Fingerprint Recognition

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Abstract – Fingerprint recognition is one of the most popular and successful methods used for person identification, which takes advantage of the fact that the fingerprint has some unique characteristics called minutiae; which are points where a curve track finishes, intersect with other track or branches off. Biometric identification systems using fingerprints patterns are called AFIS (Automatic Fingerprint Identification System). In this paper a novel method for Fingerprint recognition is considered using a combination of Fast Fourier Transform (FFT) and Gabor Filters to enhancement the fingerprint image was captured using a UareU 4000 fingerprint reader of Digital Person, Inc.

Index Terms - AFIS, FFT, Minutiaes, Recognition. Gabor filters

I. INTRODUCTION

THE biometrics is the automatic person identification claimed identity verification of an individual by using certain physiological or behavioral features associated with a given person. Traditionally, passwords (knowledge-based security) and ID cards (token-based security) have been used to access control to restricted systems or places. However, security can be easily breached in these systems when a password is divulged to an unauthorized user or a card is stolen. Furthermore, simple passwords are easy to guess by an impostor, while difficult passwords may be hard to recall a legitimate user. The emergence of biometrics technology has provided an attractive alternative to solve the problems still present in traditional verification methods.

Fingerprints are fully formed during the first seven months of the fetus development and the finger ridge configurations do not change throughout the life of an individual except, due to accidents such as bruises and cuts on the fingertips [1], [2]. This property makes fingerprints a very attractive biometric identifier. Biological organisms, in general, are the consequence of the interaction of genes and environment [1].

Fingerprint recognition represents the oldest method of biometric identification. Its history is going back as far as at least 2200 BC [3]. The use of fingerprints as a personal code has a long tradition and was already used by the Assyrians, the Babylonians, the Chinese and the Japanese [3]. Since 1897, dactyloscopy (synonym for non-computer-based fingerprint identification) has been used for criminal identification.

A fingerprint consists of ridges (lines across fingerprints) and valleys (spaces between ridges). The pattern of the ridges and valleys is unique for each individual. The probability of finding two fingerprints similar is of $1.9x10^{15}$ [1], [2].

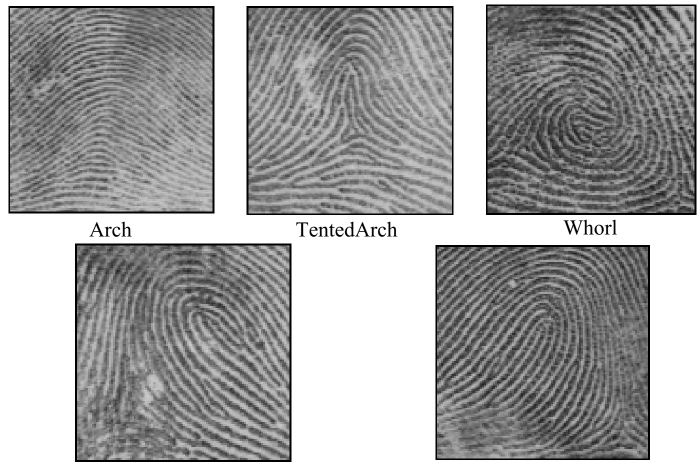

Fig. 1. Main Fingerprints

There are two major methods for fingerprint matching: Minutiae matching and global pattern matching. The first approach analyses the ridge bifurcations and endings, while the second method represents a more macroscopic approach. The last approach considers the flow of ridges in terms of, for example, arches, loops and whorls. As the equal-error-rate is low, the fingerprint recognition is very accurate. Furthermore the cost of such systems compared to other biometric systems is quite low and the user acceptance is very high. The strength of fingerprint identification is that it can be deployed in a wide range of environments, besides that it is a proven core technology and; their ability of enrolling multiple fingers can increase the system accuracy and the flexibility dramatically.

The fingerprint image acquisition can be done in two different forms, direct and indirect. The indirect way consists on the acquisition of a digital image from the impression of a fingerprint image in an appropriate piece of paper. In most cases the resulting images are of low quality with a high amount of noise. On the other hand, in the direct way the fingerprint acquisition is carried out using a special purpose scanner that allow us to have fingerprint with a reasonable image quality.

Another important characteristic that must be taken into account is the fingerprint scanner type to be used: a capacitive surface scanner or an optical type fingerprint scanner; among them the last one, which is used in this work, provides better quality images. This is an important factor because as the image quality increases, the possibility of finding false minutiae is smaller. False minutiae appear when the fingerprint image quality decreases.

