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A Review Paper on Fingerprint Image Enhancement with Different Methods

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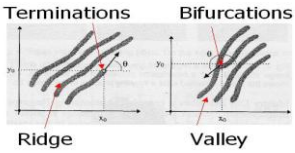
Abstract: *Image enhancement plays an important role in Fingerprint Recognition System. In this paper, we study the different techniques of enhancement of a fingerprint image in which have been used in previous work. There are so many techniques for enhancement which uses so many different image processing approaches. During study some approaches are found in spatial domain, frequency domain, some are neural network based and some are fuzzy based. Most of the fingerprint techniques use contextual filters or multi-resolution filters whose parameters depends on the local ridge frequency and orientation .The main drawback of these methods lie in the fact that false estimate of local ridge direction will lead to poor enhancement. But the estimate of local ridge directions is unreliable in the areas corrupted by noise where enhancement is most needed.*

I. INTRODUCTION

Fingerprints are today the most widely used biometric features for personal identification. Most automatic systems for fingerprint comparison are based on minutiae matching [11]. Minutiae characteristics are local discontinuities in the fingerprint pattern which represent terminations and bifurcations. A ridge termination is defined as the point where a ridge ends abruptly. A ridge bifurcation is defined as the point where a ridge forks or diverges into branch ridges (Fig. I). Reliable automatic extracting of minutiae is a critical step in fingerprint classification. The ridge structures in fingerprint images are not always well defined, and therefore, an enhancement algorithm, which can improve the clarity of the ridge structures, is necessary. Skin on human fingertips contains ridges and valleys which together forms distinctive patterns. These patterns are fully developed under pregnancy and are permanent throughout whole lifetime. Prints of those patterns are called fingerprints. Injuries like cuts, burns and bruises can temporarily damage quality of fingerprints but when fully healed, patterns will be restored. Through various studies it has been observed that no two persons have the same fingerprints, hence they are unique for every individual.



Fig(1.1)Ridge and valley structure


Fig(1.2)Fingerprint

II. Why we need enhancement of fingerprint before minutiae extraction?

The performance of minutiae extraction algorithm is heavily depends upon the quality of input image. In fingerprint image minutiae can be precisely located from the thinned ridges.

However, in practice due to the factor of sensor environment and state of human finger, a significant percentage of acquired fingerprint image is of poor quality. The ridge structure in poor quality image is always not well defined so that they cannot be detected correctly. Otherwise this will lead to the following problems, which can be:

a) A significant number of unreliable minutiae pattern can be created.
b) A large percentage of genuine minutiae can be ignored.
c) We will get false matching results.

So, In order to avoid these problems this is necessary to use enhancement algorithm which can improve the quality of the image.

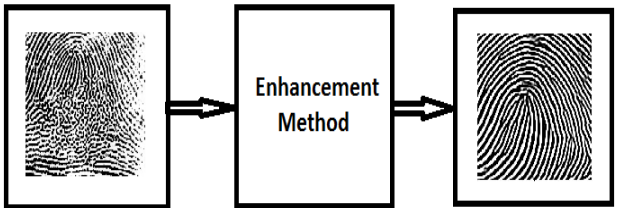


Fig.(2.1) Enhancement method

The reason for performing enhancement (2.1) is to eradicate the noise in the fingerprint images, Illuminate the parallel ridges and valleys. The efficiency of fingerprint image enhancement algorithm is greatly depends on the quality of the fingerprint images. In order to obtain robust performance of a finger print image enhancement algorithm, that can improve the transparency of the ridge structures, is very essential.

The main objective of fingerprint image enhancement is to improve the ridge characteristics of the image, as these ridges carry the information of characteristics features required for minutiae extraction. Ideally, in a well-defined fingerprint image, the ridges and valleys should alternate and flow in a locally constant direction. This regularities facilitates the detection of ridges and consequently allow minutiae to be precisely extracted from the thinned ridges. Thus, the corruption or noise has to be reduced through image enhancement techniques to get enhanced definition of ridges against valleys in the fingerprint images.

2.1Fingerprint enhancement can be conducted on either

1) Binary ridge image
2) Gray level image

Binary ridge image is an image where all the pixel values assigned to one and non pixel values are assigned to zero. The binary image is obtained by applying minutiae extraction algorithm on a gray level fingerprint image. In binary ridge image, a number of simple heuristics can be used to differentiate the spurious ridge configuration from the true ridge configuration since ridge and valley in the image run parallel to each other in a local neighborhood.

Gray level image is a image in which ridge and valleys form a sinusoidal-shaped plane wave which has a well defined frequency and orientation. A number of techniques that can take the advantage of this information that is used for the enhancement of the gray level image.

