www.ijecs.in
International Journal Of Engineering And Computer Science ISSN:2319-7242
Volume 3 Issue 6 June, 2014 Page No. 6389-6394

Comparative Analysis of Various Fingerprint Image Enhancement Algorithms

Navjot Kaur[1] , Gagandeep Singh[2] , Sahil Vashist[3]

[1]M Tech Scholar, Dept. of CSE , Chandigarh Engineering College,
Landran , Mohali , Punajb
nknavjot1@gmail.com

[2]Assistant Professor, Dept. of CSE , Chandigarh Engineering College,
Landran , Mohali ,Punjab

[3]Assistant Professor, Dept. of CSE , Chandigarh Engineering College,
Landran , Mohali ,Punjab

Abstract: ***There are various biometric features for personal identification but Fingerprints are today the most widely used biometric features for the same. Many automatic systems are there for fingerprint enhancement which is based on ridges and valleys. Automatic fingerprint recognition system is totally based on Fingerprint enhancement. It is necessary to choose the suitable enhancement technique for fingerprint, in order to reduce the post-processing part of the fingerprint recognition system. Different Fingerprint Enhancement techniques have been discussed in this work. These different methods are used by which the image quality is enhanced and Fingerprint Matching techniques are applied. These algorithms contribute to recognize the person and provide authenticity on the basis of physiological or behavioral characteristic possessed by the user. But, author's focus is on the methods of enhancement. By having the proper analysis of all the existing methods and algorithms, author can review the literature of fingerprint image enhancement methods, so as to design a new advanced and modified method for the same. With the help of these techniques we can prepare a system which is helpful to enhance the watermarked fingerprints.***

Keywords: Fingerprints, Ridge, valley, Enhancement and Recognition.

1. Introduction

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 [1].

Figure 1: A fingerprint image obtained by optical sensor

Due to the above mentioned properties, fingerprints are very popular as biometrics measurements. Especially, in law enforcement, where they have been used over a hundred years to help solve crime, unfortunately fingerprint matching is a complex pattern recognition problem. Manual fingerprint matching is not only time consuming but education and training of experts takes a long time. Therefore since 1960s there have been done a lot of effort on development of automatic fingerprint recognition systems. Automation of the fingerprint recognition process turned out to be success in forensic applications. Achievements made in forensic area expanded the usage of the automatic fingerprint recognition into the civilian applications. Fingerprints have remarkable permanency and individuality over the time. The observations showed that the fingerprints offer more secure and reliable person identification than keys, passwords or id-cards can provide. Examples such as mobile phones and computers equipped with fingerprint sensing devices for fingerprint based password protection are being produced to replace ordinary password protection methods. Those are only a fraction of civilian applications where fingerprints can be used [1].

The method that is selected for fingerprint matching was first discovered by Sir Francis Galton. In 1888 he observed that fingerprints are rich in details also called minutiae in form of discontinuities in ridges. He also noticed that position of those minutiae doesn't change over the time. Therefore minutiae matching are a good way to establish if two fingerprints are from the same person or not.

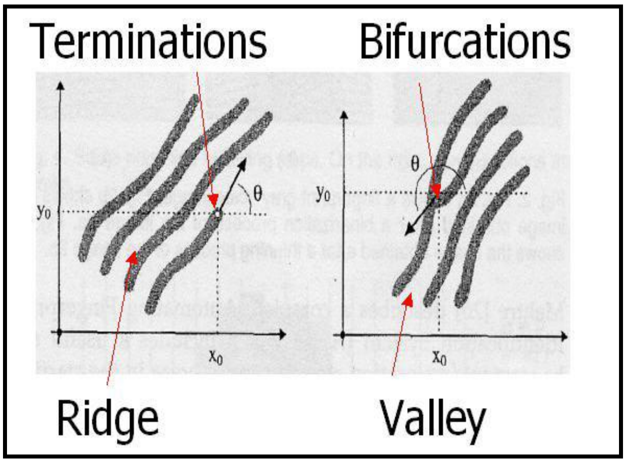


Figure 2: Minutiae (Valley is also referred as Furrow, Termination is also called Ending and Bifurcation is called Branch)

The two most important minutiae are termination and bifurcation, 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. The fingerprint recognition problem can be grouped into two sub-domains: one is fingerprint verification and the other is fingerprint identification.

