Improved AFIS for Color and Gray Image based on Biometric Triangulation

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ABSTRACT

This research presents a fingerprint image processing algorithm for personal automatic identification, which has been in development since 1998. It is principally based on the comparison of the fingerprint's biometric pattern between the fingerprint captured (original) in each session and the one stored in database. It is preferable to capture the image in color. The biometric pattern is formed by the Euclidean distances based on the triangulation of only three minutiae. This methodology locates the position and the type of each minutia to perform the triangulation. The applied metric is the statistic similarity obtained by the comparison of both biometric patterns. This technique enables one to solve translation and rotation problems. An original colored fingerprint is used in order to obtain more information about the fingerprint situation. The space color used is HCL, because it helps get a good skin color for an encrypt key, which is formed by each channel (HCL) in accordance with the skin color. This system has several applications due to its low cost and efficiency. Finally, the results obtained with this methodology were satisfactory since in all the experimental tests the system offered a rate of global success of 99 %.

Keywords: AFIS, Biometric patterns, Minutiae, Color and gray fingerprints, image processing.

1. INTRODUCTION

Nowadays, automations are becoming necessary and inevitable. This has triggered the amount of research focused on the improvement of this area. The traditional automations that are used to control personal access are generally based on magnetic systems and bar codes, logins or a combination of all the above. The systems involve the use of a card which must be physically carried by the owner, and which may be lost, damaged, forgotten or stolen. Security then becomes more vulnerable. For this reason, the identification biometric systems are the best solution to the problems mentioned above [25]. There are a great variety of biometric systems that are used in different applications. The biometric technologies commonly used are: fingerprints, hand geometry, faces, iris patterns, retina, voice and signature [16].

There are several situations in which the colors are important; the principal point is that colors can be seen by humans and every color gives a different kind of information, that is to say, if the color of an image is omitted, the identification features will also be omitted. The purpose of capturing and pre-processing fingerprints by using color image´s is to separate features from an interfering background of the foreground and to have important and additional information about the features of each fingerprint captured [4]. The performance of an AFIS is frequently affected by diverse fingerprint image quality factors [9] such as skin color and skin conditions (e.g. dryness, wetness, dirtiness, temporary or permanent cuts and bruises, spots in skin). Some of these factors cannot be avoided. Poor quality image results in spurious and missing features, thus reducing the performance level of the overall system. Therefore, this proposal recommends capturing fingerprints in color to have improved AFIS (I-AFIS). But, if it is impossible to capture the fingerprint in color, this proposal can also be used for gray fingerprint omitting the color part.

A digital fingerprint is the representation of the superficial morphology of the finger's epidermis, which is formed in the fetal period in the sixth month, being invariable across the person's life, unless they suffer alterations such as accidents, cuts or burns. The fingerprint impression is the reproduction of the fingerprint shape on a flat surface, stored in analogical format on paper or digital format in a file. In the fingerprints, the papillary crests are estimated as the darkest lines and the inter-papillary valleys are estimated as the clearest lines. The fingerprints possess a set of lines that are observed as parallel lines; however, these lines are intercepted and sometimes they finish abruptly. The points where these finish or branch off are known technically as minutiae (bifurcations).

There are two types of automatic fingerprint recognition systems: the automatic fingerprint verification system (AFVS) which includes a login and the fingerprint and the automatic fingerprint identification system (AFIS) which includes only the fingerprint [16]. This represents an approximation of the AFIS. This type of system forms part of the big biometric system family, but it is unique in its own characteristics.