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II. PROPOSED SYSTEM

The proposed fingerprint recognition system firstly acquires the fingerprint image using a biometric device UareU 4000 of Digital Persona Inc. Next a combination of two algorithms, the Fast Fourier Transform and Gabor Filters is used to enhance and reconstruct the information of the fingerprint image; as well as to extract two fundamental types of minutiaes, ending points and bifurcation. Finally the extracted features are used to perform the fingerprint recognition. The proposed system consists of the following stages

A. Acquisition
B. Distortion reduction
C. Enhancement
D. Binarization
E. Thinning
F. Minutiae Detection
G. Recognition

which are described with detail in the next subsections. Each one of these stages was evaluated using different fingerprints: high quality images (Fig. 2a), in which case it was easier to carry out the recognition process, and low quality images (Fig. 2b) in which the information is highly distorted. However even in these cases our system achieves a good recognition rates.

a) b)

Fig,2 Fingerprint. a) With sufficient information. b) With poor information.

A. Acquisition

The fingerprint acquisition was done using a biometric device UareU 4000 of Digital Persona Inc. with USB 2.0 interface (Fig. 3). The images were captured with a resolution of 512 DPI with a size of 300x300 pixels in gray scale. For this work a database with 250 fingerprints images was created that correspond to 50 different people, that is, 5 images by each person.

Fig.3 Scanner and Captured Fingerprint

B. Distortion reduction

Most fingerprint images shows distortion in the zones closed the images ends, which can be caused by different factors such as the movement of the finger at the moment of the image capture or little pressure in areas close to the scanner border. This distortion must be eliminated to assure that only useful information be processed during the minutiae extraction. Because is this distortion is not eliminated, the algorithm could detect false minutiae. To reduce the distortion, the image was cut in about 10% in each one of its 4 sides (right, left, top and bottom) taking in care that not useful information of the fingerprint be eliminated. This is shown in figure 4.

Fig4. Distortion reduction

C. Enhancement

The performance of minutiae extraction algorithms and other fingerprint recognition techniques heavily relies on the input fingerprint image quality. In an ideal fingerprint image, ridges and valleys alternate and flow in a locally constant direction [1]. In such situations, the ridges can be easily detected and minutiae can be precisely located in the image. However, in practice, due to skin conditions (e.g., wet or dry, cuts, and bruises), sensor noise, incorrect finger pressure, and inherently low-quality fingers (e.g., elderly people, manual workers), a significant percentage of fingerprint images (approximately 10%) is of poor quality.

The goal of an enhancement algorithm is to improve the clarity of the ridge structures in the recoverable regions and mark the unrecoverable regions as too noisy for further processing. Usually, the input of the enhancement algorithm is a grayscale image, while the output may either be a gray-scale or a binary image, depending on the algorithm. Most of the existing techniques are based on the use of contextual filters whose parameters depend on the local ridge frequency and orientation, where the context information includes: Ridge continuity and regularity. Because the regularity and continuity properties of the fingerprint image, occluded and corrupted regions can be recovered using the contextual information from the surrounding neighborhood. Hong et al. [4] label such regions as 'recoverable' regions. The efficiency of an automated enhancement algorithm depends on the extent to which they use contextual information. The filters themselves may be defined in spatial or in the Fourier domain.

In this work a combination of filters in both domains is used, spatial and Fourier for a better image enhancement.

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Spatial Domain Filtering

O’Gormanetal. [5] proposed, firstly, theuseofcontextual filtersforfingerprintimageenhancement,usingananisotropic smoothening kernel whose major axis is oriented parallel to the ridges. To improve the e fficiency, they recomputed the filter in 16 directions. The filter increases contrast in a direction perpendicular to the ridges; while performs a smoothingoperationinthedirectionoftheridges.

Recently, Greenberg et al. [6] proposed the use of an anisotropic filter that is based on the adaptive filtering structureproposedbyYangetal.[7].

