INTERNATIONAL JOURNAL OF COMPUTER ENGINEERING & TECHNOLOGY (IJCET)

ISSN 0976 – 6367(Print)
ISSN 0976 – 6375(Online)
Volume 4, Issue 3, May-June (2013), pp. 10-22
© IAEME: www.iaeme.com/ijcet.asp
Journal Impact Factor (2013): 6.1302 (Calculated by GISI)
www.jifactor.com

IJCET
©IAEME

PROPOSAL TO ENHANCE FINGERPRINT RECOGNITION SYSTEM

Soukaena H. Hashem[1] **Abeer T. Maolod[1]** **Anmar A. Mohammad[1]**

[1]Computer Sciences Department, University of Technology,
Baghdad/Iraq

ABSTRACT

This research concentrates on particular aspect, that is: Build Fingerprint Recognition System as in traditional but with modest suggested strategy aim to introduce an optimal fingerprint image feature's vector to the person and then considers it to be stored in database for future matching.

Selecting optimal fingerprint feature's vector strategy deal with considering 10 fingerprints for each authorized person (take the fingerprint in different time and different circumstance of user such as finger is dirty, wet, trembling, etc.). Proposal begin with apply a proposed enrollment on all 10 fingerprint for each user, the enrollment include the following consequence steps; begin with preprocessing step for each of 10 images including enhancement, then two level of feature extraction (first level to extract arches, whorls, and loops, where second level extract minutiae), after that applying proposed Genetic Algorithm to select optimal fingerprint, master fingerprint, which in our point of view present the most universal image which include more detailed features to recognition. Master fingerprint will be feature's vector which stored in database. Then return to the traditional fingerprint recognition system applying matching by testing fingerprints with these stored in database. Finally calculate measures of performance False Reject Rate (FRR) and False Accept Rate (FAR) for the traditional system and the proposed.

Keywords: fingerprint, minutiae, genetic algorithm, feature extraction, FRR, FAR.

1. INTRODUCTION

Fingerprint Recognition System is a free tool that will recognize and verify fingerprints. Fingerprint recognition identifies people by using the impressions made by the minute ridge formations or patterns found on the fingertips. Finger printing takes an image of a person's fingertips and records its characteristics - whorls, arches, and loops are recorded along with patterns of ridges, furrows, and minutiae. Information is processed as an image and further encoded as a computer algorithm [1], see figure (1).

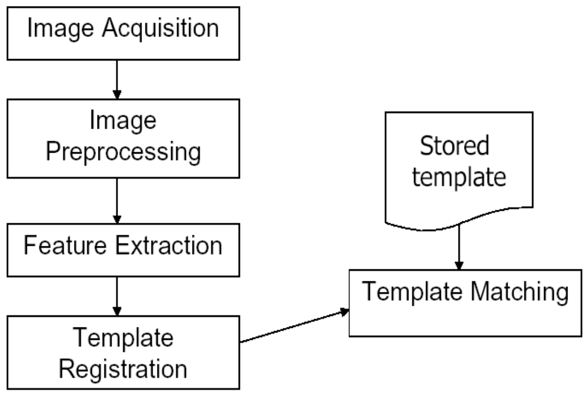


Figure (1) Fingerprint Recognition System

Among all the biometric techniques, fingerprint-based identification is the oldest method which has been successfully used in numerous applications. Everyone is known to have unique, immutable fingerprints. A fingerprint is made of a series of ridges and furrows on the surface of the finger. The uniqueness of a fingerprint can be determined by the pattern of ridges and furrows as well as the minutiae points. There are two levels of features for fingerprint recognition. These are global level represented by: **Patterns** The three basic patterns of fingerprint ridges are the **arch**, **loop**, and **whorl**. An arch is a pattern where 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. · The loop is a pattern where the ridges enter from one side of a finger, form a curve, and tend to exit from the same side they enter. In the whorl pattern, ridges form circularly around a central point on the finger. Scientists have found that family members often share the same general fingerprint patterns, leading to the belief that these patterns are inherited. The human population has fingerprints in the following percentages: Loop 65%, Whorl 30%, and Arch 5% [2], see figure (2).