Hitchcock used a dynamical binarization system that did not yield satisfactory results in fingerprint [8]. Ratha carried out the recognition of fingerprint based on minutiae considering: position, orientation and fingerprint types, but unfortunately, when the images present noise or have a minimal degree of rotation they do not achieve favorable results because the noise elimination is performed as pos-processing once the extraction of characteristics was done [3]. These works, along with the ones published by

Numann the characteristics of a system of recognition that is based on the comparison (matching) of the minutiae considering position, type and orientation [8]. On the other hand, Drahanský [20], Yilong, Jie and Xiukun considered the recognition of the minutiae distances to form the pattern, but they also take into account more than three minutiae which makes the system slower [29]. Furthermore Drahanský is made a general description for dactyloscopic system. The difference of the system proposed here is that it has an own methodology that offers an efficient alternative.

The objective of this paper is to present a reliable I-AFIS that allows fingerprints to be captured and compared with the fingerprints stored in the database to obtain personal access and information. The comparison of the fingerprint is done through the biometric pattern which is obtained from the Euclidean distances of the triangulation of three minutiae by considering position and type. This I-AFIS also considers a encrypt login or key formed by means of each channel color (HCL) of the skin color of each person. This way, the system is economic, practical and adaptable to the different needs of person identification.

2. MATERIALS AND METHODS.

2.1. Material means.

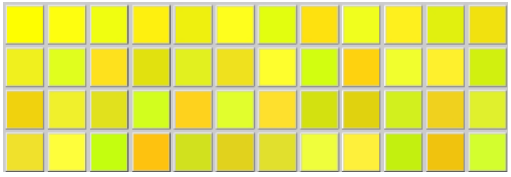
The images were captured with a resolution of 300 x 300 pixels to 500 dpi. These images were analyzed in color and gray. Fifty fingerprints were taken from different students of the Universidad Autonóma de Querétaro in 2007; from these fifty fingerprints, twenty were randomly selected to perform the test, and three of them were meticulously observed to carry out this study.

These fingerprints were analyzed from different situations, positions and types to finally obtain the system answer. This test was performed in an AMD Turion 64 Mobile Processor ML-34, with 1024 Mb memory. The development software was Delphi version 6.

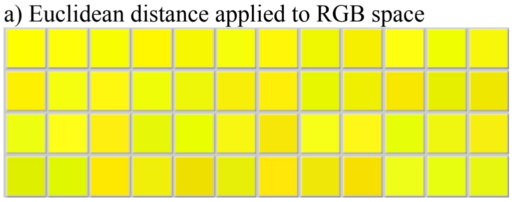
2.3. Capture and pre-process of color fingerprint image

Color transformation algorithms prepare images to separate the features and the differences between background and foreground. By using color, features invisible to the human eye can be distinguished and removed. Every image captured has background and foreground, and it is important to consider both of them in order to have more details to help identify the person.
When processing images incorporates color as part of the information, the treatment of image is more complex, not only for the important details of the fingerprint, but also for the many color space existences.

The first step is to capture the digital fingerprint with a scanner. Digital fingerprints are usually obtained in RGB format in color image. However, RGB color representation has some disadvantages: components are strongly correlated, lack of human interpretation, non uniformity, etc. A polar representation with hue, saturation and light (HSL) components allows for the solving of these problems. The HSL is the most popular polar space representation (among others like HSI, HSV, HSL) [13]. Many of these systems were developed with computer graphics applications in mind, and have a number of shortcomings for image processing and analysis task [1]. One of the spaces that consider visual perception is HCL space (Hue, Chroma, Luminance), so HCL is selected in this proposal to process the fingerprint images. The chromatic part in this space is mixed by considering the Red-Green (R-G), Green-Blue (G-B) and Blue-Red (Blue-Red), and it provides better perception uniformity than RGB (see Figure 1) [24].



a) Euclidean distance applied to RGB space



b) Cylindrical distance applied to HCL space

Figure 1. Comparison between RGB and HCL [24].

The transformation from RGB coordinate system to a hue, saturation and light coordinate system is described by Levkowitz and Herman [12].

