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A Survey on Fingerprint Enhancement Techniques using Filtering Approach

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***Abstract* — Automated personal authentication has become increasingly important in modern information driven society and in this regard fingerprint-based personal identification is considered to be the most effective tool. A fingerprint image is composed of a foreground and background areas. The foreground area is collected of ridges and valleys, whereas the background area is the region that surrounds the fingertip and is mainly noisy. Fingerprint recognition systems amount to extracting minutiae as well as identifying ridge and valley regions. This paper proposes a matching process to increased accuracy in fingerprint enhancement. The proposed method which consists of input image, database fingerprint images, preprocessing, matching algorithm, classification and output images. The pre-processing step consists of four stages: image segmentation, local normalization, local orientation estimation, and broken ridge filling. Matching Algorithm is used for computing minutiae distances between two imprints of the same finger. Results show that proposed method has verified significant quality improvement over the existing published techniques.**

***Keywords* — Automatic Fingerprint identification system (AFIS), Fingerprint enhancement, Fingerprint recognition, Fingerprint Segmentation, matching.**

I. Introduction

Fingerprint-based recognition systems have been very significant in security-related applications. Although, fingerprint-based authentication is a mature field of research, yet because of stringent requirements of speed and reliability, especially for large-scale applications, it attracts more interest of researchers than any other biometric. A fingerprint image comprises of oriented ridge–valley combinations, and possesses high degree of uniqueness because of feature points commonly known as minutiae. Various techniques are proposed for automatic extraction of minutiae from a fingerprint image. These minutiae detection methods are generally straightforward and accurate, but in the regions of low contrast, scars or broken ridges, these methods fail to extract minutiae features accurately [1]. Gabor filters (GFs) and Gabor wavelets, are applied for a multitude of purposes in many areas of image processing and pattern recognition. Mainly, the intentions for using GF and log-GF can be grouped into two categories; first, the GF aim at enhancing images and the second common goal is to extract Gabor features obtained from responses of filter banks [2].

Biometric recognition refers to the use of distinctive anatomical (e.g. fingerprints, face, iris) and behavioral (e.g. speech) characteristics for automatic individual recognition. In practice, fingerprint recognition schemes are widely spread due to its uniqueness to individuals, invariant to age, and convenient in practice. Automatic Fingerprint Identification System (AFIS) consists of several steps, such as fingerprint segmentation, enhancement, feature or minutiae extraction and matching. Fingerprint matching is roughly classified into two classes: minutiae-based and image-based methods, which primarily use minutiae information or a reference point along with a number of ridge attributes for recognition [3]. There are no longitudinal studies of growth-related effects on children's or juveniles' fingerprints. As a finger grows, so does its skin expand, effecting the relative position of the fingerprint's feature quantitatively? Hence, finger growth has also profound practical implications for law enforcement agencies: if the person being checked out has been registered as a juvenile, recovering a matching fingerprint in their databases poses serious difficulties to currently deployed automated fingerprint identification systems (AFIS) [4]. An important step in automated fingerprint identification systems (AFIS) is the process of fingerprint segmentation. Based on the collection procedure, fingerprint images can generally be divided into three groups, namely, rolled, plain and latent. Rolled and plain prints are obtained in an attended mode so that they are usually of good visual quality and contain sufficient information for reliable matching. On the other hand, latent prints are usually collected from crime scenes and often mixed with other components such as structured noise or other fingerprints. Existing fingerprint identification algorithms fail to work properly on latent fingerprint images, while they are generally applicable under the assumption that the image is already properly segmented and there is no overlap between the target fingerprint and other components [5]. In the future ubiquitous society, e-commerce will expand and the protection of personal information will become more important. In such a society, user authentification will be needed in various situations. Biometrics, which uses the physical features of the human body, makes user identification convenient and secures [6].

II. Background

The robustness of the minutiae extraction can be improved by incorporating an enhancement stage prior to the minutiae extraction stage. The enhancement stage is usually designed to achieve best results by removing degradations in fingerprint images. Enhancement techniques can improve the overall contrast and remove noise from fingerprint images. However, these techniques cannot cater for the damages caused by scars and broken ridges, as they do not exploit the local information regarding ridge direction and orientation. In order to enhance fingerprint images degraded with scars and broken ridges, the directional contextual filtering techniques have been proven to be most effective [1]. The goal of Gabor filter (GF) is to extract Gabor features obtained from responses of filter banks and to enhance the images. Typical fields of application include: Texture, Medical and biological applications, Optical character recognition, Object recognition, Biometrics, and Fingerprint recognition. All aforementioned applications have one thing in common; they use straight GFs, i.e., the x- and y-axes of the window underlying the GF are straight lines that are orthogonal [2].