Anotherapproachbasedondirectionalfilteringkernelwas proposed by Hong et al. [4], which uses a properly oriented Gabor kernel for performing the enhancement. The Gabor filters have important signal properties such as optimal joint space frequency resolution [8]. The Gabor elementary functions form a very intuitive representation of fingerprint images because they capture th e periodic, yet nonstationary nature of the fingerprint regions. Daugman [9] and Lee [10] haveusedGaborelementaryfunctionstorepresentgeneric2D images. The even symmetric fo rm of the Gabor elementary functionthatisorientedatanangle0±isgivenby

$$G(x,y) = \exp\left\{-\frac{1}{2}\left[\frac{x^2}{\delta_x^2} + \frac{y^2}{\delta_y^2}\right]\right\}\cos(2\pi f x) \tag{1}$$

Herefrepresentstheridgefrequencyandthechoiceof δ_x^2 and δ_y^2 determines the shape of the filter envelope and also thetradeofbetweenenhancemen tandspuriousartifacts.This is by far, the most popular approach for fingerprint enhancement.

While the compact support of the Gabor kernel is useful from a time-frequency analysis perspective, it does not necessarilyresultsinanefficientimageenhancementmethod.

Fig.5.ImageenhancedusingGaborfilter

Fourier Domain Filtering

Sherlock and Monro [11] perform contextual filtering completely in the Fourier domain. Here each image is convolved with precomputed filters of the same size that the processed image. However, the algorithm assumes that the ridge frequency is constant through out the image in order to avoid the requirement of a large number of precomputed filters. Therefore the algorithm does not use the full contextualinformationprovidedbythefingerprintimage.

Watson et al. [12] proposed another approach for performing the image enhancement completely in the Fourier domain. This is based on the “root filtering” technique [13], in which the image is divided into overlapping blocks in whichtheenhancedimageisobtainedas

$$I_{enh}(x,y) = FFT^{-1}\left\{F(u,v)\left|F(u,v)\right|^{k}\right\} \tag{2}$$

$$F(u,v) = FFT(I(x,y)) \tag{3}$$

Another advantage of this approach is that it does not require the computation of intrinsic images for its operation. This has the effect of in creasing the dominant spectral components while attenuating the weak components. This approach closely resembles matched filtering method. However,inordertopreservethephase,theenhancementalso retainstheoriginalspectrumF(u,v).

From the above subsections is clear that both approaches presents desirable features th at can be combined to obtain betterimageenhancementresults.Thusthispaperproposesto useacombinationofFouriertransformandGaborfilteringto carryouttheimageenhancementtask.

Fig6.ResultingenhancedimageapplyingFFT

Sincewehavethetwoenhanced imagesanalgebraicsumis madeandonlytheresultingpixelwillbewhite, ifinthetwo imagesthepixeliswhitetoo.Figure7showstheprocess.

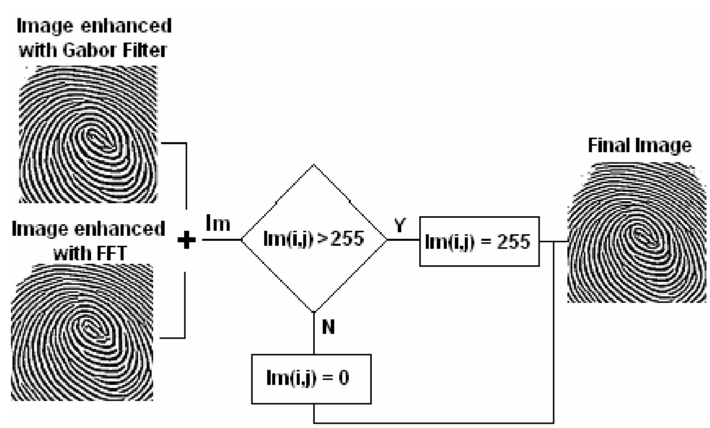

Fig7.CombinationProcess

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The result of the image using the combination of both previous explained filters is shown in figure 8.

Fig.8 Binary image with a combination of FFT and Gabor

D. Binarization

The segmented image with the crests and valleys enhanced, will be now binarized. That is, the black pixels will have a value of 0 and the white pixels a value of 1.

