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Latent Fingerprint Image Enhancement Techniques

R.Kausalya[1], A.Ramya[2]

PG Scholar, Department of Computer Science and Engineering, Kalaignar Karunanidhi Institute of Technology, Coimbatore, India[1,2]

Abstract: Fingerprint identification plays major role in crime scene investigation. Fingerprint technology is not going away any time soon from early 20th century. While the fingerprints obtained during the crime scenes are mostly latent images. Latent fingerprints are the irregular fingerprints which does not contain any clear ridge structures. In fingerprint matching techniques, the ridge lines are important to extract the features in the finger image. This paper gives an idea about latent finger image enhancement technique in order to extract the features in the latent image. Experimental results on FVC2002 databases, which results enhanced finger image.

Keywords: Binarization, Thinning, Fast Fourier transform, Ridge orientation flow.

I. INTRODUCTION

Automatic fingerprint recognition has become a widely used technology in both forensic and biometrics applications. Despite a history of a thousand years during which fingerprints have been used as individual's proof of identity and decades of research on automated systems, reliable fully automatic fingerprint recognition is still an unsolved challenging research problem. Moreover, most of the research thus far, assumes that the two fingerprint templates being matched are approximately of the same size and cover large areas of the finger tip. However, this assumption is no longer valid. The miniaturization of fingerprint sensors has led to small sensing areas and can only capture partial fingerprints. Partial fingerprints are also common in forensic applications. There are essentially three types of fingerprints in law enforcement applications. (Fig. 1): (a) rolled, which is obtained by rolling the finger "nail-to-nail" either on a paper (in this case ink is first applied to the finger surface) or the platen of a scanner; (b) plain, which is obtained by placing the finger flat on a paper or the platen of a scanner without rolling; and (c) latent's, which are lifted from surfaces of objects that are inadvertently touched or handled by a person typically at crime scenes.

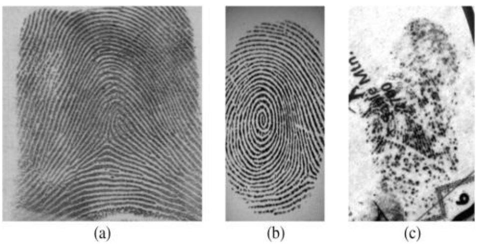

Fig.1. Fingerprint impression types

Lifting of latent's may involve a complicated process, and it can range from simply photographing the print to more complex dusting or chemical processing [2].

II. RELATED WORK

A. High Resolution Partial Fingerprint

In a live-scan AFRS, a user puts his/her finger against the prism and the contact fingerprint region will be captured in the resulting image. A small contact region between the finger and the prism will lead to a small partial fingerprint image. On such small fingerprint region, there could be very limited minutiae available for recognition. A natural way to solve the partial fingerprint recognition problem is to make full use of other fine fingerprint features abundant on the small fingerprint fragments. Most existing high resolution fingerprint recognition methods use full-size fingerprint images which capture large fingerprint areas. However, to capture the full fingerprints, high resolution fingerprint images should have much bigger sizes than conventional low resolution fingerprint images. As a result, much more computational resources are required to process the images. Considering the increasing demand of AFRS on mobile devices and other small portable devices, small fingerprint scanners and limited computational resources are very common.

B. Minutiae Detection Process

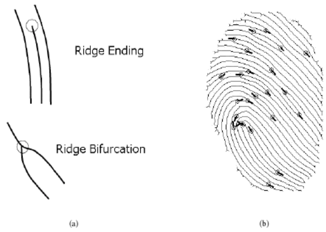

Fig. 2 (a) Minutiae Points: ridge ending and ridge bifurcation (b) detected minutiae on a skeleton fingerprint image

Minutiae, in fingerprint context, are the various ridge discontinuities of a fingerprint. There are more than 100 different types of minutiae have been identified, among which ridge bifurcations and endings are the most widely used. Minutiae-based methods have been used in many commercial fingerprint matching systems. Based primarily on a point pattern matching model, these methods rely heavily on the accuracy of minutiae extraction and the detection of landmarks like core and delta for pre-alignment. Spurious and missing minutiae can both

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introduce errors in minutiae correspondence. Equally problematic is the inability to detect landmarks to guide pre-alignment.

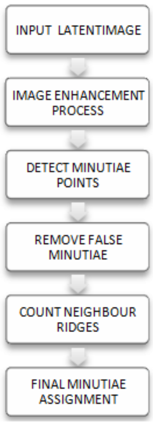


Fig. 3 Minutiae detection process

Taken together, these problems lead to sub-optimal matching accuracy. Fortunately, the contextual information provided by ridge flow and orientation in the neighborhood of detected minutiae can help eliminate spurious minutiae while compensating for the absence of genuinely missing minutiae both before and during matching. In addition, coupled with a core detection algorithm that can robustly handle missing or partially available landmarks for pre-alignment, significant improvement in matching accuracy can be expected. In this chapter, we will firstly review fingerprint feature extraction, minutiae representation, and registration, which are important components of fingerprint matching algorithms.

