International Journal of Computer Systems (ISSN: 2394-1065), Volume 02– Issue 06, June, 2015
Available at http://www.ijcsonline.com/

Touch-Less Finger-Print Recognition: A Survey

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Abstract

Our Project is to overcome drawbacks in the current techniques for touch-less fingerprint recognition. We focus mainly image preprocessing, feature extraction and feature match. Each task analyzed by classical and up-to-date methods. Depending on the analysis, an integrated solution for demonstration of fingerprint recognition is developed. Our demonstration program is coded by MATLAB. To improve the performance of system optimization at coding level and algorithm level are proposed. The enhancements of performance can be judged by conducting experiments upon a variety of fingerprint images. The touch-less fingerprint recognition system can be divided into three main modules: preprocessing, feature extraction and matching. We put more emphasis on them so that the drawbacks in current techniques can be overcame .

Keywords: *Fingerprint acquisition, mosaicking, touchless multiview imaging, feature pattern, orientation.*

I. INTRODUCTION

Range of techniques is available for identity verification using biometrics such as Iris, Face, Voice and Finger-Print. Of which finger-print recognition plays an important role in verification. Fingerprint is the feature pattern of one Finger. Each person has his own fingerprints with the sub-task, some classical and up-to-date methods in permanent uniqueness. A fingerprint is composed of many ridges and furrows. Fingerprints are not distinguished by their ridges and furrows, but by Minutia, which are some abnormal points on the ridges. Among them two are mostly significant and in heavy usage: one is called termination, which is the immediate ending of a ridge; the other is called bifurcation, which is the point on the ridge from which two branches derive.

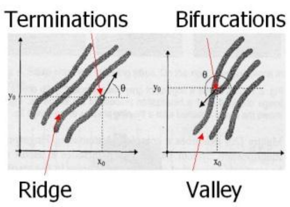
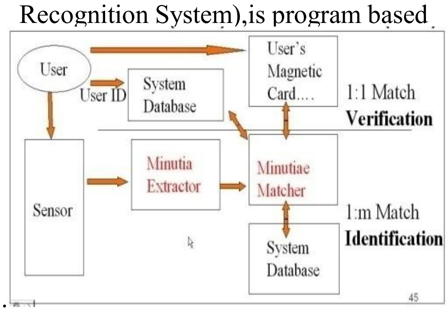


Figure : Minutia.

Fingerprint recognition grouped in verification and identification. Other than manual approach of fingerprint recognition, it is referred as AFRS (Automatic Fingerprint Recognition System),is program based



Fingerprint verification verify authenticity. User provides fingerprint together with identity. Verification system retrieves fingerprint template according to identity and matches the template with the real-time acquired fingerprint from the user. Identification is to specify fingerprint without identity, the Identification system tries to match his fingerprint with database.

II. LITERATURE SURVEY

During 1858, the first recorded systematic capture of hand and finger images for identification purposes was used by Sir William Herschel [1], Civil Service of India, who recorded a handprint on the back of a contract for each worker to distinguish employees.

Sir Francis Galton [1], in 1892, developed a classification system for fingerprints using minutiae characteristics that is being used by researchers and educationalists even today.

Sir Edward Henry [1], during 1896, paved way to the success of fingerprint recognition by using Galton's theory to identify prisoners by their fingerprint impressions. He devised a classification system that allowed thousands of fingerprints to be easily filed, searched and traced. He helped in the first establishment of fingerprint bureau in the same year and his method gained worldwide acceptance for identifying.

Mehtre et al. (1987)[2] implemented a segmentation algorithm that first partitioned a fingerprint image into blocks of 16 x 16 pixels. Then, each block was classified according to the distribution of the gradients in that block. Later Mehtre and Chatterjee (1989) extended this method by excluding blocks with a gray-scale variance that is lower than some threshold.The gray-scale variance in the direction orthogonal to the orientation of the ridges was used to classify each 16x16 block by Ratha et al. (1995). Jain and Ratha (1997) used the output of a set of Gabor filters as input to a clustering algorithm that constructs spatially compact clusters. Sun and Ai (1996) used dynamic threshold value (T) to binarize the input fingerprint images, where the dynamic threshold was suggested by Moayer and Fu (1975). The method used 5x5 pixels neighborhood to determine the local threshold value (T), which is equal to the mean value of the 5x5 pixels. The segmentation algorithm proposed by Bazen and Gerez (2000) was based on the coherence and morphology to obtain smooth regions. The same authors (Bazen and Gerez, 2001) enhanced their work to two more features namely mean and variance along with coherence. An optimal linear classifier is trained for the classification per pixel, while morphology is applied as post processing to obtain compact clusters and to reduce the number of classification errors.