1.1 Fingerprint Enhancement Techniques

A critical step in Automatic Fingerprint matching system is to automatically and reliably extract minutiae from input finger print images. However the performance of the Minutiae extraction algorithm relies heavily on the quality of the input fingerprint image. In order to ensure to extract the true minutiae points it is essential to incorporate the enhancement algorithm.

There are two ways in which author can enhance the input fingerprint image.

1. Binarization method.
2. Direct gray-level enhancement.

Binarization Method: The ridge structures in fingerprint image are not always well defined, and therefore, an enhancement algorithm is needed to improve the clarity of the ridge and valley structure. The first method of enhancement algorithm is Binarization-based fingerprint image enhancement. This process is carried out using Local Histogram Equalization, Weiner filtering, and image Binarization. Author use local Histogram equalization for contrast expansion and wiener filtering for noise reduction. The binarization process is applied by adaptive thresholding based on the local intensity mean. Finally Morphological filtering is applied to eliminate artifacts in the noise regions and to fill some gaps in valid ridgelines.

In some Binarization-based approaches the Binarization and thing process are preceded by a smoothing operation, based on convolution with a Gaussian mask, in order to regularize the starting image. The main stages in this algorithm include the following:

- Histogram equalization defines a mapping of gray-levels into gray levels such that the distribution of gray level is uniform. This mapping stretches the contrast (expands the range of gray levels) for gray levels near the histogram maxima. Histogram equalization is done by using a local window of 11X 11 pixels. This results in expanding the contrast locally, and changing the intensity of each pixel according to its local neighborhood.

- Wiener method is used for noise reduction. In this pixels-wise adaptive Wiener Filtering is carried out. The filter is based on local statistics estimated from a local neighborhood η of size 3X3 of each pixel.

- The operation that converts a grayscale image into a binary image is known as Binarization. Binarization process is carried out using an adaptive thresholding. Each pixel is assigned a new value (0 or 1) according to the intensity mean in local neighborhood. Thinned (one pixel thickness) ridge lines are obtained using morphological thinning operation.

- In the thinned binary image there appears noise like: False fridge line and gaps within a true ridge lines. The false ridgeline connections are almost perpendicular to local ridge direction. Therefore, lines with similar features are automatically removed by the post-processing and binary filtering.

2. Related Works

2.1 An Improved Method for Extraction of Fingerprint Features without Binarization

This work presents a fingerprint feature extraction method through which minutiae are extracted directly from original gray-level fingerprint images without binarization and thinning. Author's algorithm improves the performance of the existing ones along this stream. Author's experimental results demonstrate that their approach can achieve better performance in both efficiency and robustness. Author not only traced the ridges in the whole fingerprint and recorded the skeleton image, but also acquired the minutiae. Author's methods achieved good performance in both robustness and efficiency. Some experimental results are shown in figure 3. In this work, author have proposed an improved method to extract the minutiae from the original gray-level fingerprint images without the steps of binarization and thinning. The experimental results in figure 3, demonstrate that the minutiae can be extracted from original gray-level fingerprints with good performance in both efficiency and robustness [1].

