Invariant Moments Applied to Fingerprint Recognition

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***Abstract*—** In this paper an automatic fingerprint recognition system based in fingerprint features and invariant moments is explained. A fingerprint is the visible impression that papillary produces when the papillary crest contact in a surface. The fingerprint is the oldest and the most popular characteristic used for recognition or verification of people. The fingerprint has unique features called minutiae, which are points where a curve track finishes (ending), intersect or branches off (Bifurcation). In this research the enhancement image is processed using two algorithms, the first one is Fast Fourier Transform (FFT) and the second one is a bank of Gabor filters. After the enhancement process an algorithm to minutiae information extraction is applied obtaining distance, angle and coordinates from the minutiae. The invariant moments are used to discriminate between those fingerprints that are confused.

***Keywords*—**Biometrics, Fingerprint, Invariant moments, Minutiae.

I. Introduction

THE humans beings have unique morphological features that distinguish us with the others. The human biometric recognition is based on physical or behavioral features. The biometrics term comes from the Greek "bio" meaning life and "metric" measure or measuring, however more recently studies notes that the biometry meaning is a set of automated methods to analyze human beings characteristics to identify or to authenticate people. Another meaning for biometric is the automatic method for biological features identification and physiological features as ADN, face, iris, voice, fingerprints, etc. The fingerprint is unique, untransferable and constant over the time, which is ideal for identification systems or human testing besides being easier to acquire that other biometric feature.

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Fingerprint recognition represents the oldest biometric identification method. Since 1897, dactyloscopy has been used for criminal identification. A fingerprint consists of ridges (lines across fingerprints) and valleys (spaces between ridges). The ridges and valleys pattern are unique for each individual. While the quality image is higher it has less possibility to get spurious minutiae.

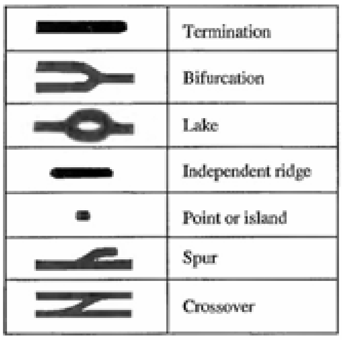

Fig. 1 different types of minutiae

II. Proposed System

The proposed system used the FFT and a Gabor filters bank for fingerprint image enhancement. After that, a thinning algorithm is applied to obtain the lines in the fingerprint with the minimum thickness which is desirable for a pixel wide and then is applied an algorithm for feature extraction obtained two fundamental features, ending line and bifurcation. Then, a feature vector based on minutiae information as a coordinates, angle and distance [1] is constructed. The proposed system consists in the following steps.

1. Acquisition image.
2. Enhancement image.
3. Cut Image.
4. Thinning stage.
5. Feature vector extraction.

6. Invariant moment's computation.

Each of these steps was performed using a database 500 different fingerprint images, with a poor and good quality, this to check the system to be robust.

A. Acquisition

The fingerprint image was obtained used a U are U 4000B Digital Persona Inc. with USB 2.0 interface optical reader using a Matlab Interface driver for this capture. The images were captured with a 512 DPI resolution and a 340x340 pixels grayscale size.

B. Enhancement

Fig. 2 Image obtained from optical reader

The performance of features extraction algorithms and other fingerprint recognition techniques relies on the quality of the input fingerprint images. The objective of an enhancement image 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. The majority of the existing techniques are based on the use of contextual filters whose parameters depend on the local ridge frequency and orientation.

The context information includes:

Ridge continuity and Regularity. Due to the regularity and continuity properties of the fingerprint image occluded and corrupted regions can be recovered using the contextual information from the surrounding neighborhood [2]. To obtain features (minutiae) reliable, the image optimization stage Fig. 3"(c)" is very important. The discontinuities generate loss of information or spurious information so if not done enhancement image could generate spurious minutiae.

In this research an algorithm that estimates the frequency and local guidelines using Fast Fourier Transform (FFT) analysis [3] Fig. 3"(a)".