The second step is the separation of background from the foreground. It has the principal fingerprint characteristics and omits other different colors from the skin color. In the foreground the different colors are stored to give additional information from each captured image session. This information can be analyzed when required. The foreground gives the average of the skin color in each channel H, C, and L. The transformation of RGB to HCL has its own formula depending on what chromatic part is mixed R-G, G-B, or B-R (it depend on skin color, the most common is the red color part, R-G, B-R) [24]. With the formula to transform RGB to HCL and another formula to change the result of the three encrypt key numbers are generated. If the image is in gray, then the encrypt key is omitted and the seeking is only done by means of a triangulation of the three minutiae.

The third step is pre-processing image where the enhancement contrast and another process play a fundamental role in many of image processing tasks. The main purpose of this step is improving the visual appearance of an image. The sub-processes applied in this step are: 1) Enhancement contrast [19], 2) Equalization of the image [23], 3) Maximums [17] and 4) Gray image [28].

2.4. Process for obtaining the biometric pattern

The first step is the image filter. This process consists of the elimination of confused zones (called noise) in the original fingerprint image. The purpose is to obtain the minimum information zones with the maximum reliability. For such effect, the Fourier transformation is made by using equation (1 and 2). In this process the image is transformed to the square size image of 256 x 256 pixels ([23], [17]).

$$F(u,v)=\sum_{x=0}^{N-1}\sum_{y=0}^{N-1} f(x,y)\exp\left[-i2\pi(ux + vy)/N\right] \quad (1)$$
$$for \quad u,v = 0,1,2,...,N-1$$

Where $F(u,v)$ is the Fourier transformation.

$$f(x,y)=\frac{1}{N^2}\sum_{u=0}^{N-1}\sum_{v=0}^{N-1} F(u,v)\exp\left[i2\pi(ux + vy)/N\right] \quad (2)$$
$$For \quad x,y = 0,1,2,...,N-1$$

Where $f(x,y)$ is the original image.

Afterwards, Norbet Wiener, Highpass or Lowpass is used to improve image ([23], [14], [11]) .

The second step is the binarization which is done by using equation (3), where the original image is transformed into two colors (black and white) [15]:

$$g(x,y)=\begin{cases} 255 \quad si \quad \left|\Delta f_{ij}\right| \succ 0; \quad is \quad crest \\ 0 \quad si \quad \left|\Delta f_{ij}\right| \prec 0; \quad is \quad valley \end{cases} \quad (3)$$

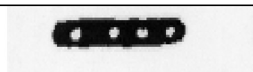
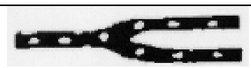
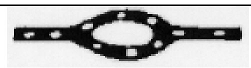
The third step is the slimming of the crests to obtain a pixel width. The algorithm of crest slimming, which is used in this research, is based on a fast slimming algorithm for characters [8]. The application of this algorithm requires a binary image where the crests are represented by one color and the rest by another. Basically, the algorithm is applied in two parts: In the first one, the pixels on the image are analyzed as candidates to be erased. In the second, the pixels can be erased as long as they do not break the crest continuity; in general, the pixels belonging to the edges are selected. This algorithm is repeated until identity is obtained.

The fourth step is the crest flattening. In this step, a comparison of the last filtered image and the captured image is made in order to accurately identify the real crests in order to eliminate imperfections [10].

The fifth step is the extraction of minutiae. Finally, the typical points that constitute the biometric pattern of the fingerprint are extracted by determining if each pixel of the slimmed image belongs to a crest (with regard to the original fingerprint) and if it does, verifies whether it belongs to a bifurcation. The types of fingerprint minutiae are given in Table 1 [18]. In a high quality image, it is common to find between 70 and 100 minutiae, which provide sufficient information to determine the fingerprint individuality [16].

In spite of the minutiae variety, the most important are the crest completions and bifurcations. The crest completions represent approximately 60.6 % of a fingerprint and the crest bifurcations 17.9 % [2]. Furthermore, several of the typical minutiae can be expressed in these two most important crests. They can be principally classified in to five types (see Table 1).