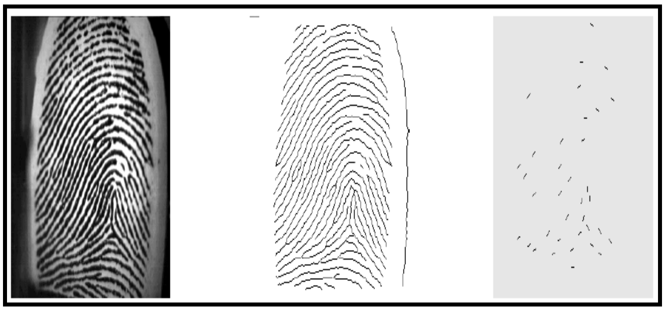


Figure 3: Input fingerprints and corresponding skeleton images and minutiae

2.2 Fingerprint minutiae extraction and matching for identification procedure based on minutiae points algorithms

This work implements the identification procedure: it matches one fingerprint among N fingerprints. It uses minutiae points based algorithms: in the enrolment step, the points are extracted from the print. Later on, during the authentication step, the points are matched. The first step is implemented using fingerprint enhancement (figure 4) and minutia filtering (figure 5). The second step is realised using Ransac under an affine transformation model. Initially, the overall results were not so good, especially with low quality prints. The main reason is because the minutia point detector does not give accurate results. Added to that, low quality print contains a lot of noise and scratches that lead to false minutia points. Finally, this algorithm worked well on all the kind of print, used for training and prints with a high contrast. Author did not tuned it on a lot of prints, that is why the overall results are not so great [2].

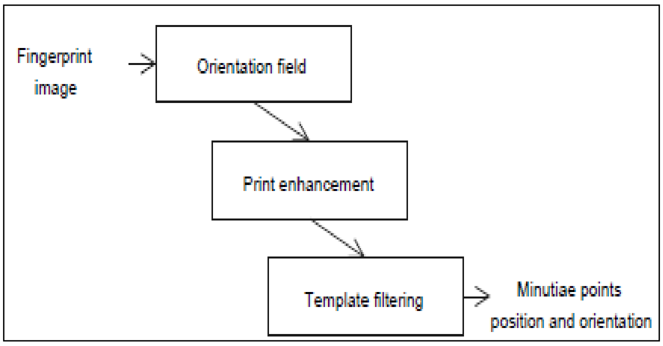


Figure 4: Minutiae points' extraction steps

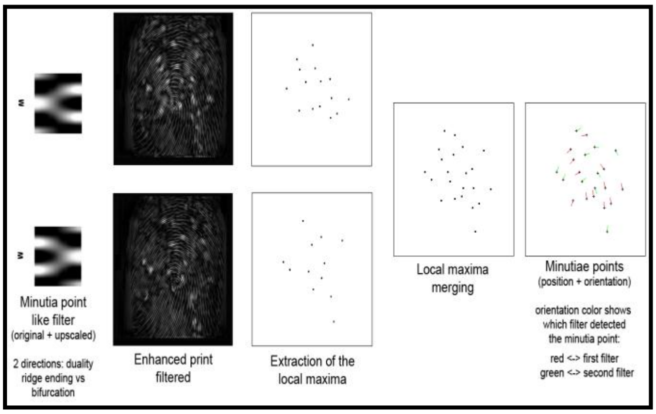


Figure 5: Template filtering algorithm

2.3 Curved-Region-Based Ridge Frequency Estimation and Curved Gabor Filters for Fingerprint Image Enhancement

Gabor filters (GFs) play an important role in many application areas for the enhancement of various types of images and the extraction of Gabor features. For the purpose of enhancing curved structures in noisy images, author introduces curved GFs that locally adapt their shape to the direction of flow. These curved GFs enable the choice of filter parameters that increase the smoothing power without creating artefacts in the enhanced image. In this work, curved GFs are applied to the curved ridge and valley structures of low-quality fingerprint images. Author has combined two orientation- field estimation methods in order to obtain a more robust estimation for very noisy images. Next, curved regions are constructed by following the respective local orientation. Subsequently, these curved regions are used for estimating the local ridge frequency. Finally, curved GFs are defined based on curved regions, and they apply the previously estimated orientations and ridge frequencies for the enhancement of low-quality fingerprint images. Experimental results (figure 6) on the FVC2004 databases show improvements of this approach. This work has described a method for RF estimation using curved regions and image enhancement by curved GFs. For low-quality fingerprint images, in comparison with existing enhancement methods, improvements of the matching performance have also been done. The RF estimation can be further accelerated if an estimate is computed only, for example, for every fourth pixel horizontally and vertically instead of a pixel-wise computation. These computing times indicate the practicability of the presented method for online verification systems. In author's opinion, the potential for further improvements of the matching performance rests upon a better OF estimation. As long as OF estimation errors occur, it is necessary to choose the size of the curved GFs and the standard deviations of the Gaussian envelope with care in order to balance strong image smoothing while avoiding spurious features [3].