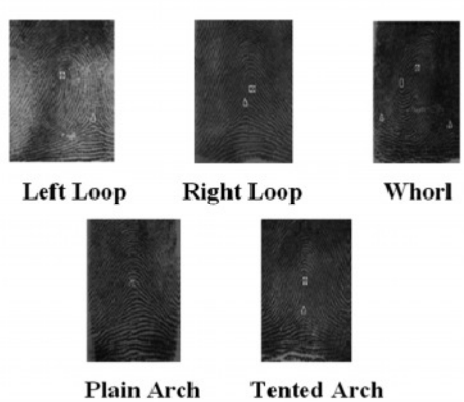


Figure (2) Arches, Loops and whorls

Local level presented by **Minutia features** are major features of a fingerprint, using which comparisons of one print with another can be made. Minutiae include: Ridge ending the abrupt end of a ridge. Ridge bifurcation a single ridge that divides into two ridges. Short ridge, or independent ridge a ridge that commences, travels a short distance and then ends. Island - a single small ridge inside a short ridge or ridge ending that is not connected to all other ridges. Ridge enclosure a single ridge that bifurcates and reunites shortly afterward to continue as a single ridge. Spur a bifurcation with a short ridge branching off a longer ridge. Crossover or bridge a short ridge that runs between two parallel ridges. Delta a Y-shaped ridge meeting. Core a U-turn in the ridge pattern [3], see figure (3).

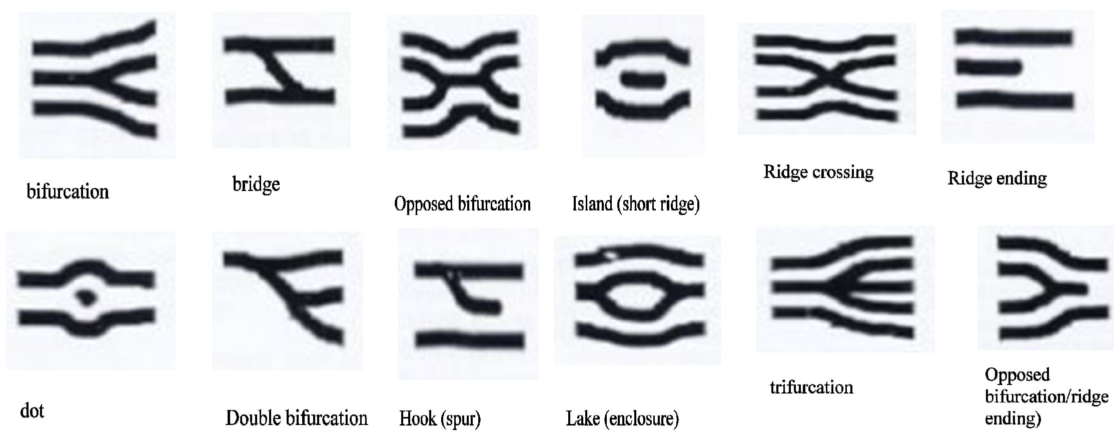


Figure (3) Minutiae types

The large number of approaches to fingerprint matching can be coarsely classified into three families.

- **Correlation-based matching**: Two fingerprint images are superimposed and the correlation between corresponding pixels is computed for different alignments (e.g., various displacements and rotations) [4].
- **Minutiae-based matching**: This is the most popular and widely used technique, being the basis of the fingerprint comparison made by fingerprint examiners. Minutiae are extracted from the two fingerprints and stored as sets of points in the two- dimensional plane. Minutiae-based matching essentially consists of finding the alignment between the template and the input minutiae sets that results in the maximum number of minutiae pairings [4, 5].
- **Ridge feature-based matching**: Minutiae extraction is difficult in very low-quality fingerprint images. However, whereas other features of the fingerprint ridge pattern (e.g., local orientation and frequency, ridge shape, texture information) may be extracted more reliably than minutiae, their distinctiveness is generally lower. The approaches belonging to this family compare fingerprints in term of features extracted from the ridge pattern. In principle, correlation- and minutiae-based matching could be conceived of as subfamilies of ridge feature-based matching; in as much as the pixel intensity and the minutiae positions are themselves features of the finger ridge pattern [6].