As we said most of the techniques use contextual filter and multi-resolution filter. But these methods also have some limitations in terms of that false estimate of local ridge direction will lead to poor enhancement. One another method which is pixel wise method, it is the simpler method Common operations include normalization, intensity transformations, histogram processing, image subtraction, image averaging. Good enhancement results can be achieved exploiting pixel-wise methods as pre-processing in advanced fingerprint recognition algorithms. Image enhancement techniques can be divided into two broad categories and Normally, enhancement techniques use various combinations of methods from these two categories. 1. Spatial domain methods. 2. Frequency domain methods.

Spatial domain refers to the image plane itself, and image processing methods in this category are based on direct manipulation of pixels in an image. Spatial domain above can be denoted by the expression:

$$g(x,y) = T[f(x,y)] \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where f (x,y) is the input image, g (x,y) is the output image and T is an operator on defined over a neighborhood of point (x,y).

Frequency domain This method consists of modifying the Fourier transform of an image and then computing the inverse transform [Discrete Fourier Transform (DFT)] to get back to input image .Thus given a digital image f (x,y), of size M x N, the basic filtering equation in which we are interested has the form:

$$g(x,y) = \Im^{-1}[H(u,v)F(u,v)] \quad \ldots\ldots (2)$$

Where $\Im^{-1}$ is the IDFT, F (u,v) is the DFT of the input image f (x,y), H (u,v) is the filter function and g (x,y) is the filtered output image. Specification of H (u,v) is simplified considerably by using functions that are symmetric about the center. This is accomplished by multiplying the input image by (-1) x+y prior to computing its transform.

III. Fingerprint Enhancement Methods

There is not any particular method of image enhancement. There are numerous techniques are available for fingerprint enhancement we need to choose between the choices of algorithms. When an image is processed the viewer is the judge who can decide how well a particular methods works. There have existed a variety of research activities along the ability of reducing noises and increasing the contrast between ridges and valleys in the gray-scale fingerprint images

3.1 Algorithm for Enhancing Fingerprint Images (B. G. Sherlock, D. M. Munro, and K. Millard) [1994]

In his proposed method Sherlock et al. [1] has described finger print image enhancement, based on non-stationary directional Fourier domain filtering. Fingerprints smoothed using directional filter and orientation is matched to local ridge orientation. The enhancement consists of filtering followed by thresholding stage. Filtering produces directionally smoothed version of the image from which most of the unwanted information has been removed. Thresholding yields the binary enhanced image. Experiment result leads to significant improvement in speed and accuracy of AFIS.

3.2 Fingerprint Image Enhancement: Algorithm and Performance Evaluation (L.Hong, Y.Wan & A.Jain)[1998]

L. Hong et al. [9] have developed a fingerprint enhancement algorithm in the minutiae extraction module. They incorporated a fast fingerprint enhancement algorithm, which can adaptively improve the clarity of ridge and valley structures of input fingerprint images based on the estimated local ridge orientation and frequency, was applied. Based on the local orientation and ridge frequency around each pixel, the Gabor filter is applied to each pixel location in the image. The performance of the image enhancement algorithm was evaluated using the goodness index of the extracted minutiae and the accuracy of an online fingerprint verification system. Experimental results show that incorporating the enhancement algorithm improves both the goodness index and the verification accuracy.

3.3 Hybrid Fuzzy Logic and Neural Network Model For Fingerprint Minutiae Extraction (Vijay Kumar Sagar and Koh Jit Beng Alex) [1999]

The presented research based on fuzzv- neuro technology in automated fingerprint recognition for the extraction of fingerprint features, known as minutiae. The work presented here is carried out earlier. In this research three minutiae extraction techniques presented are: classical approach, fuzzy approach and fuzzy neural approach. The hybrid fuzzy and neural network model performs the minutiae extraction in two stages, a fuzzy front-end and a neural back-end. Experiment results shows that using the fuzzy neural hybrid model, fingerprint minutiae extraction is more accurate since fewer false minutiae and more true minutiae are identified.

3.4 Fingerprint Image Enhancement using Filtering Techniques (S Greenberg, M. Aladjem, D. Kogan and I. Dimitrov) [2000]

S.Greenberg et al. [11] has proposed two methods for fingerprint image enhancement. The first one is based on using local histogram equalization, Wiener filtering, and image binarization. The second method is carried out by a unique anisotropic filter for direct grayscale enhancement. The results achieved are compared with those obtained through some other methods. Both methods show some improvement in the minutiae detection process in terms of either efficiency or time required.