C. Protection Issues of Latent Fingerprint Matching

In general, fingerprint recognition systems are considered as being of high security strength. Since a fingerprint data is in the order of several kilobytes, it provides the security of having a long password without the overhead of remembering that information. However, unlike a password system, in which an exact match is expected for authentication of an individual, a fingerprint recognition system can only provide the individual's identity information with a certain confidence level. Thus, some kind of distortion tolerant mechanism is required which can reduce the security strength of the system. Moreover, with the small number of features on a partial fingerprint, the security strength of partial fingerprint recognition is further diminished.

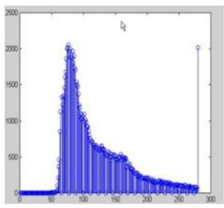
III. RESEARCH CONTRIBUTION

A. Latent Fingerprint Image Enhancement Approach

Latent fingerprint image enhancement is to make the image clearer for easy further operations. Since the fingerprint images acquired from sensors or other Medias 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. The quality of the ridge structures in a fingerprint image is an important characteristic, as the ridges carry the information of characteristic features required for minutiae extraction. Ideally, in a well-defined fingerprint image, the ridges and valleys should alternate and flow in locally constant direction. This regularity facilitates the detection of ridges and consequently, allows minutiae to be precisely extracted from the thinned ridges. However, in practice, a fingerprint image may not always be well defined due to elements of noise that corrupt the clarity of the ridge structures. This corruption may occur due to variations in skin and impression conditions such as scars, humidity, dirt, and non-uniform contact with the fingerprint capture device. Thus, image enhancement techniques are often employed to reduce the noise and enhance the definition of ridges against valleys. Two Methods are adopted in my fingerprint recognition system: the first one is Histogram Equalization; the next one is Fourier Transform.

B. Histogram Equalization

The histogram of an image is a function that provides the frequency of occurrence for each intensity level in the image as a graphical representation. Histogram equalization is to expand the pixel value distribution of an image so as to increase the perceptional information. 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.



4. (a) Original histogram

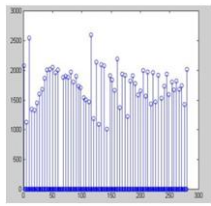


Fig. 4.(b) After the Histogram Equalization

C. Fast Fourier Transform

Fourier analysis of a periodic function refers to the extraction of the series of sines and cosines which when superimposed will reproduce the function. This analysis can be expressed as a Fourier series. The fast Fourier transform is a mathematical method for transforming a function of time into a function of frequency. Sometimes it is described as transforming from the time domain to the frequency domain. It is very useful for analysis of time-dependent phenomena.

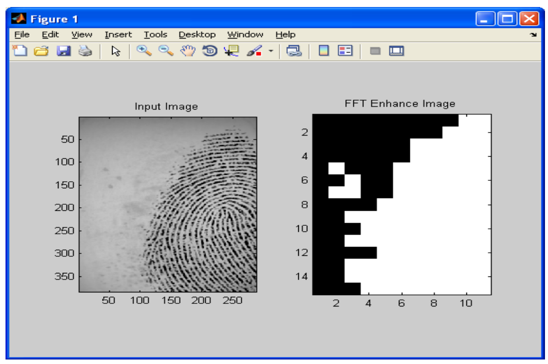


Fig .5 Fingerprint enhancements by FFT

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The enhanced image after FFT has the improvements to connect some falsely broken points on ridges and to remove some spurious connections between ridges.

D. Binarization

Most minutiae extraction algorithms operate on binary images where there are only two levels of interest: the black pixels that represent ridges, and the white pixels that represent valleys. Binarization is the process that converts a grey-level image into a binary image. The binarization process involves examining the grey-level value of each pixel in the enhanced image, and, if the value is greater than the global threshold, then the pixel value is set to a binary value one; otherwise, it is set to zero. Equation used to binarize the gray scale images:

$$G(x, y) = \begin{cases} 1 \; if \; f(x,y) > T \\ 0 \; if \; f(x,y) \leq T \end{cases}$$

Where, f(x, y) is the value of a pixel in gray-scale image and g(x, y) is the binarized image