Poor quality fingerprint images can affect both classes of recognition algorithms, as it can modify the information of the minutiae points and reference points. Therefore, it's necessary to enhance the image quality prior to identification. In literature various fingerprint enhancement techniques have been proposed. In a directional Fourier domain filtering for fingerprint enhancement relies on filtering the fingerprint image by a precomputed filter banks oriented in eight different directions, (i.e. every 22.5o). Only the one that is close to the pixel orientation is considered. However, as this method assumes the ridge frequency is constant all over the fingerprint and does not utilize its full contextual information, the enhancement effect is little [3]. Identifying humans by their fingerprints has been a success story since its early origins in ancient China. Nonetheless, the scientific foundation of fingerprint recognition still requires strengthening as demanded by the United States National Research Council in 2009. The situation is even worse when the fingerprints of juveniles are considered, which, in the same year, led the European Parliament to exempt children under 12 from having their fingerprints taken for visa purposes, so asking for a study to analyze the effects of growth on juveniles' fingerprints. The first report shall also address the issue of the sufficient reliability for identification and verification purposes of fingerprints of children under the age of 12 and, in particular, how fingerprints change with age, depend on the results of a study carried out under the responsibility of the Commission [4].

Fingerprint segmentation refers to the process of decomposing a fingerprint image into two disjoint regions: foreground and background. The foreground, also named the region of interest (ROI), consists of the desired fingerprints while the background contains noisy and irrelevant contents that will be discarded in the following processing steps. Accurate fingerprint segmentation is dangerous as it affects the accurate extraction of minutiae and singular points, which are important features for fingerprint matching. When feature extraction algorithms are applied to a fingerprint image without segmentation, lots of fake features may be extracted due to the presence of noisy background, and eventually leading to matching errors in the later stage. So, the goal of fingerprint segmentation is to discard the background, decreases the number of fake features, and thus improves matching accuracy [5].

III. PREVIOUS WORK DONE

Ghafoor et al. [1] projected a novel fingerprint enhancement approach based on local adaptive contextual filtering. The proposed enhancement system is 2-fold as it involves processing both in frequency and spatial domain. The fingerprint image is first cleaned in frequency domain and then local directional filtering in spatial domain is applied to find enhanced fingerprint. Gottschlich et al. [2] projected curved GFs that locally adapt their shape to the direction of flow. These curved GFs permit the choice of filter parameters that raise the smoothing power without creating artifacts in the enhanced image. Curved GFs are applied to the curved ridge and valley structures of low-quality fingerprint images. First, author merge two orientation- field estimation methods in order to obtain a more robust estimation for very noisy images. Next, curved regions are created by following the respective local orientation. Then, these curved regions are used for estimating the local ridge frequency. Finally, curved GFs are clear based on curved regions, and they apply the previously projected orientations and ridge frequencies for the enhancement of low-quality fingerprint images.

Fahmy et al. [3] projected enhancement method. It makes use of a recently developed fingerprint segmentation system, in order to separate the fingerprint foreground and background areas, and after speeds up the enhancement process. Next, a novel interpolation-based system is proposed to join broken ridges. Finally, in order to calculate approximately the ridge-valley spatial spacing, an accurate Radon-based system is projected. This accurate spacing is necessary for the design of 2-D directional Gabor filter that removes artifacts, and isolated black regions. Gottschlich et al. [4] studied the effect of growth on the fingerprints of adolescents, depend on which we suggest a simple scheme to adjust for growth when trying to recover a juvenile's fingerprint in a database years later. Depend on longitudinal data sets in juveniles' criminal records, shows that growth essentially leads to an isotropic rescaling, so that it can use the strong correlation between growth in stature and limbs to model the growth of fingerprints proportional to stature growth as documented in growth charts. The proposed rescaling leads to a 72%reduction of the distances between corresponding minutiae for the data set analyzed.

Zhang et al. [5] projected image decomposition design, called the adaptive directional total variation (ADTV) model, to get effective segmentation and enhancement for latent fingerprint images in this work. The projected model is motivated by the classical total variation models, but it distinguishes itself by integrating two unique features of fingerprints; i.e., scale and orientation. The projected ADTV model decomposes a latent fingerprint image into two layers: cartoon and texture. The cartoon layer includes unwanted components (e.g., structured noise) while the texture layer mainly consists of the latent fingerprint. This cartoon-texture decomposition make possible the process of segmentation, as the region of interest can be simply detected from the texture layer using traditional segmentation methods. Shimamura et al. [6] projected a new capacitive-sensing circuit technique that improves the quality of images captured with capacitive fingerprint sensor LSIs. The quality of the captured image based on the surface condition of the finger. While the finger is dry, the electrical resistance of the finger surface is tall. The finger surface resistance brings a voltage drop in the electrical potential of the finger surface (which should be grounded), which guides to poor image quality. To capture clear images when the finger is dry, the circuit method improves the image quality using the series resistance caused at the finger surface.