In [4] perform contextual filtering completely in the Fourier domain. Here each image is convolved with pre-computed filters of the same size that the processed image. However, the algorithm assumes that the ridge frequency is constant throughout the image in order to avoid the requirement of a large number of pre-computed filters. Therefore the algorithm does not use the full contextual information provided by the fingerprint image.

In [5] proposed another approach for performing the image enhancement completely in the Fourier domain. This is based on the "root filtering" technique [6], in which the image is divided into overlapping blocks in which the enhanced image is obtained as (1), (2)

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

$$F(u,v) = FFT\left(I(x,y)\right) \qquad (2)$$

Another advantage of this approach is that it does not require the computation of intrinsic images for its operation. This has the effect of increasing the dominant spectral components while attenuating the weak components. This approach closely resembles matched filtering method.

In [7] proposed, firstly, the use of contextual filters for fingerprint image enhancement, using an anisotropic smoothening kernel whose major axis is oriented parallel to the ridges. To improve the e efficiency, they recomputed the filter in 16 directions. The filter increases contrast in a direction perpendicular to the ridges; while performs a smoothing operation in the direction of the ridges. Recently, in [8] proposed the use of an anisotropic filter that is based on the adaptive filtering structure proposed in [9].

Another approach based on directional filtering kernel was proposed in [2], 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 [10]. The Gabor elementary functions form a very intuitive representation of fingerprint images because they capture the e periodic, yet non-stationary nature of the fingerprint regions. In [11] and [12] have used Gabor elementary functions to represent generic 2D images. The even symmetric form of the Gabor elementary function that is oriented at an angle 0± is given by (3)

$$G(x,y) = \exp\left\{-\frac{1}{2}\left[\frac{x^2}{\partial_x^2} + \frac{y^2}{\partial_y^2}\right]\right\}\cos(2\pi f x) \qquad (3)$$

Here f represents the ridge frequency and the choice of ∂_x^2 and ∂_y^2 determines the shape of the filter envelope and also the trade of between enhancement and spurious artifacts. 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 necessarily results in an efficient image enhancement method Fig. 3"(b)".

After of both algorithms, a binarization algorithm is applied

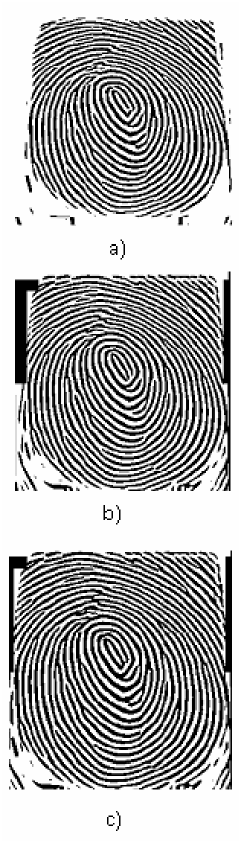

Fig. 3 (a) fingerprint image after the enhancement used FFT analysis
(b) fingerprint image after the enhancement used Gabor filters
(c) fingerprint image after added the two processes

by every output. This gives a lower cost computing. This step used a threshold if the pixel values are higher than threshold is white and the pixel values are less than threshold is black [13].

C. Cut

After the binarization, the border in fingerprint image is cut to avoid spurious minutiae and noise generated by the biometric scanner Fig. 4.

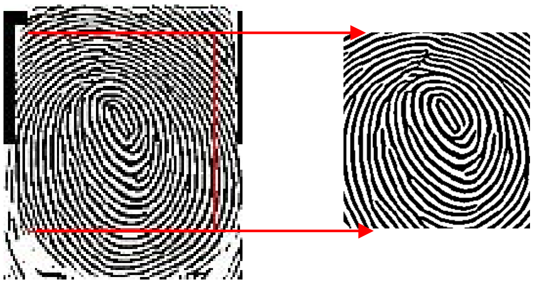

Fig. 4 image after cut

D. Thinning

Before the feature extraction stage, a thinning process is applied, this is, an algorithm where the result is an image with lines of the minimum possible thickness (one pixel) remembering that after the binarization process the image is made up only of 1 and 0, where a 1 means a white pixel and a 0 black pixel Fig 5 “(a, b, c)”.