Table 1. Types of minutiae

Type	Form
Islote: It is a small crest that must not exceed an extension of five times the thickness of a crest (2 ½ millimeter).	
Cut: It is a crest that is born in one of the sides and its race does not finish.	
Bifurcation: It is a crest that is divided in two branches.	
Bracket: It is a crest that is opened in two, giving rise to the formation of an angle.	
Enclose: It is formed by a crest that is bifurcated and is closed later, giving rise to the formation of an ellipse or a circle.	

The sixth step is the pattern comparison [27], which is based on the first biometric pattern findings. When the image is captured in color, the noise-area (dryness, temporary or permanent cuts, spots in skin, etc.) is omitted in order to match the captured fingerprint to the database fingerprint, but it is used to have details of each captured image session. Furthermore, the encrypt key is used to find the fingerprint quickly in the database and to verify the identity of the person. The biometric pattern is formed by the Euclidian distances that are obtained by only using the three minutiae triangulation. The Euclidian distance of the triangle is made by using equation (4) [6]. The triangulation is compared with the stored triangulation in the database. If the triangulation matches, then the fingerprint belongs to the same person registered in the database. With these two biometric patterns, the system is able to give a similarity index. The similarity values can range between 0% (no matching at all) and 100% (the fingerprints are identical). The system compares the biometric pattern of the original fingerprint to fingerprints that have similar encrypt key to determine the certainty of the person's identity. The objective is determined if the declared identity is real or not.

$$d=\sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2} \quad (4)$$

Where (x_1,y_1) *y* (x_2,y_2) *are the bifurcation coordenate*

3. EXPERIMENTAL RESULT

3.1. AFIS Operation

For the system operation, there are two phases: a) Inscription phase, the system registers a new person authorized by the system manager, storing the biometric pattern extraction of entry in the database and registering the identity of the new user; b) Identification phase, in this phase the individual's pattern is searched and recognized comparing the biometric pattern of the fingerprint with the corresponding biometric pattern before storing it in the database. This AFIS and encrypt key (with skin color) form

I-AFIS. Figure 2 shows the AFIS architecture. Inscription phase, Database, Identification phase and finally, the result in this figure can be seen. The connecting of these components permits the implementation of the system [16].

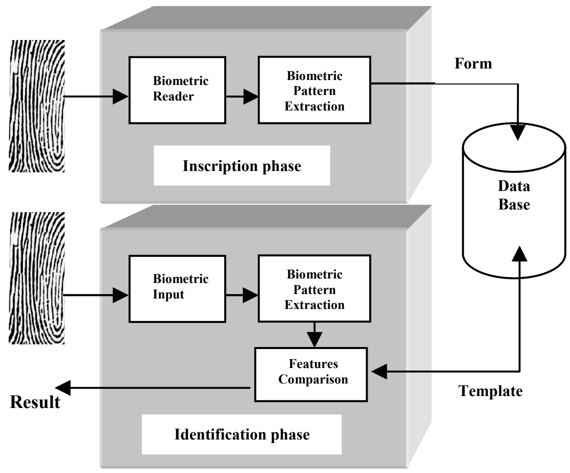
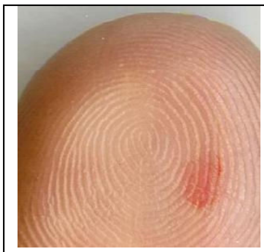


Figure 2. Automatic Fingerprint Identification System architecture

3.2. Case of color image

One example of the tests performed on one of three selected fingerprints of the database is shown in the order to verify the validity of this methodology.

First, it is important to find the encrypt key. It is found by skin color (see Figure 3).



(a) Original image

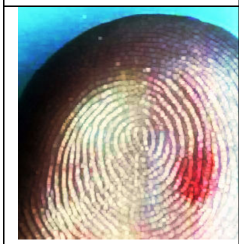
(b) Foreground and skin color H=203/2, C=86/2, L=102/2 (encrypt key 101043051).