The first Automated Fingerprint Identification System (AFIS) was developed by [3] Palm System in 1993. During 1995, the iris biometric was officially released as a commercial authentication tool by Defense Nuclear Agency. Multispectral Fingerprint Imaging (MSI) has been introduced by Lumidigm, Inc. (Rowe et al., 2005). Unlike conventional optical fingerprint sensors, MSI devices scan the subsurface of the skin by using different wavelengths of light (e.g., 470 nm (blue), 574 nm (green), and 636 nm (red)). The fundamental idea is that different features of skin cause different absorbing and scattering actions depending on the wavelength of light. Fingerprint images acquired using the MSI technology appear to be of significantly better quality compared to conventional optical sensors for dry and wet fingers. Multispectral fingerprint images have also been shown to be useful for spoof detection.

Sherlock et al. (1994) [4] proposed a fingerprint enhancement method in the Fourier domain. In this approach, a fingerprint image is convolved with precomputed filters, which result in a set of filtered images. The enhanced fingerprint image is constructed by selecting each pixel from the filtered image whose orientation is the closest to that of the original pixel. The next stage in fingerprint automation occurred at the end of 1994 with the Integrated Automated Fingerprint Identification System (IAFIS) competition. The competition identified and investigated three major challenges:

(1) digital fingerprint acquisition

(2) local ridge characteristic extraction and

(3) ridge characteristic pattern matching (David et al., 2005).

One of the most widely cited fingerprint enhancement techniques is the method employed by Hong et al. (1998) [5], which is based on the convolution of the image with Gabor filters tuned to the local ridge orientation and ridge frequency. Gabor filters (Gabor, 1946) have both frequency-selective and orientation-selective properties and have optimal joint resolution in both spatial and frequency domains. Therefore, it is beneficial to use Gabor filters as bandpass filters to remove the noise and preserve true ridge/valley structure. The stages of this algorithm include normalisation, ridge orientation estimation, ridge frequency estimation and filtering. This method was a follow up of their previous work (Hong et al., 1996). In this work, the authors introduced a new fingerprint enhancement algorithm that decomposes the input fingerprint image into a set of filtered images. A set of band pass filters can efficiently remove the undesired noise and preserve the true ridge/valley structure.

Teddy and Martin (2002)[6], described the latent fingerprint image enhancement using spectral analysis technique. The latent fingerprints are often blurred, incomplete, degraded and their spatial definition is not clear. This paper has presented techniques from frequency (spectral) analysis that can be used for the enhancement and restoration of degraded, noisy and sometimes incomplete fingerprint by using high-pass Butterworth filter and/or band-pass Butterworth filter. Rolled or flat fingerprint captured using ink or live scan usually need only the spatial filtering techniques, such as brightness, contrast, gamma and/or color map adjustment to examine the minutiae information. However for latent fingerprint, besides the spatial image enhancement filtering, one needs to use frequency (spectral) analysis techniques or a combination of both spatial and frequency enhancement techniques to isolate and enhance the degraded and often very weak, fingerprint information from a variety of background patterns.

Naji et al. (2002)[7] proposed a segmentation algorithm based on histogram equalizer and automated the method of choosing the threshold value during segmentation. Segmentation algorithms can generally be unsupervised, where a threshold is set on detected features to segment the image, or supervised where a simple linear classifier is used to classify features as part of region of interest or the background. Examples of supervised methods include the work of Alonso-Fernandez et al. (2005), where Gabor filters were used for segmentation. Apart from supervised and unsupervised methods, neural networks are also used.

Yang et al. (2003) [8] modified the method proposed by Hong et al. (1998) by discarding the inaccurate prior assumption of sinusoidal plane wave, and making the parameter selection process independent of fingerprint image. The concept of using iris pattern for identification was first proposed by Ophthalmologist Frank Burch in 1936 (Iradian Technologies, 2003).

Wu et al.(2004) [9] proposed to convolve a fingerprint image with an anisotropic filter to remove Gaussian noise and then apply Directional Median Filter (DMF) to remove impulse noise. On visual inspection, the enhancement results of Wu et al. (2004) appear to be superior to those obtained by Greenberg et al. (2000).