0	0	0					0			
0	0	0	0	0	0	0	0			
		0	0	0	0	0	0	0		
		0	0	0	0	0	0	0		
			0	0	0	0	0	0		
				0	0	0				
				0	0	0	0			
		0	0	0	0	0	0	0		
		0	0			0	0			
	0	0	0			0	0	0		
0	0	0					0	0	0	
0	0						0	0	0	0
				0	0		0	0		
			0	0	0	0	0			
		0	0	0	0	0	0			
		0	0	0	0	0	0	0		
	0	0		0	0	0	0	0		
0	0						0			
0	0					0	0			
						0	0			

a)

0	0	0					0			
0	0	2	0	0	0	0	0			
		0	2	2	2	2	2	0		
		0	2	2	2	2	2	0		
			0	2	2	2	0	0		
				0	2	0				
				0	2	2	0			
		0	0	0	0	2	2	0		
		0	0			0	0			
	0	2	0			0	2	0		
0	2	0					0	2	0	
0	0						0	2	0	0
				0	0		0	0		
			0	2	2	0	0			
		0	2	2	2	2	0			
		0	0	2	2	2	2	0		
	0	0		0	0	0	2	0		
0	0						0			
0	0					0	0			
						0	0			

b)

0							0			
0	0	2					0			
			2	2	2	2	2			
			2	2	2	2	2			
				2	2	2				
					2					
					2	2				
		0	0	0		2	2			
			0				0			
		2					2			
	2							2		
								2	0	0
								0		
				2	2		0			
			2	2	2	2				
			0	2	2	2	2			
	0	0					2	0		
0	0						0			
0	0					0	0			
						0	0			

c)

Fig.9. Process of thinning a) Original Image. b) Image with internal pixels. c) Image after the elimination of pixels limit.

E. Thinning

Before minutiae extraction, a thinning process is applied, in which the resulting image will have its lines of the minimum possible thickness with a negligible information loss.

In order to understand better the algorithm it is necessary to know some definitions. Firstly let us remember that after the binarization process the image consists only of 1 and 0, where a 1 means a white pixel and a 0 black pixel. Second, a pixel 0 (x,y) is considered to be internal, if its four neighbors (x+1,y), (x-1,y), (x,y+1) and (x,y-1) are 0 (black pixel). The limit is defined using its 8 connections. Third, a pixel is considered as a pixel limit if this isn't an internal pixel and at least one of its 8 neighbors is a 1. Finally, a pixel is considered to be a connection pixel if it is eliminated in a matrix of 3x3 and its neighbors are disconnected.

Basically, the algorithm consists in firstly, to find the internal pixels in our image and later to eliminate the pixel limit. This process is carried out until it is not possible to find more internal pixels. This process is explained with more detail as follows

The first step of this algorithm consists in finding the total internal pixels that exist in our image. Next, all pixels that are a limit pixel is eliminated, taking care that this not be a connection pixel. This first step is shown in figure 8. This algorithm is repeated until not finding more in internal pixels.

After thinning the image and not finding more internal pixels, the algorithm is applied again with a small change. In this the algorithm finds the internal pixels with only with 3 neighbor pixels and then eliminates the limits pixels.

In the previous process the elimination of internal pixels is possible. This step is made when the elimination of some limit pixel is not possible but exist an internal pixel. The last step is again the repetition of the algorithm but in this occasion finding internal pixels with two neighbors only. We must consider the elimination of an internal pixel if is not possible to eliminate some neighbor pixel. The final result after the N necessary repetitions is shown in Fig. 10.

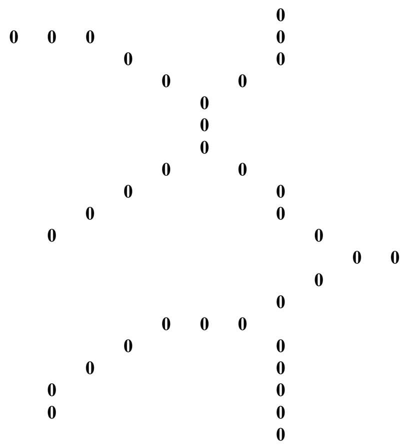


Fig. 10. Image after thinning process

The final image after the thinning process is shown in Fig. 11. The thickness of all the lines is of one pixel.

Fig. 11. Image of fingerprint after thinning process

F. Minutiae Detection

After the thinning process the image is ready for minutiae extraction so that the algorithm minutiae detection algorithm is applied. This algorithm consists on estimating the number of pixels that cross to the Pixel center (Pc); and it is calculated with the following equation:

$$Pc = \frac{1}{255}\sum_{i=1}^{8} p(i) \qquad (4)$$

$$if \begin{cases} Pc = 7 & TERMINATION \quad MINUTIAE \\ Pc = 6 & BLOCK \quad WITHOUT \quad MINUTIAE \\ Pc \leq 5 & BLOCK \quad WITH \quad BIFURCATION \end{cases}$$

where p_1 to p_8 is an ordered pixels sequence that define the block of 8 neighbors of the pixel center.

