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Adaptive Fingerprint Image Enhancement with Minutiae Extraction

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Abstract:
Fingerprint image enhancement is the basic and most required component of biometric verification system. This method proposes a fingerprint image enhancement and template based minutiae extraction techniques. For better enhancement the preprocessing stage includes global and local analysis. In the preprocessing and local analysis blocks, a nonlinear dynamic range adjustment method is used. In the global analysis and matched filtering blocks, different forms of order statistical filters are applied. The input low quality fingerprint image should be enhanced and segmented in to a binarized mode. Contrast level should be enhanced to provide better visual enhancement using SMQT method. Fingerprint images are rarely of perfect quality. They may be degraded and corrupted due to variations in skin and impression conditions. Thus image enhancement techniques are employed prior to minutiae extraction to obtain a more reliable of minutiae locations. Extracting minutiae from fingerprint is one of the most important steps in automatic fingerprint identification and classification. Minutiae are local discontinuities in the fingerprint pattern, mainly ridge ending and bifurcation. A novel approach for extracting of minutiae is attempted through a fixed size template matching process. It is helpful to increase the verification accuracy on automatic fingerprint identification system.
Keywords— Minutiae, biometric, bifurcation, ridge end, template matching.

I. INTRODUCTION

Finger print images are direction oriented patterns formed by ridges and valleys. Research has been conducted the last 50 years to develop automatic finger print identification system. It is virtually impossible that two people have the same finger print. In recent years finger prints are most widely used for personal identification. High accuracy AFIS needs a better image enhancement system in particular with low quality fingers. It proposes a method to improve the finger print based on SMQT method [2] and extracting the minutiae using template based minutiae extraction algorithm. It uses the technique such as global and local analysis, SMQT transforms and binary mask based segmentation, crossing number algorithm and template based minutiae extraction.

The fingerprint of an individual is unique and remains unchanged over a lifetime. A fingerprint is formed from an impression of the pattern of ridges on a finger. A ridge is defined as a single curved segment, and a valley is the region between two adjacent ridges. The minutiae, which are the local discontinuities in the ridge flow pattern, provide the features that are used for identification. Such as the type, orientation, and location of minutiae are taken into account when performing minutiae extraction.

An adaptive fingerprint enhancement method that is based on contextual filtering is more efficient. The term adaptive implies that parameters of the method are automatically adjusted based on the input fingerprint image However, fingerprint matching, especially when the fingerprint images have low quality or when the matching is performed. The main problem in automatic fingerprint identification is to acquire matching reliable features from fingerprint images with poor quality. Contextual filtering is a popular technique for fingerprint enhancement [1], where topological filter features are aligned with the local orientation and frequency of the ridges in the fingerprint image. The first method [2] utilizing contextual filters to enhance fingerprint images performed both the filter design and the filtering in the spatial domain. The method used a main filter having a horizontally directed pattern designed based on four manually identified parameters for each

fingerprint image. Additional directions were created by rotating the main horizontal filter while the filter size remained constant

Automatic fingerprint identification is found [11] to be a reliable biometric method used in several applications. Fingerprints are imparts formed by friction ridges of skin in fingers and thumbs. Minutiae are local discontinuities in the fingerprint pattern. Most automatic systems for fingerprint comparison are based on minutiae matching. The four classes of minutiae classification proposed by ANSI are: ridge endings, bifurcations, trifurcation and undetermined. Most automatic systems are based on a two class minutiae classification: ridge ending and bifurcation. A ridge ending is defined as the point Where a ridge ends abruptly. A bifurcation is defined as the point where a ridge forks or diverges into branch ridges.

The most commonly employed method [6] of minutiae extraction is the Crossing Number (CN). This method involves the use of the skeleton image where the ridge flow pattern is eight connected. The minutiae are extracted by scanning the local neighborhood of each ridge pixel in the image using a 3×3 window. The CN value is then computed, which is defined as half the sum of the differences between pairs of adjacent pixels in the eight-neighborhood. Using the properties of the CN, the ridge pixel can then be classified as a ridge ending, bifurcation or non-minutiae point. For example, a ridge pixel with a CN of one corresponds to a ridge ending, and a CN of three corresponds to a bifurcation.