IV. EXISTING METHODOLOGY

Fingerprint enhancement schemes based on contextual filtering are generally carried out either in frequency domain or in spatial domain. However, in this study a novel method is employed to join the advantages of both frequency and spatial domains for enhancing fingerprint images. All unwanted frequencies are filtered out in frequency domain and directional smoothing is carried out in spatial domain [1]. In Fingerprint Image Enhancement Algorithms and Performance Evaluation, an RF estimation method was planned. Failures to estimate an RF, e.g., caused due to the presence of noise, curvature, or minutiae are handled by interpolation, and outliers are removed by low-pass filtering. This method works well for good and medium quality prints, but it encounters serious difficulties obtaining a useful estimation when dealing with low-quality prints. Here, an RF estimation method following the same basic idea, i.e., to take an estimation from the gray-level profile, but which bears the following improvements in comparison with Fingerprint Image Enhancement Algorithms and Performance Evaluation.

1) The profile is derived from a curved region that is different in shape and size from the oriented window of the x-signature method.
2) We introduce an information criterion (IC) for the reliability of estimation.
3) Depending on the IC, the gray-level profile is smoothed with a Gaussian kernel.
4) Both minima and maxima are taken into account.
5) The inverse median is applied for the RF estimate [2].

Several approaches have been described to perform filtering process. However, the quality of the enhanced fingerprints specially the low quality ones, is not satisfactory. In this paper, a directional Gabor filter is proposed that makes use of the ridge frequency estimated using Radon transform. Radon transform is a continuous transform that provide a 1-D projection of a 2-D image along a specific direction θ [3]. A method for adjusting prints before matching which can easily be integrated into an existing AFIS. The method is based on median curves of stature growth charts and neither model fitting nor training is required. The soundness and effectiveness of this approach is validated by conducting several tests (i.e. verification test and identification test) [4]. The proposed Adaptive Directional Total Variation (ADTV) model can be used to effectively separate the latent fingerprint from structured noise, thus facilitating the process of fingerprint segmentation. Here first introducing the TV-L1 model, these serves as the basis for the proposed ADTV model, and then explain its capability in multiscale feature selection. Finally, planned the ADTV model [5].

V. Analysis And Discussion

While current automated fingerprint identification systems have achieved high accuracy in matching rolled/plain prints, latent fingerprint matching remains to be a challenging problem and require much human intervention. The objective of this work is to achieve accurate latent segmentation, which is an essential step towards automatic latent identification. Existing fingerprint segmentation algorithms perform poorly on latent fingerprints, as they are mostly based on assumptions that are only applicable for rolled/plain fingerprints.

Modeling the Growth of Fingerprints Improves Matching for Adolescents paper presents the first documented study on the growth of juvenile fingerprints. While some vendors of AFIS software and producers of live-scanners for babies and children may have developed in-house solutions to cope with growth effects, an independent review of these methods and their performances would be desirable, e.g., in a test conducted by NIST, analogous to the "Evaluation of Latent Fingerprint Technologies" (ELFT). This is not only motivating from a scientist's point of view, but also very important for politics and society at large: if, e.g., fingerprints of children were included in visa applications or passports and if then a considerable amount of matching errors occurred, this could undermine the trust of society in fingerprint recognition and biometrics in general. Therefore, error rates should be established in adequate tests, considering live-scan prints acquired at different resolutions, e.g., 500 and 1000 DPI, by different sensor types and models and matching prints acquired at different ages.

VI. Proposed Methodology

Following figure shows that basic steps of proposed method which consists of input image, database fingerprint images, preprocessing, matching algorithm, classification and output images.

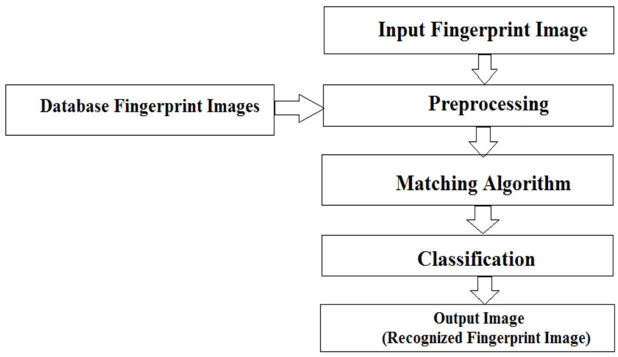

Fig.1. Proposed Method for Matching Process to Increased Accuracy in Fingerprint Enhancement

A) The preprocessing step: In this step, the fingerprint image is prepared for subsequent enhancement. In order to speed up the enhancement process, a fingerprint segmentation step is carried out. Moreover, a novel technique for joining broken ridges, as well as removal of small artifacts, is described. The pre-processing step consists of four stages: image segmentation, local normalization, local orientation estimation, and broken ridge filling. It is summarized as follows:

1) Image Segmentation: This step is responsible for separating the fingerprint area (foreground) from the image background, (area surrounding the fingertip region and is mainly noisy). Several methods have been proposed for segmentation. A simple and efficient technique is proposed. It is based on applying some morphological opening and closing operation on the range image. The range image is constructed by finding the range of the fingerprint grayscale image.