Chikkerur (2005)[10] proposed an algorithm based on Short Time Fourier Transformation (STFT), and a probabilistic approximation of dominant ridge orientation and frequency was used instead of the maximum response of the Fourier spectrum. The ridge orientation image, ridge frequency image and foreground region image are generated simultaneously while performing the STFT analysis.

L.C.Jain, U. Halici, S.B.Lee, and S.Tsutsui [11] presented the various algorithm and the techniques for intelligent biometric in finger print and face recognition. They proposed algorithm with the help of previous research with additional technique of neural network to get recognition of both finger and face with same algorithm.

E-Kyung and Bae (2006)[12][13] proposed an adaptive filter according to oily/dry/neutral images, instead of uniform filtering. To identify oily/dry/neutral, five features such as Mean, Variance, Block directional difference, Ridgevalley thickness ratio and Orientation change are used for clustering by Ward‘s clustering algorithm. After clustering, if the image is dry, then the ridges are enhanced by extracting their centerlines and removing white pixels, that is, ridge enhancement. For oily images, valleys are enhanced by dilating thin and disconnected ones, that is, 0valley enhancement. For neutral image, there is no need for filtration.

S. Chikkerur, A. Cartwright, and V. Govindaraju, Propsed[14] A Fingerprint Image Enhancement Using STFT Analysis", T. Nakamura, H. Fujiwara, M. Hirooka, and K. Sumi, [15], Fingerprint enhancement Using a Parallel Ridge Filter" for Pattern Recognition A novel method for fingerprint enhancement has been developed for that particular design, the authors proposed a preprocessing technique which included low pass filtering, segmentation and Gabor enhancement for their own-designed touch-less sensor.

D. Maltoni, D. Maio, A. K.Jain, and S. Prabhakar, [16], proposed Automatic Fingerprint Identification Systems (AFIS) accept live-scan digital images acquired with an electronic fingerprint scanner where the finger surface is directly sensed.

Existing fingerprint sensors acquire fingerprint images as the user's fingerprint is contacted on a solid flat sensor. So Y Song, C Lee, J Kim[17] proposed Intelligent Signal Processing and A preprocessing algorithm of a fingerprint image captured with a mobile camera. Fingerprint images from a mobile camera are different from images from conventional or touch-based sensors such as optical, capacitive, and thermal sensors. A New Scheme for Touchless Fingerprint Recognition System", International Symposium on Intelligent Signal Processing and Communication Systems. Even so, touch-less fingerprint recognition has been gaining attention recentlybecause it frees from the problems in terms of hygienic, maintenance, latent fingerprint problems and so forth that occur in the touch-based sensing technology. Most importantly, images captured with touch-less devices are distortion free and present no deformation since these images are exempted from the pressure of contact. Also resolved the 3D to 2D image mapping problem that was introduced by a strong view difference image rejection method. Preprocessing of fingerprint images captured with mobile camera.

In 2006, sensing technology based on multicamera system were introduced. These were termed as ―touchless imaging," and were introduced by TBS, Inc. (Parziale and Diaz-Santana, 2006)[18][19] . As suggested by the name, touchless imaging avoids direct contact between the sensor and the skin and, thus, consistently preserves the fingerprint ―ground truth" without introducing skin deformation during image acquisition. A touchless fingerprint sensing device is also available from Mitsubishi. One of the most essential characteristics of a digital fingerprint image is its resolution, which indicates the number of dots or pixels per inch (ppi).Generally, 250 to 300 ppi is the minimum resolution that allows the feature extraction algorithms to locate minutiae in a fingerprint image. FBI-compliant sensors must satisfy the 500 ppi resolution requirement. However, in order to capture pores in a fingerprint image, a significantly higher resolution (³ 1,000ppi) of image is needed. Although it is not yet practical to design solid-state sensors with such a high resolution due to the cost factor, optical sensors with a resolution of 1,000ppi are available commercially. More excitingly, optical sensors with resolutions of 4,000-7,000 ppi have also been developed, which not only allow capturing Level 3 features for identification, but also pore activities (opening and closing) for spoof detection. Recent years have seen a new high resolution fingerprint device called P3400. This is a small and cost effective fingerprint reader introduced by Zvetco Inc. This device can produce 500 dpi images and is constructed of high-quality aluminum. It is equipped with a 6-foot USB cable and is compatible with most biometric security access software packages.

Hiew, ABJ Teoh [20], proposed touch-less fingerprint recognition as it frees from the problems in terms of hygienic, maintenance and latent fingerprints. Moreover conventional techniques that used to preprocess the optical or capacitance sensor acquired fingerprint image, for segmentation, enhancement and core point detection, are still challenged. However, the conventional techniques that used to preprocess the optical or capacitance sensor. Touch-less fingerprint recognition deserves increasing attention as it lets off the problems of deformation, maintenance, and latent fingerprint problems.