Template matching process presented in logical templates at selected potential locations to detect the presence of minutiae in binary thinned image. The template matching was adapted to local ridge orientation and frequency. Here the assumptions in using templates were a) ridge width is constant in a fingerprint image; b) minutiae are not located in an area where the local orientation changes rapidly. However, in reality, ridge width is not always constant, and local orientation changes rapidly in certain areas, such as around the delta and core points.

II. RELATED WORKS

Adaptive fingerprint binarization [5] by frequency domain analysis approach for fingerprint enhancement by using directional filters and binarization is used [5]. A straightforward method for automatically tuning the size of local area is obtained by analyzing entire fingerprint image in the frequency domain. Hence, the algorithm will adjust adaptively to the local area of the fingerprint image, independent on the characteristics of the fingerprint sensor or the physical appearance of the fingerprints. Frequency analysis is carried out in the local areas to design directional filters.

Fingertip epidermis depicted [12] on smooth surfaces results in line patterns denoted as fingerprints. The raw fingerprints are usually processed to compensate for factors such as skin condition and sensor noise. Many fingerprint recognition systems use enhancement and separation of fingerprints in a pre-processing step denoted binarization. Binarization category widely used in many algorithms is denoted contextual filtering. The basic concept of the contextual filtering is to design directional filters with their shape aligned to the ridge orientation in each local area of the fingerprint. Where a filter mask [12] with horizontal direction is designed based on four parameters that are manually identified from each fingerprint.

Fingerprint enhancement by directional Fourier filtering method of enhancing fingerprint images is described [4], based upon no stationary directional Fourier domain filtering. Fingerprints are first smoothed using a directional filter whose orientation is everywhere matched to the local ridge orientation. The fingerprint is first enhanced to remove noise and any irrelevant information. The enhanced image is then encoded into a form suitable for comparison with the records held in the AFIS database. The enhancement stage [4] provides the only information available to the next stages. Consequently the performance of an entire AFIS depends critically upon the quality of enhancement. The encoding stage of the AFIS consists of two phases. (i) Minutiae detection and (ii) Minutiae reduction. The quality of this fingerprint enhancement technique should therefore be judged in terms of the suitability of the enhanced prints for the specific application of personal identification using an AFIS.

III. PROPOSED SCHEME

The proposed systems have two techniques, (i) Fingerprint image enhancement and (ii) Template based minutiae extraction. A spatial sinusoidal signal and its corresponding magnitude spectrum are illustrated together with a local fingerprint image patch and its corresponding magnitude spectrum.

1. Local fingerprint image patches are spatially and spectrally similar to a sinusoidal signal, where the dominant peaks in the magnitude spectrums of the two signals are co-located.
2. The location of the dominant peak in the magnitude spectrum of a local image area carries information about the local orientation and frequency of the fingerprint pattern.
3. The magnitude of the dominant spectral peak acts as an indicator of the quality of the fingerprint in that particular local area.

First, an innovative non-linear preprocessing block adjusts the dynamic range of the image. Second, a novel update to the previously derived global fingerprint analysis is conducted to aid the fundamental spatial frequency estimation of the fingerprint image, and where data-outlier suppression further improves the frequency estimation performance for noisy images.

Third, based on the estimated fundamental frequency from the global analysis, a local adaptive analysis adjusts the fundamental frequency to match the local image area. The local analysis proposes the use of a local dynamic range adjustment method to further improve spectral features estimation. Fourth, the matched filtering is based on the spectral features estimated in the local analysis, where an additional order-statistical filtering of the spectral features is introduced to increase the method's resilience towards noise. Finally, image segmentation separates fingerprint data from the background [1].

The proposed system has six processing blocks. (i) SMQT based enhancement. (ii) Global analysis. (iii) Local analysis. (iv) Matching and segmentation. (v) Bifurcation and ridge end template generation. (vi) Crossing number based bifurcation and ridge end detection.