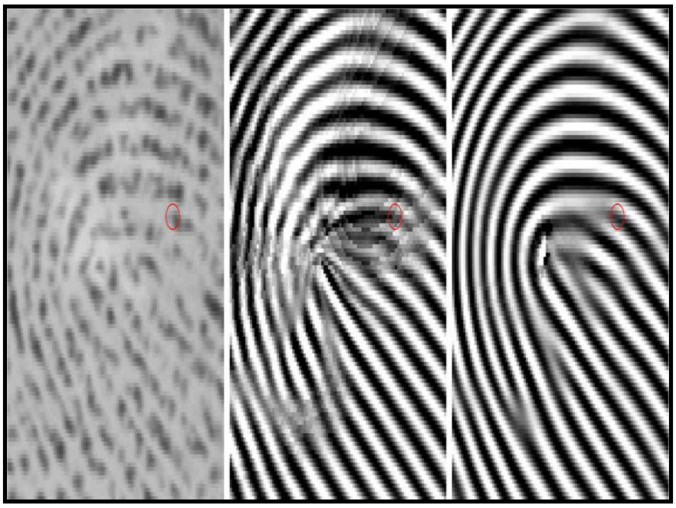


Figure 6: Detail on the left (impression 1 of finger 90 in FVC2004 database 4) is enhanced by Gabor filtering using (center) full rectangular windows and (right) full curved regions. Both filters resort to the same OF estimation and the same RF estimation based on curved regions.

2.4 Orientation Field Estimation for Latent Fingerprint Enhancement using a Dictionary of Reference Orientation Patches

A robust orientation field estimation algorithm is indispensable for enhancing and recognizing poor quality latents. However, conventional orientation field estimation algorithms, which can satisfactorily process most live-scan and inked fingerprints, do not provide acceptable results for most latents. There is a consensus in the fingerprint community that the capability of state-of-the-art fingerprint recognition systems is still not comparable to the ability of fingerprint examiners. This is particularly true for low-quality latent fingerprint matching. For this reason, manual mark-up of various features (such as minutiae) in latent's is a common practice in forensics. Author believes that a major limitation of conventional algorithms is that they do not utilize prior knowledge of the ridge structure in fingerprints. Inspired by spelling correction techniques in natural language processing, author propose a novel fingerprint orientation field estimation algorithm based on prior knowledge of fingerprint structure. Author represent prior knowledge of fingerprints using a dictionary of reference orientation patches, which is constructed using a set of true orientation fields, and the compatibility constraint between neighbouring orientation patches. Orientation field estimation for latents is posed as an energy minimization problem, which is solved by loopy belief propagation. Experimental results (figure 7) on the challenging NIST SD27 latent fingerprint database and an overlapped latent fingerprint database demonstrate the advantages of the proposed orientation field estimation algorithm over conventional algorithms [4].