B.Y.Hiew, Andrew B.J. Teoh, Member, IEEE and Y.H. Pang [21] proposed preprocessing stage presents the promising results in terms of segmentation, enhancement and core point detection. Digital camera based fingerprint recognition Feature extraction is done by Gabor filter followed by Principle Component Analysis (PCA) and the favorable verification results are attained with Cosine Angle.

G Parziale, E Diaz-Santana, R Hauke [22] presented for the first time the Surround Imager TM, an innovative multi-camera touchless device able to capture rolled-equivalent fingerprints,. The Surround Imager: A Multi-camera Touchless Device to Acquire 3D Rolled-Equivalent Fingerprints" Introduced a new touch-less device - The Surround ImagerTM, which can acquire 3D rolled-equivalent fingerprints. To make 3D touch-less fingerprints interoperable with the current AFIS system, proposed an unwrapping algorithm that unwraps the 3D touch-less fingerprint images into 2D representations that are comparable with the legacy rolled fingerprints. Due to the lack of contact between the elastic skin of the finger and any rigid surface, the acquired images free from problems of hygienic, maintenance and latent fingerprints. But still it needs some improvement as problems such as the low ridges-valleys are seen to appear.

Recently, Chengpu et al. (2008)[23] proposed the enhancement technique by using the combination of Gabor filter and Diffusion filter methods. The authors have combined the advantages of Gabor filtering and Diffusion filtering methods and proposed an enhancement method using the two filters: the lowpass filter (1D Gaussian filter) and the band-pass filter (1D Gabor filter).

Heeseung Choi, Kyoungtaek Choi, and Jaihie Kim[24] propose a new touchless fingerprint sensing device capturing three different views at one time and a method for mosaicing these view-different images. The device is composed of a single camera and two planar mirrors reflecting side views of a finger, and it is an alternative to expensive multiple-camera-based systems. The mosaic method can composite the multiple view images by using the thin plate spline model to expand the usable area of a fingerprint image.

Prabhjot Kaur, Ankit Jain ,Sonia Mittal [25] Proposed some challenging problems that occur while developing the touch-less system. These problems are low contrast between the ridge and the valley pattern on fingerprint image, non-uniform lighting, motion blurriness and defocus, due to less depth of field of digital camera. The touch-less fingerprint recognition system can be divided into three main modules: preprocessing, feature extraction and matching. Preprocessing is an important step prior to fingerprint feature extraction and matching. They put more emphasis on preprocessing so that the drawbacks stated earlier can be removed.

Alessio Pierluigi Placitelli and Luigi Gallo[26] presented a framework aimed at facilitating the development of natural,touchless user interfaces. The proposed framework, which is based on the publish-subscribe paradigm, allows product and interaction designers to rapidly prototype and test their system by building upon a set of standard modules. The frameworkalso provides the building blocks to extend the basic set of modules, easing code reuse.

Feng Liu, David Zhang,[27] Fellow Presented a touchless multiview fingerprint capture systemthat acquires three different views of fingerprint images at the same time. This device is designed by optimizing parameters regarding the captured fingerprint image quality and devicesize. A fingerprint mosaicking method is proposed to splicetogether the captured images of a finger to form a new image with a larger useful print area. Optimization design of ourdevice is demonstrated by introducing design procedure and comparing with current touchless multiview fingerprint acquisition devices.

Jainam Shah, Ujash Poshiya [28] In this p a review of touch-less fingerprint recognition systems that use digital camera. We present some challenging problems that occur while developing the touch-less system. These problems are low contrast between the ridge and the valley pattern on fingerprint image, non-uniform lighting, motion blurriness and defocus, due to less depth of field of digital camera. The touch-less fingerprint recognition system can be divided into three main modules: preprocessing, feature extraction and matching. Preprocessing is an important step prior to fingerprint feature extraction and matching. In this paper we put our more emphasis on preprocessing so that the drawbacks stated earlier can be removed.