2. LITERATURE SURVEY ON FINGERPRINT RECOGNITION SYSTEM

(Munir and Javed, 2004), present a fingerprint matching scheme that utilizes a ridge feature map to match fingerprint images. The technique described here obviates the need for extracting minutiae points to match fingerprint images. The proposed scheme uses a set of 16 Gabor filters, whose spatial frequencies correspond to the average inter-ridge spacing in fingerprints, is used to capture the ridge strength at equally spaced orientations. A circular tessellation of filtered image is then used to construct the ridge feature map. This ridge feature map contains both global and local details in a fingerprint as a compact fixed length feature vector. The fingerprint matching is based on the Euclidean distance between two corresponding feature vectors [7]. **(*Rai and et.al., 2011*)**, describe a fingerprint recognition system consisting of three main steps-fingerprint image preprocessing, feature extraction and feature matching by two different processes. First processes is based on Gabor filter and second is based on FFT (Fast Fourier Transform) filter and we use these process in the fingerprint image preprocessing steps and after getting result by first step then use feature extraction and feature matching steps simultaneously and separately for each process. After apply all steps we calculate the FAR (False Accept Rate) and FRR (False Reject Rate) for both process separately and compare results on the basis of FAR and FRR of Gabor filter based and FAR and FRR of FFT Filter based [8]. ***(Basca and Blaga, 2007)***, presenting a method of optimizing Gabor Filter Banks using an evolutionary approach. Texture segmentation has multiple usages from medical imaging to satellite terrain mapping. Gabor filters are the most widely used texture feature extractors. Multi-channel approach to texture segmentation using Gabor filters is subject to optimization. Genetic algorithms are used to generate an optimal filter bank for the source image [9]. ***(Razak and Taharim, 2009)***, this work demonstrates the application of Gabor Filter technique to enhance the fingerprint image. The incoming signal in form of image pixel will be filter out or convolute by the Gabor filter to define the ridge and valley regions of fingerprint. This is done with the application of a real time convolve based on Field Programmable Gate Array (FPGA) to perform the convolution operation. The main characteristic of the proposed approach are he usage of memory to store the incoming image pixel and the coefficient of the Gabor filter before the convolution matrix take place. The result was the signal convoluted with the Gabor coefficient [10].

3. PROPOSAL OF FINGERPRINT RECOGNITION SYSTEM

Before explain the proposal and entre in the details will at first introduce an analysis view about the Fingerprint recognition system, and then present the general proposed algorithm.

3.1. Analysis of Fingerprint Recognition problems

There are many points must be considered in account for avoiding the failure and unreliability of the system:

1. Direct matching between the fingerprint pattern to be identified and many already known patterns has problems due to its high sensitivity to errors such as various noises, damaged fingerprint areas, or the finger being placed in different areas of fingerprint scanner window and with different orientation angles, finger deformation during the scanning procedure.

2. A single registered fingerprint may have 100 or more identification points that can be used for identification purposes. There is no exact size requirement as the number of points found on a fingerprint impression depends on the location of the print.
3. A good reliable fingerprint processing technique requires sophisticated algorithms for reliable processing of the fingerprint image: noise elimination, minutiae extraction, rotation and translation-tolerant fingerprint matching. The algorithms must be fast for comfortable use in applications with large number of users.
4. Fingerprint weaknesses, requires careful enrollment, potential high False Reject Rate (FRR) due to: pressing too hard, scarring, misalignment, dirt.

3.2. The Proposed Framework of Fingerprint Recognition

In this section will introduce the proposed framework of fingerprint recognition in generic steps of algorithm, and then explain each step separately.

Algorithm: Proposed Framework of Fingerprint Recognition

Input: database of fingerprints images of authorized persons each one have 10 Fingerprints.

Output: Fingerprint recognition system with high quality.

Initialization: Image specifications are 8-bit gray scale (256 levels), 500 dpi resolution, (1-by-1) inch size.