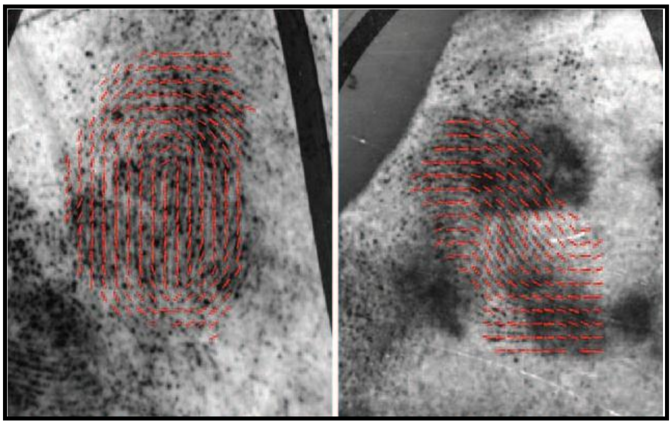


Figure 7: Minutiae extraction of two different images

Figure 8: (a). Rough snap shot of input fingerprint

(b). Enhanced and extracted fingerprints of input image

2.5 Segmentation and Enhancement of Latent Fingerprints: A Coarse to Fine Ridge Structure Dictionary

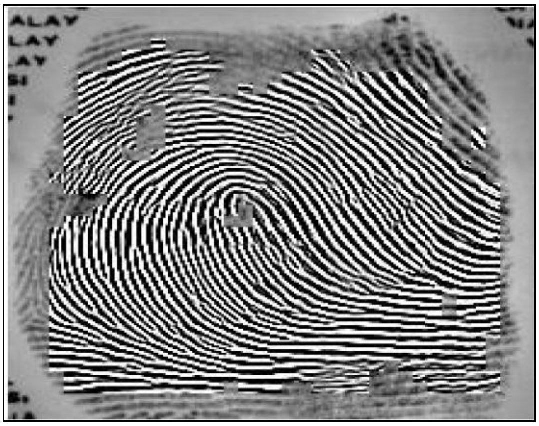
In this work, a dictionary-based approach is proposed for automatic latent segmentation and enhancement towards the goal of achieving "lights-out" latent identification systems.

Latent fingerprint matching has played a critical role in identifying suspects and criminals. However, compared to rolled and plain fingerprint matching, latent identification accuracy is significantly lower due to complex background noise, poor ridge quality and overlapping structured noise in latent images. Accordingly, manual markup of various features (e.g., region of interest, singular points and minutiae) is typically necessary to extract reliable features from latents. To reduce this markup cost and to improve the consistency in feature markup, fully automatic and highly accurate ("lights-out" capability) latent matching algorithms are needed. Given a latent fingerprint image, a total variation (TV) decomposition model with $L1$ fidelity regularization is used to remove piecewise-smooth background noise. The texture component image obtained from the decomposition of latent image is divided into overlapping patches. Ridge structure dictionary, which is learnt from a set of high quality ridge patches, is then used to restore ridge structure in these latent patches. The ridge quality of a patch, which is used for latent segmentation, is defined as the structural similarity between the patch and its reconstruction. Orientation and frequency fields, which are used for latent enhancement, are then extracted from the reconstructed patch. To balance robustness and accuracy, a coarse to fine strategy is proposed. Experimental results on two latent fingerprint databases (author.e., NIST SD27 and WVU DB) show that the proposed algorithm outperforms the state-of-the-art segmentation and enhancement algorithms and boosts the performance of a state-of-the-art commercial latent matcher. Although state of the art AFIS have already achieved impressive accuracy in ten print search (rolled prints or slaps), latent matching or search is still a challenging problem due to presence of complex background noise and poor quality of friction ridge structure in many latent's. Author have proposed an automatic latent segmentation and enhancement algorithm based on image decomposition and coarse to fine ridge structure dictionaries. Experimental results on two different latent fingerprint databases, NIST SD27 and WVU DB, in conjunction with three different COTS matchers show that the proposed algorithm is able to improve the performance of two COTS ten print matchers and can even boost the performance of a state-of-the-art latent matcher by weighted match score fusion [5].