3.5 New Enhancement Algoithm for Fingerprint Images (Byung-Gyu Kim, Han-Ju Kim and Dong-Jo Park) [2002]

Kim et al. [2] presented an improved algorithm for enhancement of fingerprint image on the basis of the image normalization and Gabor Filter. Firstly, the adaptive normalization based on block processing is suggested for improvement of fingerprint images. An input image is partitioned into sub-blocks with the size of K x L at first and the region of interest (ROI) of the fingerprint image is acquired. Secondly, a new technique for selection of two important parameters of Gabor filter is devised. The proposed algorithms were tested with NIST fingerprint images and show significant improvement in the experiments

3.6 A modified Gabor filter design method for fingerprint image enhancement (Jianwei Yang, Lifeng Liu, Tianzi Jiang,Yong Fan) [2003]

In this research work has proposed a novel filter design method for fingerprint image enhancement[5]. Yang developed an improved version of the TGF, called the modified Gabor filter (MGF). The modification of the TGF made the MGF more accurate in preserving the fingerprint image topography. The remarkable advantages of the MGF over the TGF consist in preserving fingerprint image structure and achieving image enhancement consistency. Experimental results indicate that the proposed MGF enhancement algorithm can reduce the FRR of a fingerprint matcher by approximately 2% at a FAR of 0.01%.

3.7 Fingerprint image Enhancement method using directional median Filter (Chaohong Wu, Zhixin Shi and Venu Govindaraju) [2004]

Chaohong Wu et al. [3] proposed a new approach to fingerprint image enhancement, which is based on integration of Anisotropic Filter and directional median filter (DMF). DMF join broken fingerprint ridges, fill out the holes of fingerprint images, smooth irregular ridges and remove some annoying small artifacts between ridges. Experiment results show that Gaussian-distribute noises are reduced by Anisotropic Filter and impulse noises efficiently by DMF.

3.8Fingerprint Enhancement and Matching by Genetic Algorithms (Xuejun Tan, Bir Bhanu)[2005]

In this paper, Xuejun Tan et al. propose a fingerprint-matching approach based on genetic algorithms (GA), which tries to find the optimal transformation between two different fingerprints. Enhancement has done by the the following steps: Block direction, computation, smoothing, segmentation and binarization. In order to deal with low-quality fingerprint images, which introduce significant occlusion and clutter of minutiae features, they design a fitness function based on the local properties of each triplet of minutiae. The experimental results on National Institute of Standards and Technology fingerprint database, NIST-4, not only show that the proposed approach can achieve good performance even when a large portion of fingerprints in the database are of poor quality, but also show that the proposed approach is better than another approach, which is based on mean-squared error estimation.

3.9 Adaptive Fingerprint Binarization by Frequency Domain Analysis (J. Strom Bartunek, M. Nilsson, J. Nordberg and I. Claesson) [2006]

J.S. Bartunek et al. [6] proposed a new method for fingerprint enhancement by using directional filters and binarization. They derived a technique where the proper size of the local area is automatically determined for each individual fingerprint. Frequency analysis is also carried out in local area to design directional filters. The proposed algorithm was tested on numerous fingerprint images taken from the different databases. The proposed adaptive fingerprint binarization algorithm shows a good ability to tune itself to each fingerprint image.

3.10 Fingerprint Image Enhancement Using STFT Analysis (Sharat S. Chikkerur, Alexander N. Cartwright and Venu Govindaraju) [2007]

S. Chikkerur et al. [12] introduced a new approach for fingerprint enhancement based on Short Time Fourier Transform (STFT) Analysis. STFT is a well known technique to analyze non-stationary signals. The algorithm estimates all

the intrinsic properties of the fingerprints such as the foreground region mask, local ridge orientation and local frequency orientation. Chikkerur compared the presented approach to other filtering method and showed that their technique performs efficiently. They also objectively measured the improvement in recognition rate due to enhancement and obtained a 17% improvement in the recognition rate on a set of 800 images from the FVC2002 database.

3.11Image Enhancement for Fingerprint Minutiae- Based Algorithms Using CLAHE, Standard Deviation Analysis and Sliding Neighborhood [2008]

Sepasian et al. [10] presented a method to investigate the performance of a three-step procedure for the fingerprint enhancement, using CLAHE (contrast limited adaptive histogram equalization) together with Clip Limit, standard deviation and sliding neighborhood as stages during processing of the fingerprint image. In first step CLAHE with clip limit is applied to enhance the contrast of the small tiles to eliminate the artificially induced boundaries existing in the fingerprint image. In a second step, the image is decomposed into an array of distinct blocks and the discrimination of the blocks is obtained by computing the standard deviation of the matrix elements to remove the image background and obtain the boundaries for the region of interest. In final step by using a slide neighborhood processing, an enhancement of the image is obtained by clarifying the Minutiae in each specific pixel, process known as thinning. The analysis of its possible advantages is carried out through a simulated investigation.