In fingerprint image enhancement the preprocessing stage increases the reliability of the image. The global analysis is the process of the whole fingerprint image. Local analysis is dividing the fingerprint images into the blocks. Then matching and segment the fingerprint image and get the enhanced fingerprint image. Minutiae extraction is the process of finding the specific point in the fingerprint.

A. SMQT Based Enhancement

Successive Mean Quantization Transform [2] (SMQT) is used as a dynamic range adjustment for fingerprint. SMQT can be viewed as a binary tree build of a simple mean quantization unit. SMQT yield a balanced fingerprint image enhancement. The transform is described and applied in speech processing and image processing. In image processing the transform is applied in automatic image enhancement and dynamic range compression.
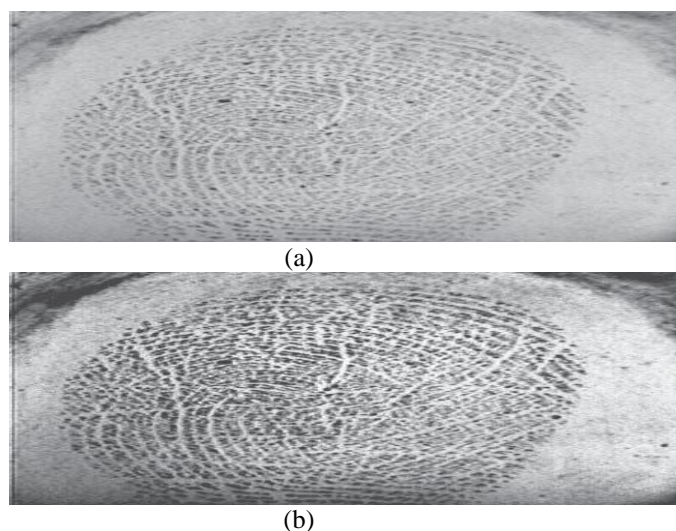

(a)

(b)

Fig 1. (a) Fingerprint image and (b) corresponding SMQT enhanced image.

Large regional contrast variation is quite typical for low quality fingerprint images which require a high dynamic range usage in order to not embed fingerprint ridges in the background. Hence, the SMQT enhancement [16] is performed using eight bits so as to avoid the risk of obstructing important data in heavily noisy fingerprint images. In addition, the eight bit SMQT used in the preprocessing requires only a fractional amount of processing as opposed to other parts of the proposed Method. Optimizing the processing load on this part of the algorithm yields therefore only an insignificant reduction of processing power but increases the risk of reduced performance.

B. Global Analysis

The magnitude spectrum of a fingerprint image typically contains a circular structure around the origin. The circular structure stems from the fact that a fingerprint has nearly the same spatial frequency throughout the image but varying local orientation. The circular structure in the magnitude spectrum has been used for estimating fingerprint quality. The circular spectral structure was exploited to detect the presence of a fingerprint pattern in the image. The radially dominant component [1] in the circular structure corresponds to the fundamental frequency of the fingerprint image. This fundamental frequency is inversely proportional to a fundamental window size which is used as a base window size method.

The fundamental fingerprint frequency is estimated in the global analysis according to the following steps:

1. A new processing stage suppresses data outliers by a median filter.
2. A radial frequency histogram is computed from the magnitude spectrum of the median filtered image.
3. The fundamental frequency of the fingerprint is assumed located at the point where the radial frequency histogram attains its maximal value. The radial frequency histogram is herein proposed to be smoothed in order to reduce the impact of spurious noise.

