iJRASET
International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 3 **Issue:** IV **Month of publication:** April 2015

DOI:

www.ijraset.com

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Volume 3 Issue IV, April 2015
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

A Review on Various Fingerprint Recognition and Enhancement Techniques

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Abstract--Fingerprint image enhancement is required to make the image clearer for subsequent operations. Since the fingerprint images obtained from sensors or the other media are not assured with perfect quality, the various enhancement methods are required for raising the contrast between ridges and furrows and for connecting the false broken points of ridges due to insufficient level of ink, are very useful for keeping a higher accuracy to fingerprint recognition. Fingerprint images are rarely of perfect quality as they may be damaged or corrupted due to variations in impression conditions. Quality of fingerprint images plays a vital role in the performance of automatic identification and verification algorithms. Thus, image enhancement techniques are required prior to minutiae extraction to obtain a more reliable estimation of minutiae locations. This paper presents various approaches for fingerprint image enhancement.

I. INTRODUCTION

Fingerprints have been used for over a decades and are the most common method used form of biometric authentication. Fingerprint authentication is commonly used in forensic science to support criminal findings, and in biometric systems such as commercial identification and recognition devices. The fingerprint of an individual is completely different from any other individual and remains unchanged over a lifetime. A fingerprint is formed by an impression of the ridges pattern on a finger. A ridge is defined as a curved segment, and a valley is the area between two adjacent ridges. The minutiae, which are the local irregularities in the ridge flow pattern, provides the features that are used for authentication [2].

The most popular and widely used bio recognition system is fingerprint recognition system because of the fact that fingerprints of different human are unique and remain same during the entire lifetime. Even twins have different fingerprint pattern. A fingerprint can be seen as smoothly varying line pattern formed by separate crest (ridges) and troughs (valleys) on the surface of the finger [5].

Figure 1: A ridge ending and a bifurcation example.

Fingerprint is one of the famous method used for personal recognition or identification, a fatal Fingerprint ridges are formed during the third to fourth month of its development. The ridge begins to develop on the skin of the thumbs and fingers. The objective of these ridges is to give the fingers a strong grasp and to avoid slippage over anything. thus allow the us to grasp and pick up the objects [7].

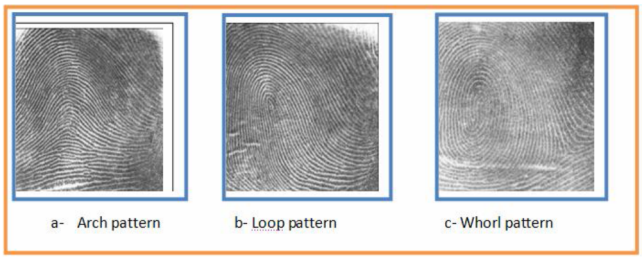

Figure 2: Types of fingerprint patterns.

The three most basic patterns of fingerprint ridges are the arch, loop, and whorl as shown in figure (2).
Arch Pattern- The ridges enter from one side of the finger, rise in the center forming an arc, and then exit the other side of the finger.
Loop Pattern- The ridges enter from one side of a finger, form a curve, and then exit on that same side.
Whorl Pattern:- Ridges form circularly around a central point on the finger.
About 65 percent of people in the total population has loops, 30 percent have whorls, and 5 percent have arches.
The various types of minutiae points are shown below. Prior to feature extraction and matching the clarity of ridges and valleys of the fingerprint image should be improved to make them more suitable for the minutiae extraction algorithm i.e. minutiae can be extracted easily for the matching purpose [7].

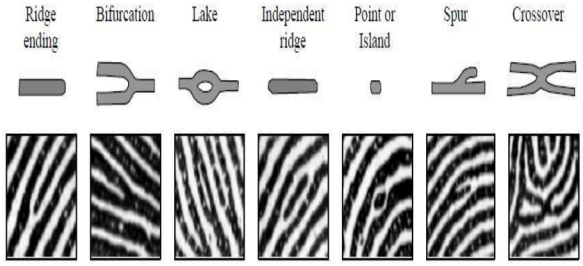

Figure 3. Various Types of Minutiae

The most common approach to implement a minutia extractor is a three-stage approach. The preprocessing, minutia extraction and post processing stage as shown in figure (4).