2.6 Fingerprint Image Enhancement based on the estimated local ridge orientation and frequency

Author present 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. Author have evaluated the performance of the image enhancement algorithm using the goodness index of the extracted minutiae and the accuracy of an online fingerprint verification system. A critical step in automatic fingerprint matching is to automatically and reliably extract minutiae from the input fingerprint images. However, the performance of a minutiae extraction algorithm relies heavily on the quality of the input fingerprint images. In order to ensure that the performance of an automatic fingerprint identification/verification system will be robust with respect to the quality of input fingerprint images, it is essential to incorporate a fingerprint enhancement algorithm in the minutiae extraction module. Author have developed a fast fingerprint enhancement algorithm which can adaptively improve the clarity of ridge and valley structures based on the local ridge orientation and ridge frequency estimated from the inputed image. The performance of the algorithm is evaluated using the goodness index of the extracted minutiae and the performance of an online fingerprint verification system which incorporates author's fingerprint enhancement algorithm in its minutiae extraction module. Experimental results show that author's enhancement algorithm is capable of improving both the goodness index and the verification performance. The algorithm also identifies the unrecoverable corrupted regions in the fingerprint and removes them from further processing. This is a very important property because such unrecoverable regions do appear in some of the corrupted fingerprint images and they are extremely harmful to minutiae extraction. These properties suggest that author's enhancement algorithm should be integrated into an online fingerprint verification/identification system. The global ridge and valley configuration of fingerprint images presents a certain degree of regularity. A global model of the ridges and valleys that can be constructed from partial "valid" regions can be used to correct the errors in the estimated orientation images, which, in turn, will help the enhancement. Currently, author are investigating such a model-based enhancement algorithm. The configurations of ridges and valleys within a local neighbourhood vary with the quality of input fingerprint images, so well-defined sinusoidal-shaped waves of ridges and valleys may not always be observed. Global features are needed for a more precise region mask classification. Experimental results (figure 9) show that incorporating the enhancement algorithm improves both the goodness index and the verification accuracy [6].

Figure 9: (a). Rough snap shot of input fingerprint



(b). Enhanced and extracted fingerprints of input image

3. Conclusion

Fingerprint recognition is a challenging problem and there is still a lot of work that needs to be done in this area. Over the past ten years, fingerprint enhancement and recognition has received substantial attention from researchers in biometrics, pattern recognition, image processing, and cognitive psychology communities. This common interest in fingerprint enhancement technology among researchers working in diverse fields is motivated both by the remarkable ability to recognize people and by the increased attention being devoted to security applications. Applications of fingerprint recognition can be found in security, tracking, multimedia, and entertainment domains. For low-quality fingerprint images, in comparison with existing enhancement methods, an improvement of the matching performance is very much needed. In future we will propose a method which describes a method for ridge frequency estimation using curved regions and image enhancement by curved some advanced adaptive filters.

Acknowledgement

The author would like to thank Amanpreet , Manpreet and the anonymous reviewers for their valuable comments.

References

[1] J. Yang, Lifeng Liu, and Tianzi Jiang, “An Improved Method for Extraction of Fingerprint Features” National Laboratory of Pattern Recognition, Institute of Automation, Chinese Academy of Sciences, Beijing 100080, P. R. China.

[2] Philippe Parra, “Fingerprint minutiae extraction and matching for identification procedure” Department of Computer Science and Engineering University of California, San Diego La Jolla, CA 92093-0443.

[3] Carsten Gottschlich, “Curved-Region-Based Ridge Frequency Estimation and Curved Gabor Filters for Fingerprint Image Enhancement” IEEE TRANSACTIONS ON IMAGE PROCESSING, VOL. 21, NO. 4, APRIL 2012.

[4] Jianjiang Feng, Jie Zhou, Anil K. Jain, “ Orientation Field Estimation for Latent Fingerprint Enhancement” IEEE TRANSACTIONS ON PATTERN ANALYSIS AND MACHINE INTELLIGENCE, VOL. 35, NO. 4, APRIL 2013.

[5] Kai Cao, Eryun Liu, Anil K. Jain, “Enhancement of Latent Fingerprints: A Coarse to Fine Ridge Structure Dictionary” IEEE Transactions on Pattern Analysis and Machine Intelligence Segmentation.

[6] L. Hong, Y. Wan, and A. K. Jain, “Fingerprint image enhancement: algorithm and performance evaluation”, IEEE Transactions on Pattern Analysis and Machine Intelligence 20(8), pp. 777-789.