A radial frequency histogram A(ω) is obtained by integrating the magnitude spectrum $|F(\omega,\theta)|$ along the polar angle θ, according to

$$A(\omega) = \frac{1}{2\pi} \int_0^{2\pi} |F(\omega,\theta)| d\theta \quad (1)$$

The radial frequency at the point where the radial frequency histogram attains its largest value corresponds to the fundamental frequency ω_f of the fingerprint image

$$\omega_f = \arg \max_{\omega \in [\omega_{min}, \pi]} A_s(\omega) \quad (2)$$
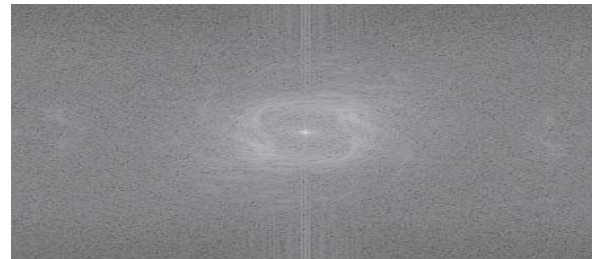
The lower search boundary is computed as

$$\omega_{min} = \frac{2.\pi.10}{\max(N_1, N_2)} \quad (3)$$

The fundamental frequency ω_f, computed in Eq. 2, is inversely proportional to a fundamental area size L_f according to

$$L_f = \frac{2\pi}{\omega_f} \quad (4)$$

(a)

(b)

Fig 2. (a) Fingerprint image and (b) corresponding magnitude spectrum.

The adaptive behavior is due to that the estimated fundamental area size acts as a base window size in all stages of the method.

Hence, no parameter tuning is required to use the proposed method for different sensors or applications.

C. Local Analysis

The purpose of the local analysis is to adaptively estimate local spectral features corresponding to fingerprint ridge frequency and orientation. Most parts of a fingerprint image containing ridges and valleys have, on a local scale, similarities to a sinusoidal signal in noise. The magnitude of the dominant spectral peak in relation to surrounding spectral peaks indicates the strength of the dominant signal. These features are utilized in the local analysis. A similar method based on local spectral analysis. The size of the local area in the local analysis is M × M, where M is an odd-valued integer computed as,

$$M=2\left\lfloor \frac{k.L_f}{2} + 1 \right\rfloor -1 \qquad (5)$$

Where the parameter k is a design parameter that controls the number of fundamental periods are enclosed by each local area. Due to the local variability of a fingerprint, for example in regions around deltas, cores and minutiae where the fingerprint ridges are curved or when the local ridge frequency deviates from the estimated fundamental frequency ω f , two additional local area sizes are introduced. A larger local area size, denoted as M+×M+, where M+ = $(1 + η)$ ·M, and a smaller local area size, denoted as M−×M−, where M− = $(1 − η)$ ·M, are considered here. Note that both M+ and M− are forced to be odd valued integers. The design parameter η ∈ [0, 1] defines the change, growth and shrinkage, of the larger and smaller area sizes in relation to the nominal local area size.

Each local area is centered around the point $(n1,n2)$ in the preprocessed image $X(n1,n2)$ according to

$$J_{n1,n2}(m1,m2) = X(n1 + m1, n2 + m2) \qquad (6)$$

Where m1= $\left(-\frac{M-1}{2} \cdots \frac{M-1}{2} \right)$ and

m2= $\left(-\frac{M-1}{2} \cdots \frac{M-1}{2} \right)$ are coordinates in the local area.

The following steps are carried out for each local area in the local analysis:
1. A local dynamic range adjustment is proposed to be applied to each local area.
2. A data-driven transformation is conducted in order to improve local spectral features estimation. The data for each local area is windowed and zero padded to the next larger power of two.
3. A local magnitude spectrum is computed and the dominant spectral peak is located from which the local features frequency, orientation and magnitude are estimated.
4. A test if the local area needs to be reexamined, using a larger and a smaller size of the local area, is conducted. The local analyses are

repeated using these alternative area sizes if a reexamination is required.