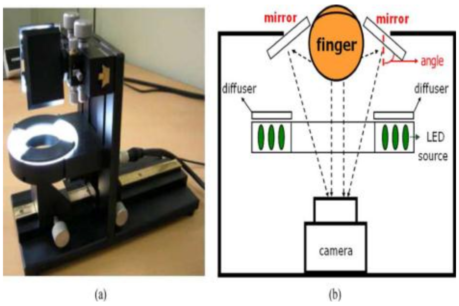
Anju Mohan1 and Prof. Shilpa P. Kodgire[29] Many sensors were developed for fingerprint recognition systems in which the user‘s finger print is placed on a sensor. Due to this contact the input fingerprint from the same finger can be different and there can be fingerprint issues which can lead to forgery and hygienic problem. For this reason touchless fingerprint recognition has been developed in which the fingerprint is acquired using a high resolution webcam. The acquired images are subjected to pre-processing steps and the region of interest is extracted.

European Commission Joint Research Centre [31] The objective of this study is to carry out a thorough and integrated in-depth assessment of the technical feasibility of different age limits for fingerprint recognition - in particular of children aged between 6 and 12 years - in the context of large-scale databases. The study should give therefore an answer as to whether the change of size of fingerprints of this age group - related to the growth process of fingerprints has a crucial impact on accuracy for verification.

A. SYSTEM DESIGN

Most of the Fingerprint sensors are uses ―touch" method since it is simple. Touch sensors acquire fingerprint images as fingerprint is contacted on a solid flat sensor. The person requires to press his/her finger against a flat rigid surface, so called touch-based methods. This acquired image compared with image stored in device and depending on the matching percentage of both the images the access is given to the user. Touching or rolling a finger onto a rigid sensing surface, elastic skin of deforms. The quantity and direction of the pressure applied by the user, introduce distortions, noise, and inconsistencies on the captured fingerprint image and causes negative effects, with increasing complexity for matching.

The touch-less fingerprint technology requires no contact between skin of finger and sensing area, is a remote sensing technology to capture the ridge-valley pattern to provides essential information. Digital camera is used to present a touch-less fingerprint recognition system. Images are acquired using these cameras.



Prototype & Schematic view

A touchless multiview fingerprint capture system that acquires three different views of fingerprint images at the same time. This device is designed by optimizing parameters regarding the captured fingerprint image quality and device size. A fingerprint mosaicking method is proposed to splice together the captured images of a finger to form a new image with a larger useful print area.

A. System Level Design

A fingerprint recognition system constitutes of fingerprint acquiring device, minutia extractor and minutia matcher

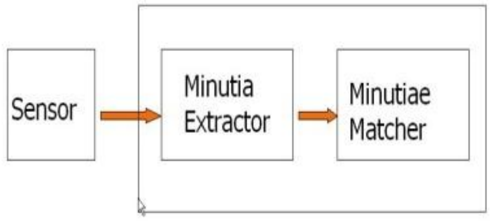


Fig. : Fingerprint Recognition System

Optical or semi-conduct sensors used for acquisition. They have high efficiency and acceptable accuracy except for some cases that the user's finger is too dirty or dry. The minutia extractor and minutia matcher modules are explained in detail in the next part for algorithm design and other subsequent sections.

B. Algorithm Level Design

To implement a minutia extractor, preprocessing, minutia extraction and post processing stage are used.

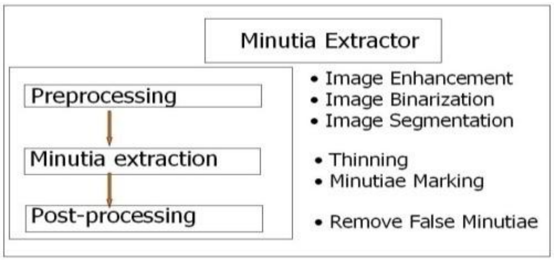
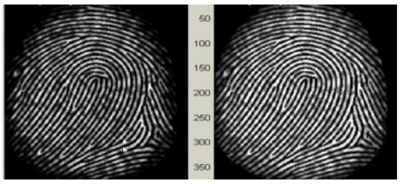


Figure: Minutia Extractor

For preprocessing stage, Histogram Equalization and Fourier Transform is used, to enhance image then image is binarized using the locally adaptive threshold method. The image segmentation task is fulfilled by a three-step approach: block direction estimation, segmentation by direction intensity and Region of Interest extraction by Morphological operations. For post-processing, more rigorous algorithm is developed to remove false minutia. Also a novel representation for bifurcations is proposed to unify terminations and bifurcations. The minutia matcher with two minutia as a reference pair matches associated ridges first. If ridges match well, two fingerprint images are aligned and matching is conducted for remaining minutia. Enhancement is for making image clearer for further operations. Since the fingerprint images acquired from sensors are not assured with perfect quality, those enhancement methods, for increasing the contrast between ridges and furrows and for connecting the false broken points of ridges due to insufficient amount of ink, are very useful for keep a higher accuracy to fingerprint recognition. Two Methods are adopted in my fingerprint recognition system: Histogram Equalization; and Fourier Transform. Histogram Equalization: To expand the pixel value distribution of an image so as to increase the perceptional information Histogram Equalization is carried. The original histogram of a fingerprint image has the bimodal type the histogram after the histogram equalization occupies all the range from 0 to 255 and the visualization effect is enhanced.