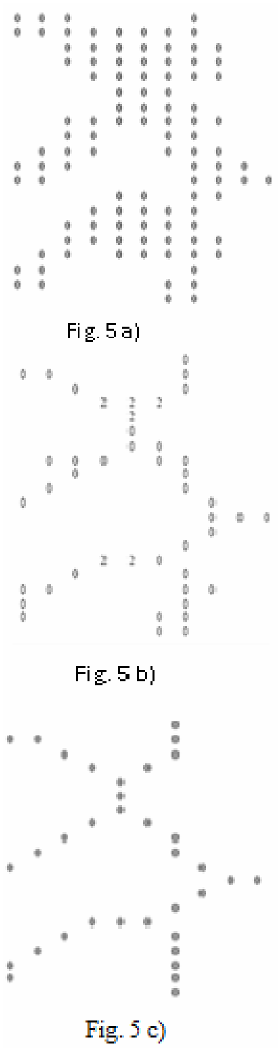

Fig. 5 this image shown the fingerprint thinning process (a) initial image (b) image after finding limited pixel (c) final image

In the last figure notes that image values obtained in the fingerprint thinning process are in their pixels binary values. Based in [14], a pixel 0 is internal if its four neighbors are 0 (black pixel). A boundary pixel is not an internal pixel and one of its 8 neighbors is a 1. A connection pixel is that to be removed its neighbors were disconnected.

The first step in this algorithm is to find all the internal pixels that exist in our image and delete all limit pixels, taking care that is not a pixel connection.

After thinning the image and not finding more internal pixels, applies again the same algorithm with a change, which is to find an internal pixels only with 3 neighbor pixels in 0 and then remove the limit pixels getting an image with thin lines Fig 6.

In the last image as show the picture obtained in the fingerprint thinning process.

Fig. 6 final image obtained after the thinning process

E. *Feature Extraction*

After the thinning process the image is ready so that the algorithm of detection of minutiae is applied. The algorithm consists in to calculate the number of pixels that cross to Pixel center (Pc) and it is calculated with the equation (4):

$$Pc = \sum_{i=1}^{s} p(i) \tag{4}$$

Here, Pc 0 to Pc 7 are pixels subsequent an ordered sequence of pixels that define the block of 8 neighbors of Pc and val (Pc) is the pixel value Fig. 7 “(a, b, c)”.

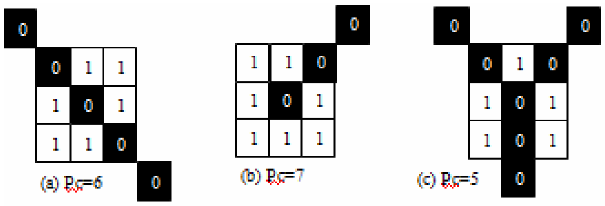

Fig. 7 this image shown the window 3*3 that makes the evaluation of the possible cases in the fingerprint image (a) block without minutiae (b) ending (c)bifurcation

In last image as shown the possible cases in the evaluation of the blocks on the thinning image, if Pc=6 in this block no exist minutiae, if Pc=5 in this block exist a feature of type bifurcation, if Pc=7 in this block exist a feature of type end of line. This process is performed on the entire optimal image applying a 3x3 sampling, found the position with regard to the image described by an ordered pair (x, y), this represent their position in the image Fig. 8.

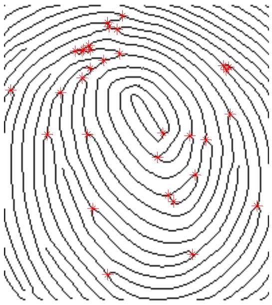

Fig. 8 final fingerprint image with features (minutiae) of the points highlighted with *

F. *Compute Distance and Angle*

The compute of the angle is done through the stroke of a triangle between the coordinates (x_1, y_1) regarding the minutiae that will make the assessment (x_2, y_2) this process is a point against all and so on for each minutiae “(Fig. 9)”. The distance is carried out using the same triangle mentioned previously, but now we computed the hypotenuse with the Pythagoras theorem in equation (5).