D. Template Based Minutiae Extraction

Template based minutiae extraction technique uses the crossing number algorithm. The most commonly employed method of minutiae extraction is the Crossing Number (CN) concept. This method involves the use of the skeleton image where the ridge flow pattern is eight connected. The minutiae are extracted by scanning the local neighborhood of each ridge pixel in the image using a 3×3 window. The CN value is then computed, which is defined as half the sum of the differences between pairs of adjacent pixels in the eight neighborhood. The ridge pixel can then be classified as a ridge ending, bifurcation or non-minutiae point. The crossing number Cn (P) at data point p is defined as the half of the cumulative successive differences between pairs of adjacent pixels belonging to the 8-neighbourhood at P.

$$Cn(P) \quad = \frac{1}{2}\sum_{i=2}^{8}\left| val(P_i) - val(P_{i-1)} \right| \qquad (7)$$

Minutiae points are extracted during the enrollment process and then for each authentication. In a fingerprint, they correspond to either a ridge ending or a bifurcation. There is a duality between the two types of minutiae: if the pixel brightness is inverted, ridge endings become bifurcations and vice versa. The position of the minutia point is at the tip of the ridge or the valley. The orientation is given by the orientation of the arrow formed by the ridge or the valley. First, the local orientation field needs to be computed. This will allow enhancing the print using oriented Gabor filter, and then better detect minutiae point using template matching procedure.

IV. EXPERIMENTAL RESULTS

The performance provided by the proposed method is put
in relation to other published fingerprint image enhancement methods evaluated on FVC databases in a NIST related manner. The method presented by Chikkerur et. al. demonstrated 24.6% and 23.1% of relative improvement for EER and FMR100, respectively, on the FVC2002 Db3a database in comparison to the NIST method. This should be contrasted to the proposed method which reduces

EER by 34.3% and FMR100 by 36.4% on the same database. The fingerprint enhancement method proposed by Fronthaler et. al. improvement of EER compared to the methods by Hong et. al. The relative EER improvement compared to the NIST method on FVC2004 Db1a to Db4a are 17.2%, 13.7%, 19.3% and 4.1%, respectively. The corresponding relative EER improvement of the proposed method in relation to NIST is 29.9%, 45.4%, 6.1% and 7.0% for the same databases, this method shows an improvement for three of the four databases in FVC2000.
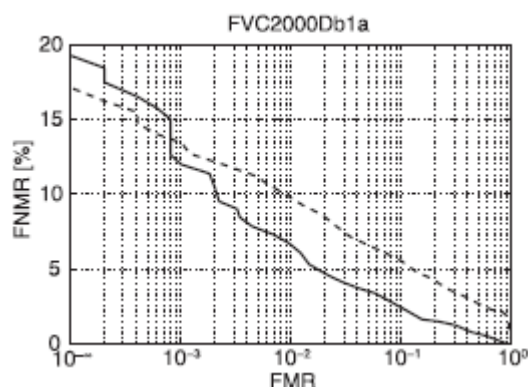

Fig 4. Experimental Result

A recently published method by Gottschlich demonstrates an improvement of EER in comparison for the same databases. The different settings of curved Gabor filters exhibit relative EER improvement compared to the NIST method between 27.6% to 33.1% for Db1a, 33.6% to 37.9% for Db2a, 17.7% to 22.6% for Db3a, and 11.0% to 17.8% for Db4a respectively. The combination of curved Gabor filters and oriented diffusion filtering yields relative EER improvement compared to the NIST method between 35.9% to 38.6% for Db1a, 47.3% to 54.7% for Db2a, 32.3% to 45.2% for Db3a, and 26.0% to 32.9% for Db4a respectively.

V. CONCLUSION

A preprocessing using the non-linear SMQT dynamic range adjustment method is used to enhance the global contrast of the fingerprint image prior to further processing. Estimation of the fundamental frequency of the fingerprint image is improved in the global analysis by utilizing a median filter leading to a robust estimation of the local area size. A low order SMQT dynamic range adjustment is conducted locally in order to achieve reliable features extraction used in the matched filter design and in the image segmentation. The matched filter block is improved by applying order statistical filtering to the extracted features, thus reducing spurious outliers in the feature data. The proposed method combines and updates existing processing blocks into a new and robust fingerprint enhancement system. The updated processing blocks lead to a drastically increased method performance where the EER is improved by a factor two, and the AAC is improved by a factor 12, in relation to the original method. The proposed method improves the performance in relation to the NIST method, and this is particularly pronounced on fingerprint images having a low image quality.

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