Process:

Step1: Enrollment, for each person input the 10 fingerprints image into the following consequences steps to select optimal fingerprint feature's vector to accomplish the enrollment,

1. **Image preprocessing**, enhancement using histogram equalizer.
2. **Apply rough segmentation using Gabor filter**, here the aim is to extract the global features, global patterns (plain arch, tended arch, left loop, right loop, and whorl).
3. **Image Binarization** will binarized images so that it will be in black and white (matrix of zeros and ones elements).
4. **Apply soft segmentation for** finding interesting area of the image what is called region of interest (ROI). It presents the preliminary step of thinning process.
5. **Thinning is** how the ridges will reduce into 1 pixel so that the useful and useless ridges will be clear. Here the aim is to extract the local features; local patterns (Minutia features).
6. **Build proposed vectors and applying proposed Genetic Algorithm**, each vector will consist of both patterns of global features obtained by Gabor filter and patterns for Minutia obtained by thinning so will get 10 vectors. Then apply GA to optimize a solution, to get optimal vector which present full description of fingerprint global and local features.
7. **End For**

Step2: Identification, Recognition and matching, when some of authorized persons entered his fingerprint image, this image will enhanced, rough segmented by Gabor filter, binarized, soft segmented to find ROI, finally thinned. All that to build it is vector to match it with identical stored vector of that authorized person.

End.

3.2.1. Fingerprint Image Preprocessing

Now will begin with fingerprint database enrollment process, the last process have consequence steps (from enhancement to feature extraction) will be introduced in the following subsections. Figure (4) introduces first 10 fingerprints for one person. For each 10 image will apply the following image processing steps.

Figure (4): Source fingerprint image

3.2.1.1 Fingerprint Image Enhancement

Enhancement for the 10 fingerprint image will performed using some algorithms, the proposal will use Histogram equalization, to spread pixels of an image so that it will fill the pixel values distribution of an image to increase the perceptional information. Figures (5) show the enhanced image using Histogram equalization. The enhanced image then will take the range from 0 to 255 pixels.

Figure (5): After histogram

3.2.1.2 Fingerprint Image Rough Segmentation

Fingerprint images may have background information that does not represent the fingerprint itself. Segmentation removes the background information and is the effective step in the pre-processing of the fingerprint image. A Gabor filter is linear filter whose impulse response is defined by a harmonic function multiplied by Gaussian function. The Fourier transform of a Gabor filter's impulse response is the convolution of Fourier transform of harmonic function and the Fourier function of Gaussian function. g(x, y) = s(x, y) w_r (x, y), where s(x, y) is a complex sinusoidal, known as the carrier, and w_r(x, y) is a 2-D Gaussian-shaped function, known as the envelop. The general function of Gabor filter can be represent as,

$$G(x, y, \theta, f_0) = \exp\left\{-\frac{1}{2}\left(\frac{x_\theta^{\ 2}}{\sigma_x^2} + \frac{y_\theta^{\ 2}}{\sigma_y^2}\right)\right\}.\cos(2\pi f_0 x_\theta), \quad (1)$$

$$\begin{bmatrix} x_\theta \\ y_\theta \end{bmatrix} = \begin{bmatrix} \sin\theta & \cos\theta \\ -\cos\theta & \sin\theta \end{bmatrix}\begin{bmatrix} x \\ y \end{bmatrix}. \quad (2)$$

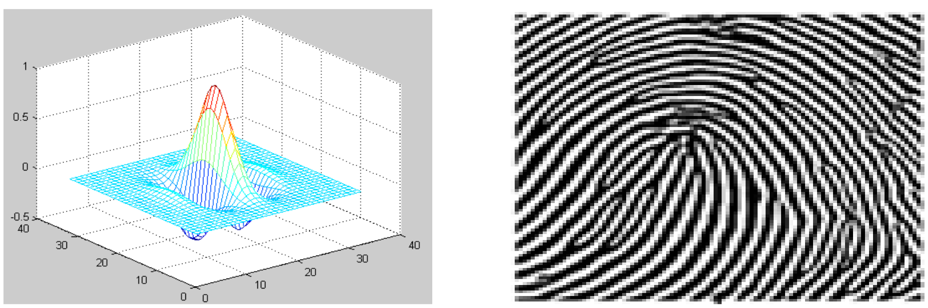
where θ is the ridge orientation with respect to vertical axis, f_0 is the selected ridge frequency in xθ – direction, σ_x and σ_y are the standard deviation of Gaussian function along the xθ and yθ axes respectively and the [xθ, yθ] are the coordination of [x,y] after a clockwise rotation of the Cartesian axes by an angle of (90-θ). Referring to the function in (1), the function G(x,y,θ , $f_{0)}$ can be decomposed into two orthogonal parts, one parallel and the other perpendicular to the orientation θ.