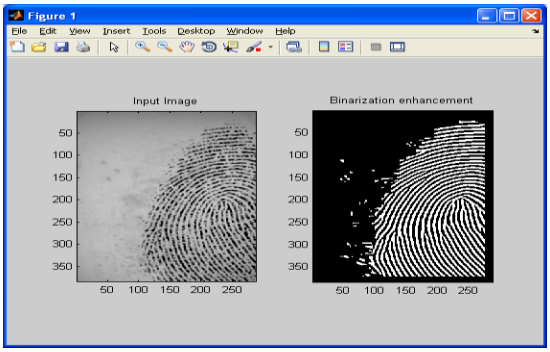


Fig.6.Binarization Enhancements

E. Ridge Orientation Flow Estimation

The ridge orientation map it is possible to define a common orientation for each 32x32 pixel block of the fingerprint image. Thus, for each block of the image, its corresponding orientation is used to select among the filtered images which one shall be used to compose the final filtered image.

- Estimate the block direction for each block of the fingerprint image with WxW in size (W is 32 pixels by default).
- Calculate the gradient values along x-direction (gx) and y-direction (gy) for each pixel of the block.
- For each block, use following formula to get the Least Square approximation of the block direction.

$tg2ß = 2 \sum \sum (g_x * g_y) / \sum \sum (g_x^2 - g_y^2)$ for all the pixels in each block.

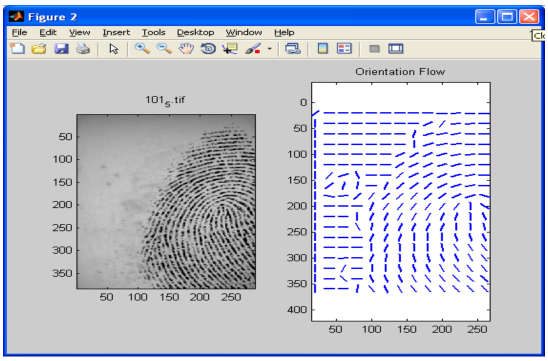


Fig.7 Direction map.

F. Minutiae Extraction

Ridge Thinning

Ridge Thinning is to eliminate the redundant pixels of ridges till the ridges are just one pixel wide uses an iterative, 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

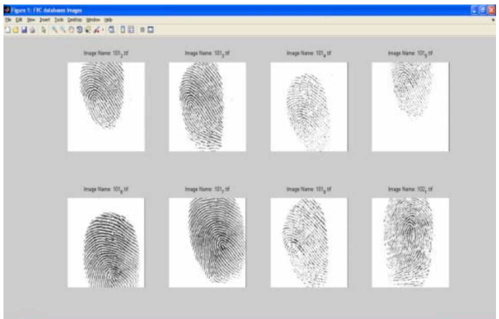
Minutiae Marking

After the fingerprint ridge thinning, marking minutia points is relatively easy. But it is still not a trivial task as most literatures declared because at least one special case evokes my caution during the minutia marking stage. 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. A special case that a genuine branch is triple counted. Suppose both the uppermost pixel with value 1 and the rightmost pixel with value 1 have another neighbor outside the 3x3 window, so the two pixels will be marked as branches too.

IV. EXPERIMENTAL RESULTS

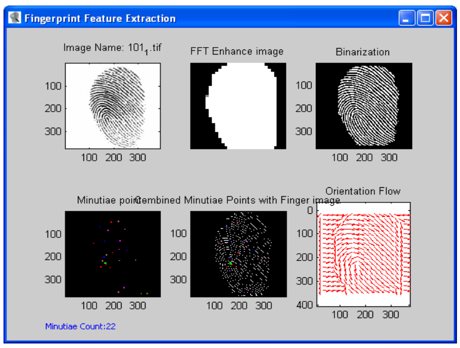
A. Input Design

The input of two databases, the FVC2002 database Db1 set A which contains 800 fingerprint images with 100 fingers having 8 impressions each, and fingerprint database from the University of Bologna, consisting of 168 fingerprint images formed by 21 fingers with 8 impressions each. The parameters of the algorithm were tuned with the FVC2002 database Db1 set B, which contains 80 fingerprints (10 fingers with 8 impressions each).



B. Output Design

Output design generally refers to the results and information that are generated by the system. This system shows the result for the users to view the output in an efficient manner.



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V. CONCLUSION

Verdict the fingerprint evidence plays usual role in law enforcement agencies. Fingerprint obtain during the crime scenes contain extremely noise characteristics. This makes difficult to extract the fingerprint features. We need to enhance those images before undergoing feature extraction technique. The latent fingerprint image enhancement techniques were discussed in this paper. With the help of this techniques, will be able to improve the latent image quality and also to reduce the errors during matching process. Experimental results shown were done using the FVC 2002 databases.

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