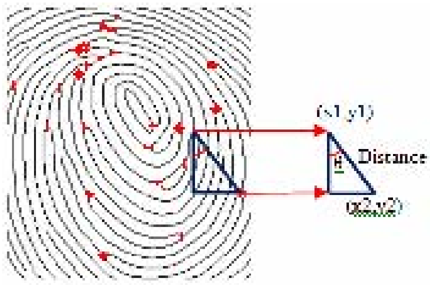

Fig. 9 the last image shown as computes the distance and angle between minutiae

In the previous image is showed the triangle that is used for compute the distance using the equation (5):

$$D = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2} \tag{5}$$

And the angle with equation (6):

$$\theta = \tan^{-1}\left(\frac{y}{x}\right) \tag{6}$$

Where: θ Is the angle

$$y = (y_1 - y_2) \tag{7}$$

$$x = (x_1 - x_2) \tag{8}$$

y_1, y_2 Are the coordinates in the y axis.

x_1, x_2 Are the coordinates in the x axis

A vector characteristic is generated for each minutia this vector contains the distance, angle and coordinates of the minutiae with these vectors a matrix is generate for an image. The vector is formed in the following manner (7):

$$vector = [D, \theta, x_1, y_1] \quad (9)$$

Here
D = distance
θ = angle
x_1 = coordinate in axis x
y_1 = coordinate in axis y

With the characteristic vector, a comparison is done between the characteristic vectors of the fingerprint image of test and the characteristic vectors from fingerprint image that are contained into the database. If in the comparison obtained more than one winner applied the verification stage. Here, is the translation of the fingerprint image of test with respect to the fingerprint image that is at the database as well as its minutiae. In the translation, look for similar minutiae in fingerprint into the database and test fingerprint, in the same neighborhood. After this, compute the difference between coordinates. With these values translated the image and minutiae of test image at the same point that the fingerprint into the database.

The invariant moments are image descriptors that conserve the geometry features of the image, then, after of translation, computed the seven invariants moments(10-16) to rotation and translation [15]-[17]

$$\phi_1 = \eta_{20} + \eta_{02} \quad (10)$$

$$\phi_2 = (\eta_{20} + \eta_{02})^2 + 4\eta_{11}^2 \quad (11)$$

$$\phi_3 = (\eta_{30} + 3\eta_{12})^2 + (3\eta_{21} + \eta_{03})^2 \quad (12)$$

$$\phi_4 = (\eta_{30} + \eta_{12})^2 + (\eta_{21} + \eta_{03})^2 \quad (13)$$

$$\phi_5 = (\eta_{30} + 3\eta_{12})(\eta_{30} + \eta_{12})\left[(\eta_{30} + \eta_{12})^2 - 3(\eta_{21} + \eta_{03})^2\right] + (3\eta_{21} + \eta_{03})(\eta_{21} + \eta_{03})\left[3(\eta_{30} + \eta_{12})^2 - (\eta_{21} + \eta_{03})^2\right] \quad (14)$$

$$\phi_6 = (\eta_{20} - \eta_{02})\left[(\eta_{30} + \eta_{12})^2 - (\eta_{21} + \eta_{03})^2\right] + 4\eta_{11}(\eta_{30} + \eta_{12})(\eta_{21} + \eta_{03}) \quad (15)$$

$$\phi_7 = (3\eta_{21} + \eta_{03})(\eta_{30} + \eta_{12})\left[(\eta_{30} + \eta_{12})^2 - 3(\eta_{21} + \eta_{03})^2\right] + (3\eta_{21} + \eta_{30})(\eta_{21} + \eta_{03})\left[3(\eta_{30} + \eta_{12})^2 - (\eta_{21} + \eta_{03})^2\right] \quad (16)$$

For each minutiae of the fingerprint image of test, this is contained in a window of 10*10 Fig. 10 with respect to the fingerprint image of the data base, with the fingerprint image of the database without moving and the fingerprint image of test transferred a signal is generated.

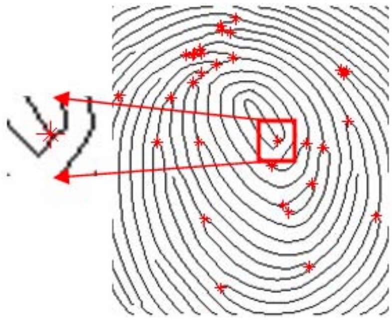

Fig. 10 window of 10*10 to compute the invariants moments

In the last image showed the window of 10*10 that is used for obtained the invariants moments to rotation and translation.