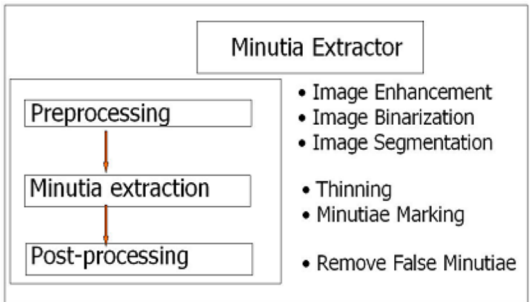

Figure 4: Minutia extractor

Fingerprint images are rarely of good quality. They may be damaged and corrupted with elements of noise due to many factors including variations in skin and impression conditions. This damage or degradation can result in a significant number of spurious minutiae being created and genuine minutiae being ignored. A critical step in studying the statistics of fingerprint minutiae is to reliably extract minutiae from fingerprint images. Thus, it is necessary to use image enhancement techniques prior to minutiae extraction to obtain a more reliable estimate of minutiae locations [1].

A. The Proposed Fingerprint Algorithm

In a fingerprint, the dark lines of the image are called the ridges and the white area between the ridges is called valleys. This work is done applying several steps to achieve our goal:

1) Collect several fingerprint image for the same person.
2) Construct a specific fingerprint database.
3) Classify the fingerprint according to their characteristics.
4) Construct the algorithm to recognize the pattern.
5) Test the implemented algorithm to check its accuracy.

The implemented algorithm is constructed via several components as shown in figure (5).

Volume 3 Issue IV, April 2015
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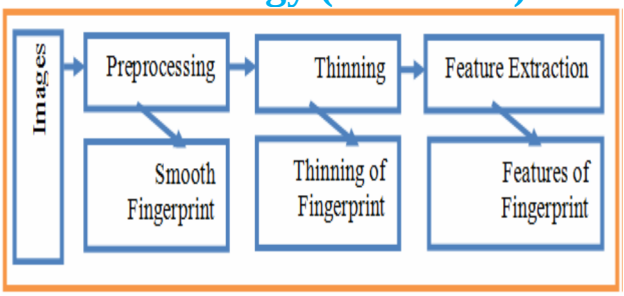

Figure 5. Components of fingerprint system

1) *Preprocessing Process:* Preprocessing process refers to the process of preparing the input fingerprint image to be ready for the next step of the system, in which it produces a good enough quality of output fingerprint image. Preprocessing of image contains the following steps .

Image acquisition.
Converting the input image into gray scale image.
Remove the not needed parts from the image.
Make orientation of image into exact position.
Noise removal operation such that fingerprint pattern are not affected.
Image resizing into exact size.

2) *Thinning Process:*Thinning process refers to the process of reducing the thickness of the lines as possible with minimum losses. This process is so important to identify the exact pattern of the fingerprint image. Fingerprint thinning process offered the following performance:

Lines of output image should be a single pixel as possible.
Lines of output image should not have any discontinuity as possible.
Lines of output image should be return to its centre pixel as possible.
Eliminate all redundancy and unwanted pixels.

3) *Feature Extraction Proces:* Feature extraction process depends on the above processes and it is the main part of the overall system in which it extracts the required characteristic of the fingerprint pattern. This process is very sensitive process and concentrated on illuminate the required characteristics of the Minutiae's; this can be implemented via Minutiae detection and Minutiae enhancement and Minutia extraction.

II. LITERATURE SURVEY

A. *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 valleys. After the operation, ridges in the fingerprint are highlighted with black color while valleys are white. A binarization method is performed to binarize the fingerprint image. That named method comes from the mechanism of transforming a pixel value to 1 if the value is larger than the mean intensity value of the current block (16x16) to which the pixel belongs.

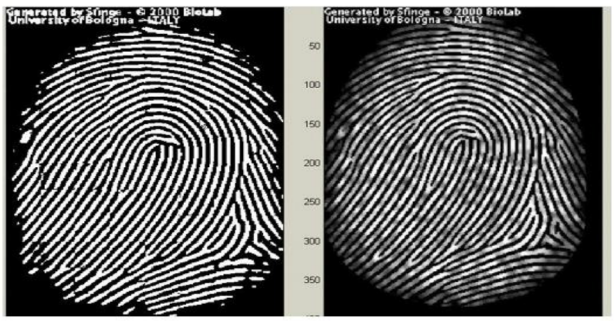

Figure 6. Binarization

B. Fingerprint Image Segmentation

In general, only a Region of Interest (ROI) is useful to be recognized for each fingerprint image. The image part without effective ridges and furrows is first discarded since it only holds the background information. Then the 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. For extract the ROI, a two-step method is used. Step first is block direction estimation and direction variety check [5], while the second is intrigued from some Morphological methods.