The figure after the histogram equalization is



Original Image (Left). Enhanced image (Right)

Fingerprint Enhancement by Fourier Transform Image divided into small processing blocks (32 by 32 pixels) and perform

Fourier transform according

$$F(u,v)=\sum_{x=0}^{M-1}\sum_{y=0}^{N-1} f(x,y)\times\exp\left\{-j2\pi\times\left(\frac{ux}{M}+\frac{vy}{N}\right)\right\} \quad (1)$$

for u = 0, 1, 2, ..., 31 and v = 0, 1, 2, ..., 31.

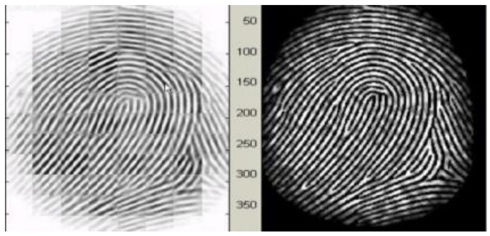
To enhance a specific block by its dominant frequencies, we multiply the FFT of the block by its magnitude a set of times. Where the magnitude of the original FFT = abs(F(u,v)) = |F(u,v)|.Get the enhanced block according to $g(x,y)=F^{-1}\left\{F(u,v)\times|F(u,v)|^{k}\right\}$ (2) ,

where $F^{-1}(F(u,v))$ is done by:

$$f(x,y)=\frac{1}{MN}\sum_{x=0}^{M-1}\sum_{y=0}^{N-1} F(u,v)\times\exp\left\{j2\pi\times\left(\frac{ux}{M}+\frac{vy}{N}\right)\right\} \quad (3)$$

for x = 0, 1, 2, ..., 31 and y = 0, 1, 2, ..., 31.

The k in formula (2) is an experimentally determined constant, which we choose k=0.45 to calculate. While having a higher "k" improves the appearance of the ridges, filling up small holes in ridges, having too high a "k" can result in false joining of ridges. Thus a termination might become a bifurcation. Figure presents the image after FFT enhancement.



Enhanced image after FFT has improvements to connect some falsely broken points on ridges and removes some spurious connections between ridges. Image found after consecutive binarization operation is good.

Fingerprint Image Binarization :- Fingerprint Image Binarization is to transform the 8-bit Gray fingerprint image to a 1-bit image with 0-value for ridges and 1-value for furrows. After the operation, ridges in the fingerprint are highlighted with black color while furrows are white.

Fingerprint Image Segmentation:- Only a Region of Interest (ROI) is useful to be recognized for each fingerprint image. The image area without effective ridges and furrows is first discarded. Then bound of remaining effective area is sketched out since the minutia in the bound region are confusing with those spurious minutia that are generated when the ridges are out of the sensor. To extract the ROI, a two-step method is used. The first step is block direction estimation and direction variety check, second is intrigued from some Morphological methods. Block direction estimation :- Estimate the block direction for each block of the fingerprint image with WxW in size(W is 16 pixels by default). The algorithm is: Calculate the gradient values along x-direction (g_x) and y-direction (g_y) for each pixel of block. Two Sobel filters are used to fulfill task. For each block, use Following formula to get Least Square approximation of block direction.tg2ß = 2 ∑ ∑ (gx*gy)/∑ ∑ (gx2-gy2) for all the pixels in each block.The blocks without significant information on ridges and furrows are discarded based on the following formulas: E = {2 ∑ ∑ (gx*gy)+ ∑ ∑ (gx2-gy2)}/ W*W*∑ ∑ (gx2+gy2)

ROI extraction by Morphological operations

‗OPEN‘ and ‗CLOSE‘ Morphological operations are adopted. The ‗OPEN‘ operation can expand images and remove peaks introduced by background noise. The ‗CLOSE‘ operation can shrink images and eliminate small cavities.