For these tests took 10 images of fingers thumbs rights of 10 different people. The images have a 340*430 size in gray scale with 510 dpi and taking 5 for training and the remaining 5 for the test.

III. Results

In the Fig. 11 and Fig. 12 images show the fingerprint images obtained during the translation process Fig. 13 of the fingerprint image of test Fig. 12 with respect to fingerprint images into database Fig. 11 also show the coordinates of the fingerprint image of test after translation with respect to the coordinates of the fingerprint image into the database.

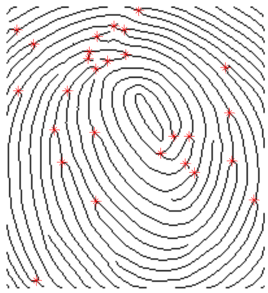

Fig. 11 fingerprint image into of database

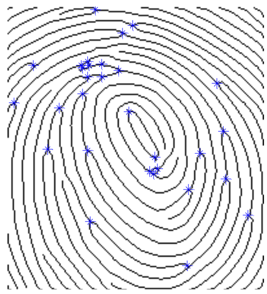

Fig. 12 fingerprint image of test before translation

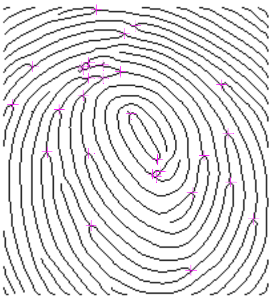

Fig. 13 fingerprint image of test after the translation

The performance of the translation process first compute the distance between the same minutiae of the fingerprint image of test and of the fingerprint image into the database, with this distance translates the all minutiae and also translates the fingerprint image of test complete Fig. 14.

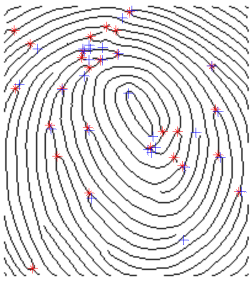

Fig. 14 coordinates of the fingerprint image of test after the translation

In the last image shown the coordinates of the fingerprint image after translate with respect to the coordinates of the fingerprint image into database, recall that the images although are of same person in the moment to obtain the impression is different position and applied force, so some minutiae exist in a fingerprint and in the other not and the distances are different.

The following images show the signals obtained after the apply invariants moments to rotation and translation algorithm on fingerprint images later applied translation process to fingerprint image of test. The first image is the signal obtained of the fingerprint image into database Fig. 15, the second is the signal obtained of the fingerprint image of test without translate Fig. 16 and the third is the signal obtained of the fingerprint image of test after translate Fig.17.

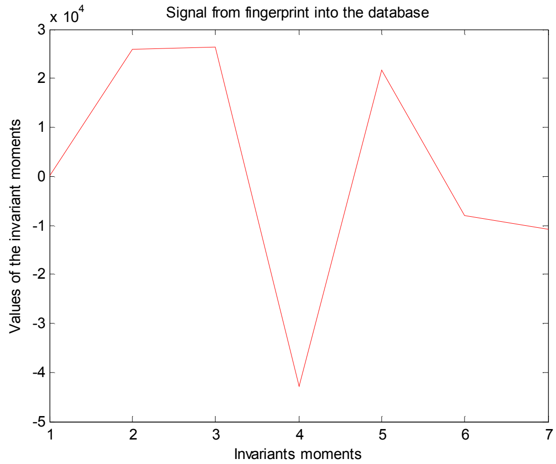

Fig. 15 signal generated by seven invariants moments of the fingerprint image into the database