2) Local Normalization: In order to reduce the local variations along ridges and valleys, the fingerprint image within the segmentation contour, is normalized to a pre-specified mean and variance.

3) Local Orientation Estimation: In this step, the dominant directions of the ridges in the normalized fingerprint image are obtained. The least mean square algorithm is used.
4) Broken Ridge Filling: Due to the fingertip scars or noise, fingerprint images may contain broken ridges. The proposed technique eliminates the existence of these broken ridges as well as small artifacts. It based on using interpolation to join broken ridges.

B) Matching Algorithm: For computing minutiae distances between two imprints of the same finger, the second fingerprint image was aligned to the first one using that rotation and translation which minimized the SMSD between the images' corresponding POI (Points of Interest). For each marked finger, computed the SMSD of the imprints at first and last CO (rolled), reporting the SMSDs' median as a measure of typical mismatch. This was repeated with the imprint at first CO (check-out) rescaled according to the MGCS; considering the ratio of the SMSD with and without rescaling for each person's marked finger gave the relative improvement per finger gained by rescaling. Comparing the plain control imprint to the rolled imprint, both at last CO (Check_Out), obtained a measure of mismatch at the same time-point, i.e., excluding any growth effects.

C) Classification: Since fingerprint matching algorithms are typically based on the distance of matched POIs, expect similar improvements in matchers' performance, too. To make sure that the results do not depend on the particular matching algorithm used. To assess the practical relevance of the rescaling, determined the false rejection and false acceptance rates (FRR and FAR, respectively) in verification tests using different matching algorithms; in this scenario, the matcher must decide whether a query fingerprint belongs to the same person who registered previously to the database. As FAR and FRR are functionally related via a threshold parameter, measured verification performance in terms of equal error rates.

VII. Possible Outcome And Results

The previous steps are applied to enhance some low quality fingerprint images. When matches the enhanced fingerprint images using the proposed method, with those obtained using the Hong technique, the STFT technique, and the Yang technique. The enhancing capabilities of the proposed method are clear. This upgraded performance is also qualitatively tested by computing the average of the incline of the enhanced images. As the original clean fingerprint is unidentified, it is proposed to calculate the average of the incline of the enhanced fingerprint. Obviously, as the quality of the enhanced fingerprint increases, the ridges are well defined and subsequently the norms of the fingerprint incline increases.

Conclusion

This paper presents a new simple method for enhancing low quality fingerprint images. This step is key for the subsequent minutiae extraction and automatic fingerprint identification. These developments allow us to recover the performance of the directional Gabor filtering technique used in the final enhancement stage. Results have tested the significant improvements achieved, when applying this technique to low quality fingerprints, compared with other methods.

References

[1] Mubeen Ghafoor, Imtiaz A. Taj, Waqas Ahmad, Noman M. Jafri, "Efficient 2-fold contextual filtering approach for fingerprint enhancement" IET Image Process, VOL. 8, NO. 7, 2014
[2] Carsten Gottschlich, "Curved-Region-Based Ridge Frequency Estimation and Curved Gabor Filters for Fingerprint Image Enhancement" IEEE TRANSACTIONS ON IMAGE PROCESSING, VOL. 21, NO. 4, APRIL 2012
[3] M. F. Fahmy and M. A. Thabet, "A Novel Scheme for Fingerprint Enhancement", IEEE, 978-1-4799-3821-6/14, 2014
[4] Carsten Gottschlich, Thomas Hotz, Robert Lorenz, Stefanie Bernhardt, Michael Hantschel, and Axel Munk, "Modeling the Growth of Fingerprints Improves Matching for Adolescents" IEEE TRANSACTIONS ON INFORMATION FORENSICS AND SECURITY, VOL. 6, NO. 3, SEPTEMBER 2011
[5] Jiangyang Zhang, Rongjie Lai, and C.-C. Jay Kuo, "Adaptive Directional Total-Variation Model for Latent Fingerprint Segmentation" IEEE TRANSACTIONS ON INFORMATION FORENSICS AND SECURITY, VOL. 8, NO. 8, AUGUST 2013
[6] Toshishige Shimamura, Hiroki Morimura, Satoshi Shigematsu, Mamoru Nakanishi, and Katsuyuki Machida, "Capacitive-Sensing Circuit Technique for Image Quality Improvement on Fingerprint Sensor LSIs" IEEE JOURNAL OF SOLID-STATE CIRCUITS, VOL. 45, NO. 5, MAY 2010

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