$$G(x, y, f_0)\Big|_{\theta=90^\circ} = G_{BP}(x, f_0)G_{LP}(y)$$

$$G_{BP}(x, f_0) - \exp\left\{-\frac{1}{2}\left(\frac{x^2}{\sigma_x^2}\right)\right\}\cos(2\pi f_0 x)$$

$$G_{LP}(y) = \exp\left\{-\frac{1}{2}\left(\frac{y^2}{\sigma_y^2}\right)\right\} \tag{3}$$

where G_{BP} is only a band-pass Gaussian function of x and f_0 parameters while G_{LP} is only a low-pass Gaussian filter of y parameter. Figure (6) present peace of fingerprint image (center) after applying Gabor method on it and also present Gabor visualization for this image.



(a) (b)

Figure (6): a- Gabor visualization for an Fingerprint image, b- Enhanced fingerprint image.

3.2.1.3 Fingerprint Image Binarization

Gray scale image will binarized, see figure (7), so that it will be in black and white (matrix of zeros and ones elements) the binarization will done by choosing carefully a threshold value where the values for image matrix over the threshold value will become 1(black) and values less than threshold will be 0 (white), binarization show the minutiae in the image.

Figure (7): Binary image

3.2.1.4 Fingerprint Image Soft Segmentation

After binarization a segmentation for the image will done where the interesting area of the image identified and as what we call region of interest (ROI), there are two step for segmentation is **Block direction** and the second step is identifying the **region of interesting.** **Block direction,** Considering the block direction is done by calculating the x-direction and y-direction for a given block this done by using sobel filter and calculating the gradient value by formula.

$$tg2\,\theta = 2\sin\theta\cos\theta\,/(\cos 2\theta - \sin 2\theta) \ldots\ldots\ldots. (4)$$

the formula is to calculate x-direction and y-direction for each block and consider them as sine and cosine values , when that done for every block we could got blocks with useful information so that no ridges and furrows in the region as a result we shall remove them . The following formula is for discovering and discarding the unnecessary blocks,

$$E = \{2\sum\sum \quad (gx*gy)+\sum\sum \quad (gx2-gy2)\}/\ W*W*\sum\sum \quad (gx2+gy2) \quad \ldots\ldots.. (5)$$

Where if E is under a certain threshold value then the block is considered as aback ground block not belongs to the fingerprint. Figure (8), show the results.

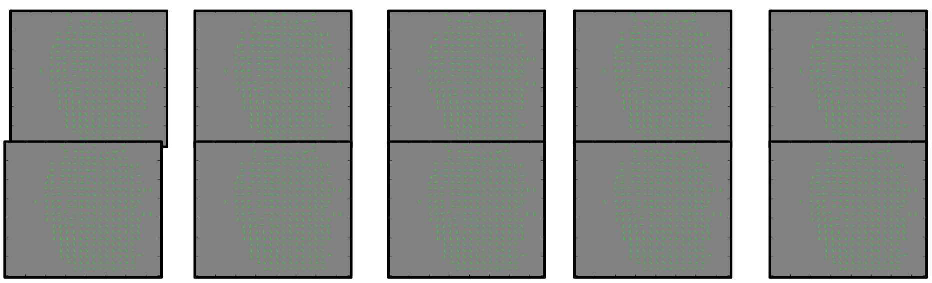


Figure (8): Block direction

Region of Interest, After specifying the valuable direction we can use the 'OPEN' and 'CLOSE' to present that region, the 'OPEN' operator is to show the new image and cut off the peaks in background, see figure (9), where the 'CLOSE' operator is to reduce the image so that removing the small cavitations .By subtracting the close area form the open area will got a bound area and inner area.