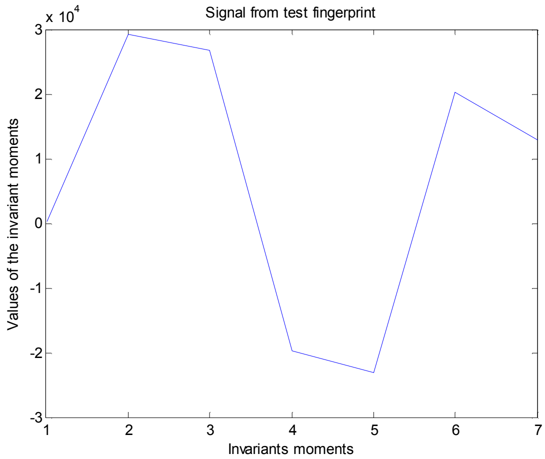

Fig. 16 signal generated by seven invariants moments of the fingerprint image of test without translation

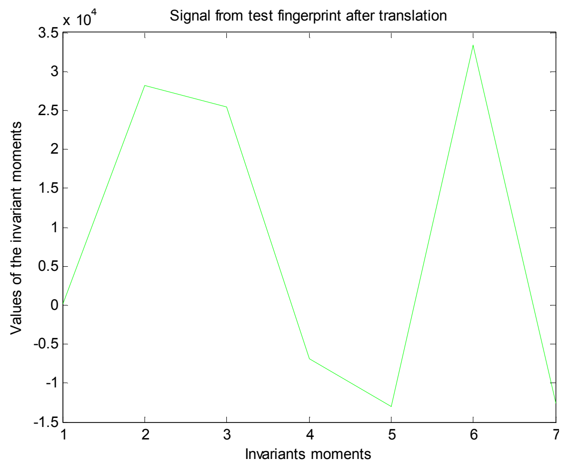

Fig. 17 signal generate by seven invariants moments of the fingerprint image of test after translate

The following images show the comparison between the signals obtained after the applied the invariants moments to rotation and translation algorithm to fingerprint image of test of a person contained into database Fig. 18.

Also, in Fig. 19, Fig. 20 and Fig. 21 are the signal generated with the invariants moments used a fingerprint of test that is not into the database. In Fig. 22 the comparison of the signals obtained of fingerprint image contained into database and a fingerprint image of test of a person that is not contained in database.

The red signal is from fingerprint image into the database, this signal is the template to the test image, the blue signal is from fingerprint image of test without translation and the green signal is from fingerprint image of test after the applied invariants moments to rotation and translation. Recall the invariants moments only are competed when in the comparison obtained more than one winner

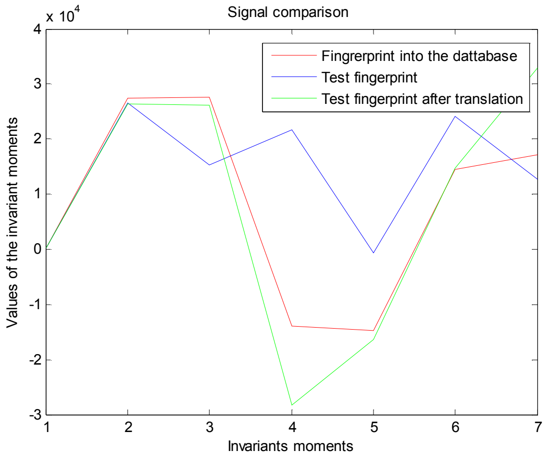

Fig. 18 comparison the signals of the same person using invariants moments to rotation and translation

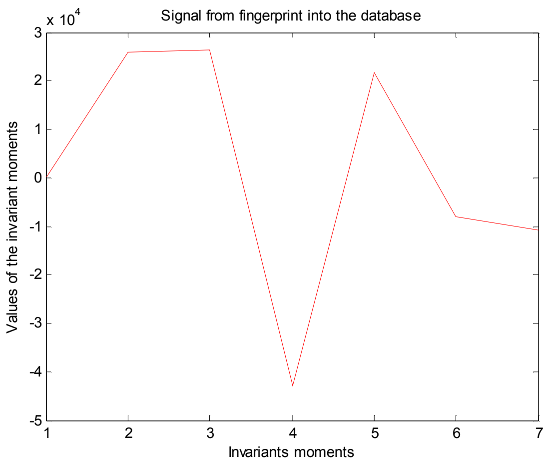

Fig. 15 signal generated by seven invariants moments of the fingerprint image into the database