1) Block direction estimation: 1.1 Estimate the block direction for each block of the fingerprint image with WxW in size (W is 16 pixels by default).

The algorithm is:

I. Calculate the gradient values along x-direction (gx) and y-direction (gy) for each pixel of the block.

II. For each block, use Following formula to get the Least Square approximation of the block direction.

tg2ß = 2 ∑∑ (gx*gy)/∑∑ (gx2-gy2) for all the pixels in each block. The formula is easily understand by regarding gradient values along x-direction and y-direction as cosine value and sine value. So the tangent value is estimated nearly the same as the way illustrated by the following formula.

tg2□ = 2sin□cos□ / (cos2□ -sin2□)

1.2 After finished with the estimation of block direction, blocks without significant information on ridges and furrows are discarded based on the following formulas:

E = {2 ∑∑ (gx*gy) + ∑∑ (gx2gy2)}/W*W*∑∑(gx2+gy2)

For each block, if its certainty level E is below a threshold value, then the block is regarded as a background block. Direction map is shown in the following diagram. Assume there is only one fingerprint in each image.

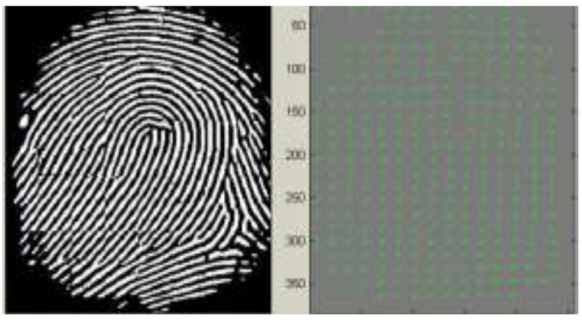

Figure 7. Direction map.
Binarized fingerprint (left), Direction map (right**)**

2) Roi Extraction By Morphological Operations: Two Morphological operations called „OPEN" and „CLOSE" 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.

C. Image Enhancement Using Filters

Generally filters are used to filter unwanted things or object in a domain or surface. In digital image processing, mainly the images are affected by various noises. The main purpose of the filters are to improve the quality of image by enhancing is to improve interoperability of the information present in the images for human visual.

Low- pass filter is a type of filter used for the image enhancement. It preserves the smooth region in the image and removes the sharp variation leading to blurring effect. The frequency domain technique is based on the convolution theorem. It decomposes an image from its spatial domain form of brightness into frequency domain components.

Gabor filter being a band pass filter has both orientation-selective and frequency-selective properties and has optimal joint resolution in both spatial and frequency domain therefore, a Gabor filter which is a band pass filter tuned to the corresponding frequency and orientation can effectively removes the undesired noise and preserve the ridge-valley structure of the fingerprint image. The Gabor filter is a two-dimensional filter formed by the combination of a cosine with a two-dimensional Gaussian function and it has the general form:

$g(x, y, \theta, f, \sigma x; \sigma y) = \exp\{-1/2[x_\theta^2/\sigma_x^2+y_\theta^2/\sigma_y^2]\} \cos(2\pi.f.x_\theta)$ (1)

x_θ = x.cos ɵ + y.sin ɵ (2)

y_θ = -x.sin ɵ + y.cos ɵ (3)

In (1), the Gabor filter is centered at the origin. ɵ denotes the rotation of the filter related to the x-axis and f the local frequency. σ_x and σ_y signify the standard deviation of the Gaussian function along the x- and y-axis, respectively.

The main advantage of curved Gabor filters is that they enable the choice of larger curved regions and high values for σ_x and σ_y without creating spurious features. In this way, curved Gabor filters have a much greater smoothing potential in comparison to traditional GF. For curved GFs, the only limitation is the accuracy of the OF and RF estimation, and no longer the filter itself.

Methods	Based On	Advantage
Enhance the image's contrast	CLAHE(contrast limited adaptive histogram equalization)	Eliminate the artificially induced boundaries.
Extract the ROI	Block direction estimation	Blocks without significant information on ridges and furrows are discarded.
Improved images using filters	Curve Gabor filter	Curved Gabor filters have a much greater smoothing potential in comparison to traditional GF.