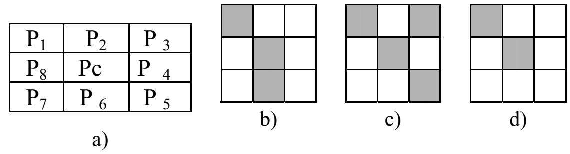
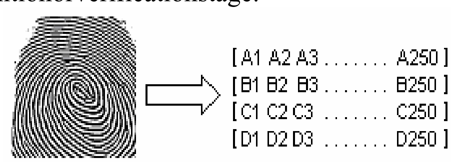


Fig. 12a) Window of 3x3 used to find minutiaes. b) Block without minutiaes. c) Block with bifurcation. d) Block with ending.

Figure 12a shows the configuration of the mask used to locate bifurcations and ending, while Fig. 12b, 12c and 12d are the possible configurations that we can find. A Pc=7 means that we are on a window with an ending. A Pc=6 means that does not exist bifurcation or ending and finally a value of Pc ≤5 means that we have found a bifurcation.

This process is carried out on all the binary image applying nonoverlapping windows of 3x3. The result of this process is a vector with the characteristic points that later will be used in the recognition or verification stage.



A=Distances between minutiaes B=Angles between minutiaes C=Coordinate in x axis D=Coordinate in y axis

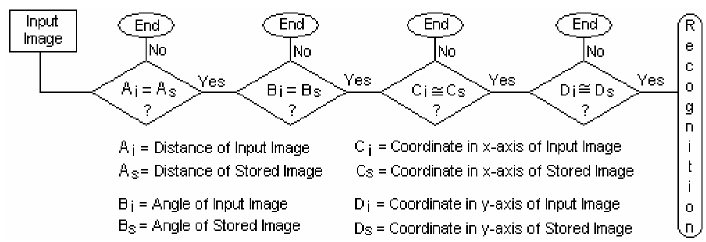


Fig. 13. Recognition Process

G. Recognition

The fingerprint recognition process was done using three important characteristics: mi nutiae coordinates, distance between coordinates and angles between each coordinate. The reason of to use three character istics is to be able to have a smaller percentage of error in the recognition.

Therefore, the information of each stored fingerprint consists of a 4x500 matrix. This matrix is compound by four vectors that consist of the two coordinates of first minutiae, the distance to following minutiaa nd the angle that they form. The total size of our stored matrix is of 400x500.

The recognition is made of the following form: Firstly the image is captured and enhanced as described before. Next the feature extraction is carried out as described in the above paragraph, resulting in a matrix of 4x500. Then this matrix is compared with each matrix of our database. .Firstly, equal distances are located and are ta ken only those with the same angle. Later, are eliminated the coordinates which are very different to assure in this way a better recognition..

After several tests we considered that a threshold of greater than 5 provides a good recognition, this means that the recognition exists only when the input image contains more than 5 comparison results equal to the stored ones in our data base.

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III.RESULTS

Thetestsweredonewithadatabaseof250fingerprintsof fiftydifferentpeople,thisis,fivesamplesbyperson.

The tests consisted of the recognition of 51 people, 50 peoplewithstoredfingerprintandonepersonwithfinigeprintt notstored.Eachpersonmadefivetestsandtheresultsare:

TABLEI.TESTRESULTSMADETO21IMAGES

Image	Recognition	False Acceptance	False Rejection
TOTALPERCENTAGE	94.1%	2.3%	3.6%

The programming of the capture of the fingerprint image using a biometric scanner and the process of recognition or verificationweremadeinMatlab7.

IV.CONCLUSIONS

The performance of a fingerpri nt feature extraction and matching algorithms heavily depends upon the quality of the inputfingerprintimage.Wepresentedanewfingerprintimage enhancement algorithm based in a filter's combination in the Fourierandspatialdomain.

One of the best algorithms for the enhancement of fingerprints is Gabor Filter. The main characteristic of these filters is: It has optimal joint directional and frequency resolutionbutdoesnothandlehighcurvatureregionswelldue to block wise approach. Angular and radial bandwidths are constant.

The reason of to use a second method of enhancement is foreliminatingtheproblemofhandlehighcurvatureregions, sincetheenhancementbymean sofFFTpresentthefollowing characteristic:veryrobustevennearregionsofhighcurvature but marked by large storage requirements. Frequency of ridgesisassumedtobeconstant.

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