skeleton image.
In latent image, the ridge orientation and frequency features are very difficult to extract because of the presence of structured noise in the background. So Fourier domain is used to extract the latent features. In Fourier domain, the latent image is divided into blocks. Considering locally all the extracted blocks, a sub-image can be extracted and smoothened it using the Gaussian mask and then get the weighted image. Then the magnitude spectrum is obtained and takes peak points of the highest magnitude values. Next find orientation levels corresponding to that peak points. For extracting minutiae features from latent the image should be enhanced. This is mainly done to improve the image quality and to improve the matching accuracy. The orientation at block *(x,y)* is computed as:

$$O(x,y) = \frac{1}{2}\arctan\left(\frac{u}{v}\right) \quad (1)$$

For refining latent features enhanced feedback[1][4] mechanism is used. The enhanced feedback is obtained by the orientation differences of each overlapping block between the rolled and plain and latent prints. The extracted features within each block are then refined based on the feedback from features extracted in the corresponding rolled and plain block. Enhanced feedback consists of orientation differences between each extracted latent ridge orientation closest to the rolled and plain orientation and latent ridge frequency corresponding to the selected orientation.
From the reconstructed orientation field singular points (core and delta) which are detected using the Poincare index method[11]. The gradient of the compound phase *Gcp(x,y)* at block *(x,y)* can be computed as:

$$Gcp(x,y)= Gc(x,y)- Gt(x,y) \qquad (2)$$

where*Gc(x,y)* and*Gt(x,y)* represent the gradients of the continuous phase and of the twist phase respectively. *Gs(x,y)* can be computed from the spiral phase[14].
The robust reconstruction algorithm of minutiae features to estimate phase offset *P(x,y)* and reconstructs the continuous phase by following method. Starting with a queue containing the top left-most block (assume *P(x,y)* to be 0), in each iteration a block is obtained from the queue and each of its connected neighbours is checked to see if it has been reconstructed (*P(x,y)*has been estimated). If one of the connected neighbouring blocks has not been reconstructed, that block's phase offset is estimated and put in the queue. This method is continued until the queue becomes null (i.e. for all the blocks phase has been reconstructed). A subsidiary image is used to record the reconstructed blocks. After the reconstruction of continuous phase, the reconstructed fingerprint can be obtained by fusing the continuous phase and twist phase. The reconstructed latent fingerprint is overlay on the skeleton image of the each top k candidate list. The reconstructed fingerprint image matches with the accurate fingerprint images. The reconstructed latent fingerprint does not contain a few spurious minutiae, especially in the region of singularity.

After reconstruction of latent image, the similarity score computation between latent and rolled and plain for improving the matching accuracy. The functions to compute the similarity between the rolled and plain features and the refined latent features after feedback should result in improved similarity between mated latent rolled and plain pairs. The candidate list is resorted based on the updated match scores between the latent and the rolled and plain.

4. CONCLUSION

The latents are partial impressions of the finger, and thus have relatively smaller area containing friction ridge patterns. They generally exhibit poor quality in terms of ridge clarity due to the presence of complex background noise and have large non-linear distortions due to variations in the finger pressure. The idea of enhanced feedback in latent fingerprint matching is to incorporate a data flow between the matching module and feature extraction module and reconstructs the orientation field and minutiae. A reconstructed latent image is obtained by reconstructing the orientation field by fusing the continuous and twist phase. The reconstructed latent image helps to improve the matching accuracy and reduce the fault percentage rate.

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