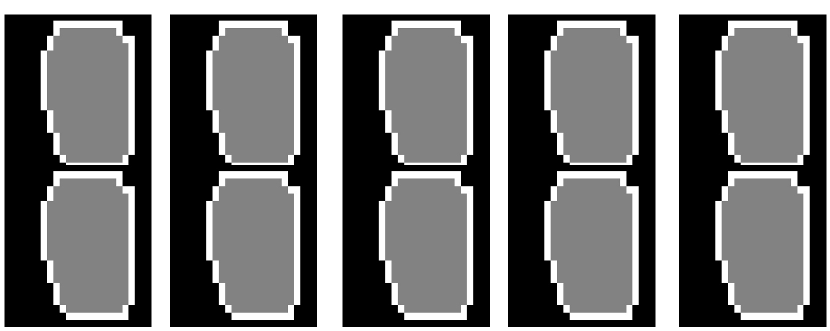


Figure (9): Region of Interest

3.2.1.5. Fingerprint Image Thinning

In thinning stage the ridges will reduced into 1 pixel so that the useful ridges will be clear and the useless ridges will clear also, see figure (10). An advantage of this method is that it doesn't produce a discontinuity on the lines , the algorithm is deleting points that lie outer boundaries of the ridge where the width is longer than one pixel but if that may cause a disconnectivety on the graph the pixel will not be deleted.

Figure (10): Thinning

The thinned image may contain some unnecessary spikes and breaks which may lead to recognition of false minutiae those spikes and breaks should be removed in order to extract the minutia, as in traditional, see figure (11), if an angel comes with a branch and ridge is larger than the 70 degrees and less than the 110 degrees, and if the length of the branch is less than the 20 pixel so that this branch will be removed. Also if a break in some ridge is less than 15 pixels and no other ridges will pass through it, then this break will connected. Aligning minutia, in windows is to decide making minutia as bifurcation or termination. For the matrix that will be saved, the following steps are prepared: present the each bifurcation as three termination, each termination will be presented by three elements: x-coordinate, y-coordinate, and orientation.

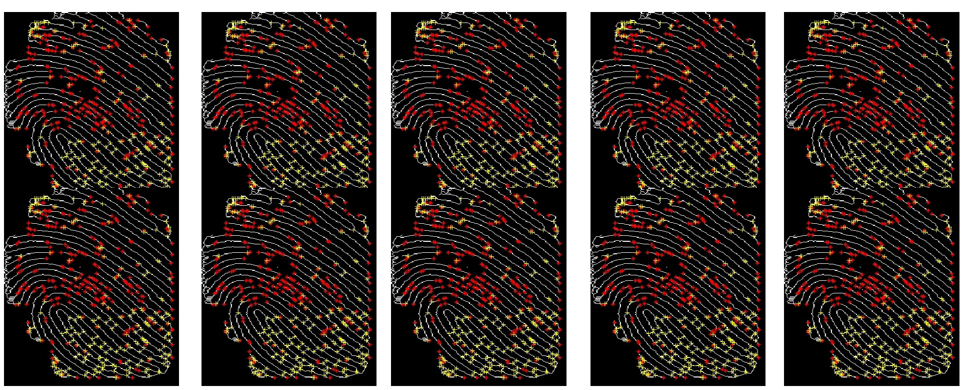


Figure (11) Extract minutia from the fingerprint

3.2.1.6. The Proposed Genetic Algorithm To Select Optimal Feature's Vector

From all above we can say the proposal apply two levels of segmentations, these are:

1. Rough segmentation which done by Gabor filter, from this segmentation extract the global patterns of fingerprint (plain arcs, tented arcs, left loop, right loop, and whorl).

2. Soft segmentation which done by there are two step for segmentation is block direction and the second step is identifying the region of interesting followed by thinning, from these three steps will extract local patterns of fingerprint (miniature).
3. Build vectors are constructing the population of GA; each vector will contain both global patterns and local patterns.

To apply a genetic algorithm for solving problem of selecting master fingerprint from one class, this research propose to define or to select the following component:

Note: oi represent symbol of global patterns and pi represent symbol of local patterns.