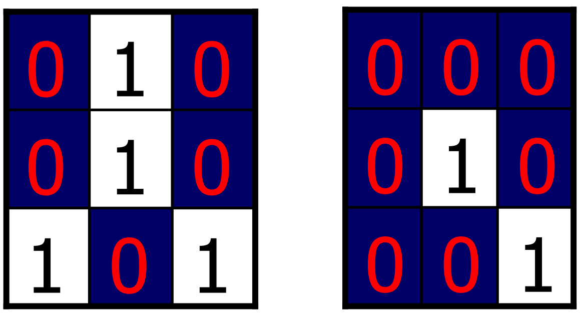
III. MINUTIA EXTRACTION

A. Fingerprint Ridge Thinning

Ridge Thinning is to eliminate the redundant pixels of ridges till the ridges are just one pixel wide. One method is parallel thinning algorithm. In each scan of the full fingerprint image, the algorithm marks down redundant pixels in each small image window (3x3). And finally removes all those marked pixels after several scans. Another method uses a one-in-all method to extract thinned ridges from gray-level fingerprint images directly. This method traces along the ridges having maximum gray intensity value. However, binarization is implicitly enforced since only pixels with maximum gray intensity value are remained. The advancement of each trace step still has large computation complexity although it does not require the movement of pixel by pixel as in other thinning algorithms. Thus the third method is bid out which uses the built-in Morphological thinning function in MATLAB.

A. Minutia Marking

After the fingerprint ridge thinning, marking minutia points is relatively easy. In general, for each 3x3 window, if the central pixel is 1 and has exactly 3 one-value neighbors, then the central pixel is a ridge branch. If the central pixel is 1 and has only 1 one-value neighbor, then the central pixel is a ridge ending



IV. MINUTIA POSTPROCESSING

A. False Minutia Removal:

The preprocessing stage does not totally heal the fingerprint image. Actually all the earlier stages themselves occasionally introduce some artifacts which later lead to spurious minutia. These false minutia will significantly affect the accuracy of matching if they are simply regarded as genuine minutia. So some mechanisms of removing false minutia are essential to keep the fingerprint verification system effective. My procedures in removing false minutia are:

1. If the distance between one bifurcation and one termination is less than D and the two minutia are in the same ridge(m1 case) . Remove both of them. Where D is the average inter-ridge width representing the average distance between two parallel neighboring ridges.

2. If the distance between two bifurcations is less than D and they are in the same ridge, remove the two bifurcations. (m2, m3 cases).

3. If two terminations are within a distance D and their directions are coincident with a small angle variation. And they suffice the condition that no any other termination is located between the two terminations. Then the two terminations are regarded as false minutia derived from a broken ridge and are removed. (case m4,m5, m6).

4. If two terminations located in short ridge with length less than D, remove two terminations (m7).

Proposed procedures in removing false minutia have two advantages. The ridge ID is used to distinguish minutia and the seven types of false minutia are strictly defined comparing with those loosely defined by other methods. The second advantage is that the order of removal procedures is well considered to reduce the computation complexity. It surpasses the way adopted by [10] that does not utilize the relations among the false minutia types. For example, the procedure3 solves the m4, m5 and m6 cases in a single check routine. And after procedure 3, the number of false minutia satisfying the m7 case is significantly reduced.

B.Unify Terminations And Bifurcations:- Since various data acquisition conditions such as impression pressure can easily change one type of minutia into other, most researchers adopt unification representation for both termination and bifurcation. So each minutia is completely characterized by following parameters at last: 1) x-coordinate, 2) y-coordinate, and 3) orientation. The orientation calculation for a bifurcation needs to be specially considered. All three ridges deriving from the bifurcation point have their own direction, represents the bifurcation orientation. Here I propose a novel representation to break a bifurcation into three terminations. The three new terminations are the three neighbor pixels of the bifurcation and each of the three ridges connected to the bifurcation before is now associated with a termination respectively.

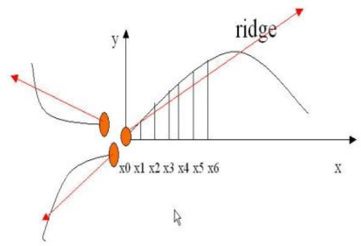


Figure:- A bifurcation to three termination

And the orientation of each termination (tx,ty) is

estimated by following method : Track a ridge segment whose starting point is the termination and length is D. Sum up all x-coordinates of points in the ridge segment. Divide above summation with D to get sx. Then get sy using the same way.Get the direction from:

atan((sy-ty)/(sx-tx)).