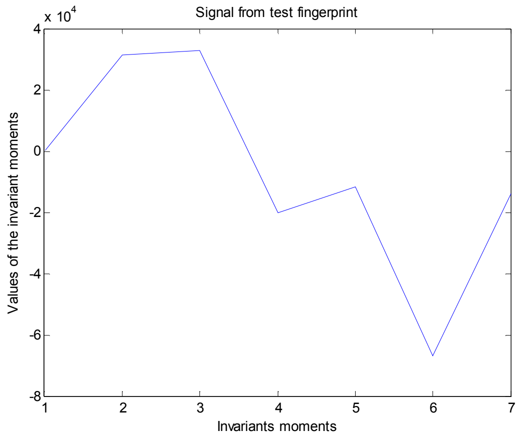

Fig. 16 signal generated by seven invariants moments of the fingerprint image of test without translation

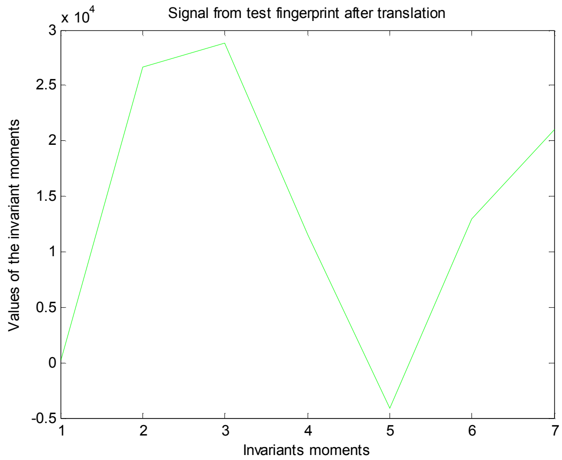

Fig. 17 signal generate by seven invariants moments of the fingerprint image of test after translate

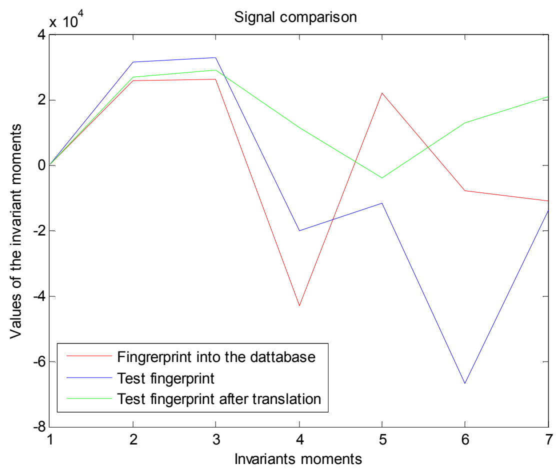

Fig. 19 comparison the signals of the different people using invariants moments to rotation and translation

As seen, the signal generated used invariants moments with a fingerprint of the people without register into the database are totality different to the signal created with a fingerprint contained in database.

The comparison used the characteristic vector was made used different thresholds after in the translation process and compute of the invariants moments to rotation and translation used a window of 10*10 to generate the signals. The results for training phase are show in "table I" and The results for recognition phase are show in "table II".

TABLE I
RESULTS FOR TRAINING PHASE

Threshold	window	Percentage of recognition
17	10¨10	98.20%

TABLE I I
RESULTS FOR RECOGNITION PHASE

Threshold	window	Percentage of recognition
17	10¨10	89.30%

IV. CONCLUSIONS

In this article used two algorithms to get a reliable fingerprint image. The images with low quality after the enhancement have a good quality hence are more reliable than in the moment when were collected.

The percentage of the same minutiae in different images the same person using both algorithms (85.75%) is better than if we use only one (FFT=76.85, Gabor =80.53), In obtaining the moments of each item and compare them with those of another fingerprint of the same person we realize that to be the same point even though has moved some pixels retains its characteristics to obtain invariants moments to rotation and translation.

The invariants moments algorithm used gave us good results since being transferred to the test image and as saw in the signals from this are very similar with this can be used for training of an artificial neuronal network to recognize the person that is owns this fingerprint.

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