1. A genetic representation or encoding schema for potential solutions to the problem, here each fingerprint will be presented as a vector each vector consist from the following:
   (no. of global pattern, (o1, (position (x, y coordinates), orientation, texture, object shape and topology), o2(…..), on(……), no. of local patterns, (p1, (position (x, y coordinates), orientation, texture, object shape and topology), p2(…..), pn(……)).
2. A way to create an initial population of potential solutions, the initial population already created with image processing algorithms which established the vectors. So this mean the initial population of each 10 person's fingerprint, will be these 10 images represented by vectors.
3. An evaluation function that plays the role of the problem environment (best fingerprint), rating solutions in terms of their "fitness". Here the proposed evaluation function for each fingerprint is ***f(vector) = (no. of object + ∑ (features of each objects))***.
4. Genetic operators that alter the composition of offspring. *One-point crossover* is the most basic crossover operator, where a crossover point on the genetic code is selected at middle of vector which separate global and local features, and two parent vectors are interchanged at this point.
5. Crossover exploits existing vectors potentials, but if the population does not contain all the encoded information needed to find the best vector, no amount of vector mixing can produce a satisfactory solution. For this reason, a mutation operator capable of spontaneously generating new vector is included. The most common way of implementing mutation is to flip a some feature with a probability equal to a very low, given mutation rate (MR). A mutation operator can prevent any single feature from converging to a value through the entire population and, more important, it can prevent the population from converging and stagnating at any local optima.
6. Values for the various parameters that the genetic algorithm uses population size, rate of applied operators, etc..In our particular problem we use the following parameters of the genetic algorithm: Population size, *pop-size* = 10 (the parameter was already used), Probability of crossover, PC = 1, Probability of mutation, PM = 0.001 (the parameter will be used in a mutation operation).
7. Continue with genetic processing until obtain the optimized vector to be the master vector.
8. Order the other nine vector according their nearest from the master vector and store them as a measure in some suspected instances of recognition.

3.2.2. Identification, Recognition and Matching

After accomplishing the six steps above, the enrollment would be accomplished. When enrollment performed for all authorized persons, the system of fingerprint recognition

will be ready to recognize images of fingerprint authorized or not. Recognition process depend on method used in matching, matching will done when some of authorized persons entered his fingerprint image, this image will submitted to the five consequence image processing enhancement, rough segmentation by Gabor filter, binarization, soft segmentation to find Block Direction and ROI, finally thinning. All that to build it is vector to match it with corresponding stored vector of that authorized person.
Fingerprint matching will applied in this research is based on finding the Euclidean distance between the corresponding feature vectors (entered and stored). The Euclidean distance of the vector of the entered fingerprint image and vector of corresponding stored can be calculated as follows,

$$\varepsilon = \| \Omega - \Omega_k \| \qquad (6)$$

where Ω_k is a vector of stored fingerprint. When get a minimum score that belong to the best alignment of the two fingerprints being matched. If the Euclidean distance between two feature vectors is less than a decided threshold, then the decision that the two fingerprint images come from the same finger, otherwise a decision that the two fingerprint images come from different fingers.

4. EXPERIMENTAL WORKS AND RESULTS

In this proposal we depend on 100 fingerprint images for 10 persons, so each person will has 10 images. Enrollment process will do for all these 100 images to finally detect the master image for each person and other nine nearest images. So there are two databases in this enrollment: preliminary and secondary. Preliminary will store master images vectors, which has in our experimental just 10 vectors. Secondary will store the most nearest vector to the master vector, which will used in uncertainties cases. The matching stage must be flexible because 100% match may never occur, for that the matching stage is depending on determined a threshold value, in our proposal will give 98.5% -98% as a threshold, so if the two global patterns or two local patterns is in a box and no scaling for them they are matched. In traditional matching score calculated as in the following equation,

$$\textbf{Matching Score} = \frac{\textbf{Number of minutia pairs that match}}{\textbf{Total number of minutia pairs}}$$

In our proposal will as in follow,

$$\textbf{Matching Score} = \frac{\textbf{Number of global pairs and local pairs that match}}{\textbf{Total number of global pairs and local pairs}}$$

In both traditional and proposal there are the two probabilities these are: two fingerprint from two different persons may produce a high Matching Score (an error); two fingerprints from the same person may produce a low Matching Score (an error). So as usual in all systems there are **two types of error**:
FAR = ratio of number of instances of pairs of different fingerprints found to (erroneously) match to total number of match attempts.

$$\text{FAR(n)} = \frac{\text{Number of successful independent fraud attempts against a person n}}{\text{Number of all independent fraud attempts against a person n}}$$

FRR = ratio of number of instances of pairs of same fingerprint are found not to match to total number of match attempts.

$$\text{FRR(n)} = \frac{\text{Number of rejected verification attempts for a qualified person(or feature) n}}{\text{Number of all verification attempts for a qualified person(or feature) n}}$$

The performance of a fingerprint recognition system can be evaluated by measuring its false reject rate (FRR) and false accept rate (FAR). By evaluating the FRR and FAR, the threshold of matching score deciding whether to reject or accept a match is set to optimizing the performance. If we take less threshold value it means the probability of accepted image will be high and rejected image will be low and due to this, chances of occurring error will be increased and vice versa. Our obtained simulation results are shown in table (1) below.