3.12 An enhancement algorithm for low quality fingerprint image based on edge filter and Gabor filter (Xue Jun-tao, Liu Jie & Liu Zheng-guang) [2009]

Jun-tao et al. [16] proposed an enhancement algorithm based on edge filter and Gabor filter. In first step, a gray based algorithm is used to enhance the edge and segment the image. Then a multilevel block size method is used to extract the orientation field from segmented fingerprint image. In final step, Gabor filter is used to fulfill the enhancement of the fingerprint image. The experiment results show that the proposed enhancement algorithm is effective than the normal Gabor filter algorithm. The fingerprint image enhance by the algorithm has better enhancement effect.

3.13 On Latent Fingerprint Enhancement (SoweonYoon, Jianjiang Feng and Anil K. Jain) [2010]

Yoon et al. [13**]** proposed a latent fingerprint enhancement algorithm which requires manually marked region of interest (ROI) and singular points. The core of the proposed enhancement algorithm is a novel orientation field estimation algorithm, which fits orientation field model to coarse orientation field estimated from skeleton outputted by a commercial fingerprint SDK. Experimental results on NIST SD27 latent fingerprint database indicate that by incorporating the proposed enhancement algorithm, the matching accuracy of the commercial matcher was significantly improved.

3.14 A New Framework for improving low Quality Fingerprint Images (J. Choudhary, Dr.S. Sharma, J.S. Verma) [2011]

This method present a fingerprint image enhancement method which can adaptively improve the clarity of ridge and furrow structures of input fingerprint image based on the frequency and spatial domain filtering, local orientation estimation, local frequency estimation and morphological operation. The proposed Enhancement algorithm is tested on 100 fingerprint images which are selected randomly and without repetition from database DB-finger to evaluate the efficiency. There set of operation applied on the database DB-Finger that Improve the quality of fingerprint Image.

3.15 An Efficient Fuzzy Based Filtering Technique for Fingerprint Image Enhancement (K. Srinivasan and C. Chandrasekar) [2012]

K. Srinivasan et al. [8] developed an efficient fingerprint enhancement technique via fuzzy based filtering. In his work they employed a fuzzy modeling approach for removing the noise as well as for improving the luminosity of the ridges. Moreover, the fuzzy filter values are evaluated and superior results are produced in the image domain. The probabilities of gray values are measured from the position of the input image pixel. The proposed technique is implemented in MATLAB. The quality of the reconstructed images is determined by measuring the PSNR of FVC2002 fingerprint database. The proposed fingerprint enhancement system using fuzzy based filtering techniques gives high PSNR and low MSE when compared to the Gabor filtering based fingerprint enhancement method.

3.16 Fingerprint Image Enhancement: Segmentation to Thinning (I. G. Babatunde, A. O.Charles, A. B. Kayode and O. Olatubosun) [2012]

I.G. Babatunde et al. [9] modified some of the submodels of an existing mathematical algorithm for the fingerprint image enhancement to obtain new and improved versions. The new versions consist of different mathematical models for fingerprint image segmentation, normalization, ridge orientation estimation, ridge frequency estimation, Gabor filtering, binarization and thinning. The implementation was carried out in an environment characterized by Window Vista Home Basic operating system as platform and Matrix Laboratory (Matlab) as frontend engine. The results show that the modified sub-models perform well with significant improvement over the original versions. The results also show the necessity of each level of the enhancement.

IV. CONCLUSION

During this different techniques of fingerprint enhancement of fingerprint are studied. Most of the existing enhancement techniques are based on Gabor filter. Gabor filters are both frequency and orientation selective tuned by ridge

direction and ridge frequency. It works on both spatial and frequency domains. The main drawback of these methods lies in the fact that false estimate of local ridge direction will lead to poor enhancement. Gabor filter is time consuming and parameter selection such as ridge centre frequency, radial bandwidth and central orientation, requires am empirical setup. There are also some more techniques for this purpose such as normalization, ridge orientation estimation, ridge frequency estimation, region of interest extraction, block direction, computation, segmentation, filtering, binarization, morphological thinning then the final step minutiae extraction and matching. Techniques using histogram equalization which is followed by binarization with further preprocessing gives very good results and consumes less time as compared to Gabor filters.

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