II. CONCLUSION

Since the fingerprint images obtained from sensors are not with perfect quality therefore various enhancement methods are required for increasing the contrast between ridges and furrows and for connecting the false broken points of ridges due to insufficient level of ink, are very useful for keeping a higher accuracy to fingerprint recognition. Thus, it is necessary to employ image enhancement techniques prior to minutiae extraction to obtain a more reliable estimate of minutiae locations.

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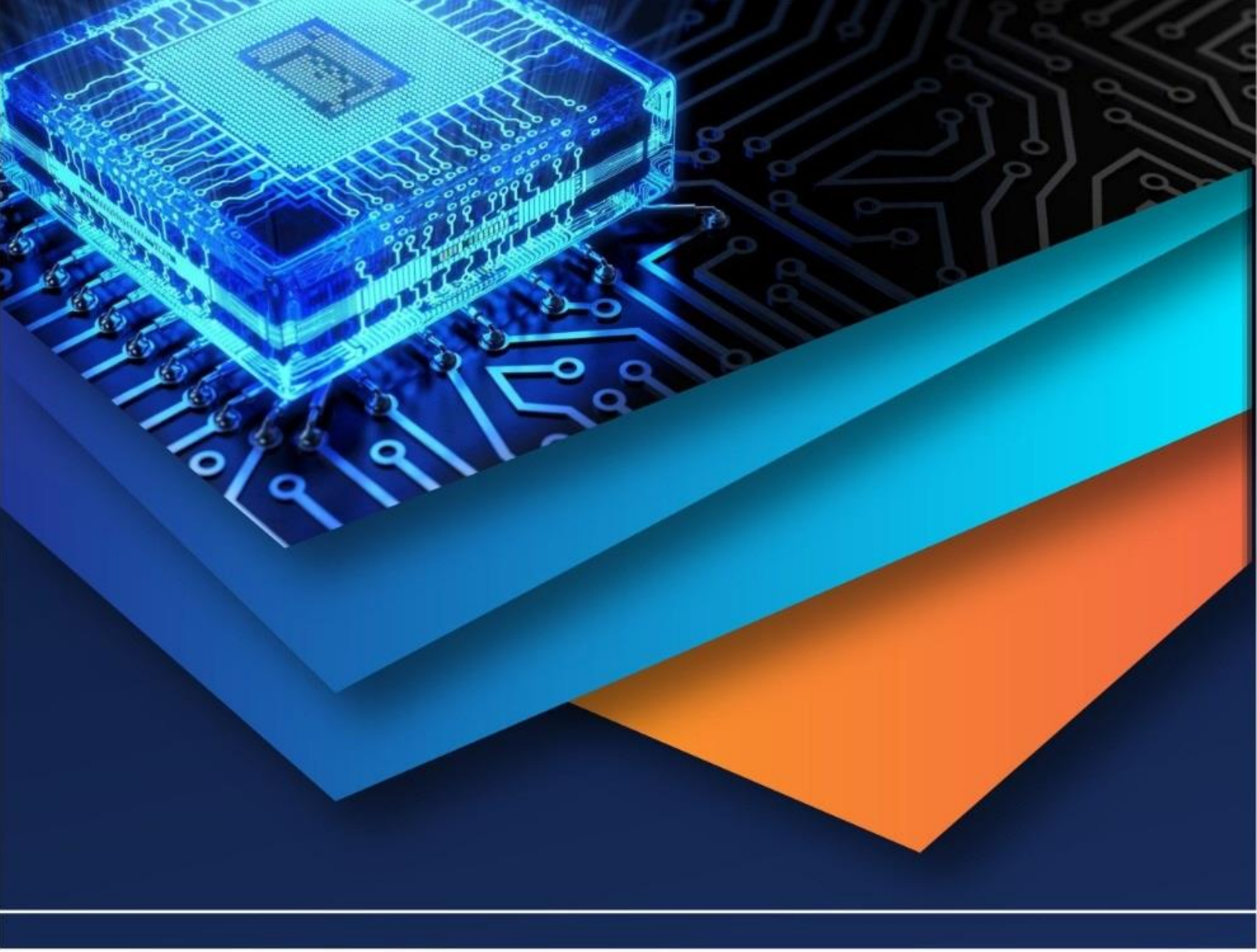

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