Table (1): FAR and FRR with traditional and proposal

Recognition System	FAR Threshold# 98%	FRR Threshold# 98%	FAR Threshold# 98.5%	FRR Threshold# 98.5%
Traditional	0.95%	23.11%	0.84%	24.41%
Proposed	0.22%	15.57%	0.11%	15.98%

5. CONCLUSIONS

The proposal introduce an idea to optimize feature's vector of fingerprint image that by taking several impressions for one person in different circumstances that to consider all features may be losses in some cases of person's impressions. GA was a good tool for optimizing features vector among 10 vectors for each person. Using Gabor filter in rough segmentation level enhance the extractions of global pattern features. The reason for increase accuracy of the proposal belongs to considering both patterns ridges and minutiae in calculating matching scores. Our proposal calculates the results FAR and FRR with two thresholds to ensure of proposal accuracy as shown in table (1) above.

REFERENCES

1. Maltoni, D., Maio, D., Jain, A.K., & Prabhakar, S., "Handbook of fingerprint recognition" , New York: Springer, 2003.
2. Tabassam Nawaj, Saim Parvaiz,Arash Korrani, Azhar-Ud- Din, "Development of Academic Attendance Monitoring System Using Fingerprint Identification", International Journal of Computer Science and Network Security (IJCSNS), **9**, No.5, pp.164-168, 20 May 2009.

3. Huang P. , Chang C. Y. , Chan C., "Implementation of An Automatic Fingerprint Identification System", IEEE, EIT, 2007 Proceeding, p.p. 412-417, 2007.
4. Ross, A., Jain, A., and Reisman, J. "A hybrid fingerprint matcher", Pattern Recognition 36, 7 (July 2003), 1661 1673.
5. Jea T., Chavan V. K., Govindaraju V., and Schneider J. K., "Security and matching of partial fingerprint recognition systems". In Proceeding of SPIE, number 5404, pages 39–50, 2004
6. Ratha, N., Chen, S., and Jain, A. , "Adaptive flow orientation based feature extraction in fingerprint images". Pattern Recognition 28, 11 (1995), 1657–1672.
7. Munir M. U. and Javed M. Y. , "Fingerprint Matching using Gabor Filters", National Conference on Emerging Technologies 2004 College of Electrical and Mechanical Engineering, National University of Sciences and Technology Rawalpindi, Pakistan, 2004.
8. Rai R., Rai A. , Bagla and Singhal A. , " COMPARATIVE ANALYSIS OF GABOR FILTER AND FTT FILTER BASED FINGERPRINT RECOGNITION SYSTEM", International Journal of Information Technology and Knowledge Management January-June 2011, Volume 4, No. 1, pp. 177-180.
9. Basca C. A. and Blaga L. ,"Texture Segmentation.Gabor Filter Bank Optimization Using Genetic Algorithms", 2007, http://rbrad.ulbsibiu.ro/publications/papers/EUROCON2007.pdf
10. Razak A. H. A. and Taharim R. H., " Implementing Gabor Filter for Fingerprint Recognition Using Verilog HDL", Center for Electronics Engineering Studies (CEES), Faculty of Electrical Engineering, Universiti Teknologi MARA, 40450 Shah Alam, Selangor. 2009 5th International Colloquium on Signal Processing & Its Applications (CSPA), 2009.
11. Shekhar R Suralkar and Prof (Dr) Pradeep M. Patil, "Fingerprint Verification using Steerable Filters", International Journal of Electronics and Communication Engineering &Technology (IJECET), Volume 4, Issue 2, 2013, pp. 264 - 268, ISSN Print: 0976- 6464, ISSN Online: 0976 –6472.
12. Nazrul H. Adnan, Khairunizam Wan, Shariman Ab and Juliana A. Abu Bakar, "Principal Component Analysis for the Classification of Fingers Movement Data Using Dataglove "Glovemap"", International journal of Computer Engineering & Technology (IJCET), Volume 4, Issue 2, 2013, pp. 79 - 93, ISSN Print: 0976 – 6367, ISSN Online: 0976 – 6375.