V. MINUTIA MATCH

The minutia match algorithm determines whether the given two minutia sets are from the same finger or not. An alignment-based match algorithm It includes two consecutive stages: one is alignment stage and the second is match stage.

A. *Alignment stage:*

Given two fingerprint images to be matched, choose any one minutia from each image, calculate the similarity of the two ridges associated with the two referenced minutia points. If the similarity is larger than a threshold, transform each set of minutia to a new coordination system whose origin is at the referenced point and whose x-axis is coincident with the direction of the referenced point.

1. The ridge associated with each minutia is represented as a series of x-coordinates (x_1, $x_2 \ldots x_n$) of the points on the ridge. A point is sampled per ridge length L starting from the minutia point, where the L is the average inter-ridge length. And n is set to 10 unless the total ridge length is less than 10*L.So the similarity of correlating the two ridges is derived from:

$S = \sum^{m}_{i=0} x_i X_i / [\sum^{m}_{i=0} x_i^2 X_i^2]$^0.5,

where ($x_{i\sim}x_n$) and ($X_{i\sim}X_N$) are the set of minutia for each fingerprint image respectively. And m is minimal one of the n and N value. If the similarity score is larger than 0.8, then go to step 2, otherwise continue to match the next pair of ridges.

2. For each fingerprint, translate and rotate all other minutia with respect to the reference minutia according to the following formula:

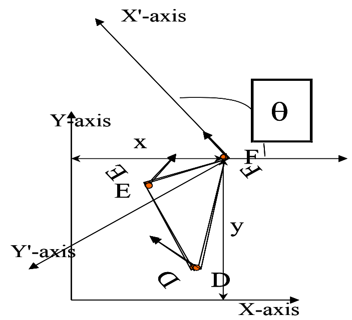
$$\begin{pmatrix} xi\_new \\ yi\_new \\ \theta i\_new \end{pmatrix} = TM * \begin{bmatrix} (xi - x) \\ (yi - y) \\ (\theta i - \theta) \end{bmatrix}$$

,

where (x,y,θ) is the parameters of the reference minutia, and TM is

$$TM = \begin{pmatrix} \cos\theta & -\sin\theta & 0 \\ \sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

Diagram illustrate effect of translation and rotation .



The new coordinate system is originated at minutia F and the new x-axis is coincident with the direction of minutia F. No scaling effect is taken into account by assuming two fingerprints from the same finger have nearly the same size. Lin's method uses the rotation angle calculated from all the sparsely sampled ridge points. My method use the rotation angle calculated earlier by densely tracing a short ridge start from the minutia with length D. Since I have already got the minutia direction at the minutia extraction stage, obviously my method reduces the redundant calculation but still holds the accuracy. Also Lin's way to do transformation is to directly align one fingerprint image to another according to the discrepancy of the reference minutia pair. But it still requires a transform to the polar coordinate system for each image at the next minutia match stage. My approach is to transform each according to its own reference minutia and then do match in a unified x-y coordinate. Therefore, less computation workload is achieved through my method.

B. *Match stage*

After getting two set of transformed minutia points, the elastic match algorithm used to count the matched minutia pairs by assuming two minutia having nearly the same position and direction are identical.

The matching algorithm for the aligned minutia patterns needs to be elastic since the strict match requiring that all parameters (x, y, θ) are the same for two identical minutia is impossible due to the slight deformations and inexact quantization of minutia My approach to elastically match minutia is achieved by placing a bounding box around each template minutia. If the minutia to be matched is within the rectangle box and the direction discrepancy between them is very small, then the two minutia are regarded as a matched minutia pair. Each minutia in the template image either has no matched minutia or has only one corresponding minutia. The final match ratio for two fingerprints is the number of total matched pair over the number of minutia of the template fingerprint. The score is 100*ratio and ranges from 0 to 100. If the score is larger than a pre-specified threshold, the two fingerprints are from the same finger. However, the elastic match algorithm has large computation complexity and is vulnerable to spurious minutia.

VI. CONCLUSTION

My project has combined many methods to build a minutia extractor and a minutia matcher. The combination of multiple methods comes from a wide investigation into research paper. Also some novel changes like segmentation using Morphological operations, minutia marking with special considering the triple branch counting, minutia unification by decomposing a branch into three terminations, and matching in the unified x-y coordinate system after a two-step transformation are used in my project, which are not reported in other literatures I referred to. Also a program coding with MATLAB going through all the stages of the fingerprint recognition is built. It is helpful to understand the procedures of fingerprint recognition. And demonstrate the key issues of fingerprint recognition.

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