Figure 3. Foreground determines encrypt key

Figure 4 shows steps in the case of color image,in (a) is applied the enhancement contrast to original image (Figure 2 (a)), in (b) the equalization of the color image is applied, in (c) the first edge enhancement is carried out by applying maximums, in (d) detection of the foreground is carried out by considering the skin color, in (e) the binarization image is carried out (it takes place once the image was converted to grayscale, the noise reduction was applied and the edge enhancement was done), in (f), the slimming of the crests is carried out to obtain a pixel width, in (g) the graphic triangulation of three opposing bifurcations is done with the objective of finding the distances of the respective legs to form the biometric pattern. Finally (h) shows the database fingerprint which will be matched with captured biometric patter (g). (j) shows that the person is found and the triangulations are very similar (See Table 2, Statical Similarity, C 18º for this case).

(a) Enhancement contrast

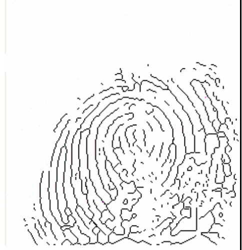
(b) Equalization histogram



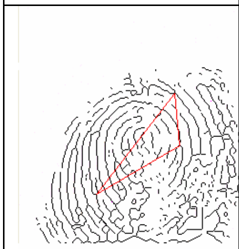
© Maximums

(d) Detection of the foreground

(e) Binary image.

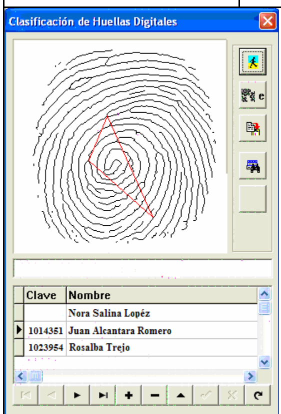


(f) Slimming



(g) The graphic triangulation to form the biometric pattern.

(h) The database fingerprint



(i) The matching with obtained skin color and biometric pattern.

Figure 4. Steps in the case of color image.

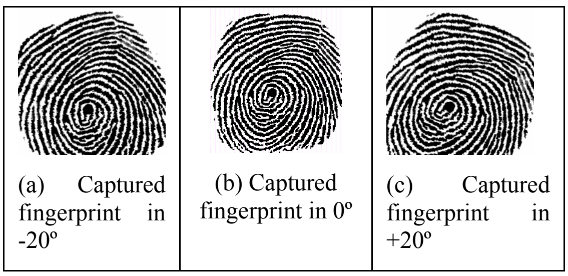
3.3. Case of gray image

This is a typical example of the gray images to find the statistical similarity of the biometric pattern for two of remaining selected fingerprints of the database; three forms were considered according to the acquired position of the fingerprints: -20º, 0º and +20º approximately (see Figure 5). Table 2 gives the details of the obtained results.

Table 2. Statical Similarity

Case	d1	d2	d3	H_BD	d'1	d'2	d'3	E1	E2	E3	Statical Similarity %
-20º	18	21	29	1096	18	21	29	0	0	0	100
0 º	18	21	29	1096	18	21	29	0	0	0	100
+20 º	18	20	28	1096	18	21	29	0	1	1	97.14
-20 º	34	49	61	1121	34	51	61	0	2	0	98.64
0 º	34	51	61	1121	34	51	61	0	0	0	100
+20	35	50	61	1121	34	51	61	1	1	0	98.38
C +18 º	34	51	61	1121	33	51	62	1	0	1	98.04

d1, d2, d3 are the Euclidian distances (in pixel) of the biometric pattern in the fingerprint to be recognized. In the same way, d'1, d'2 and d'3 are the Euclidian distances of the biometric pattern captured in the database. E1=d1-d'1, E2=d2-d'2 and E3=d3-d'3. H_BD is database fingerprint. C+18º is color fingerprint. Finally, the statistical similarity is the degree of comparison of both patterns.



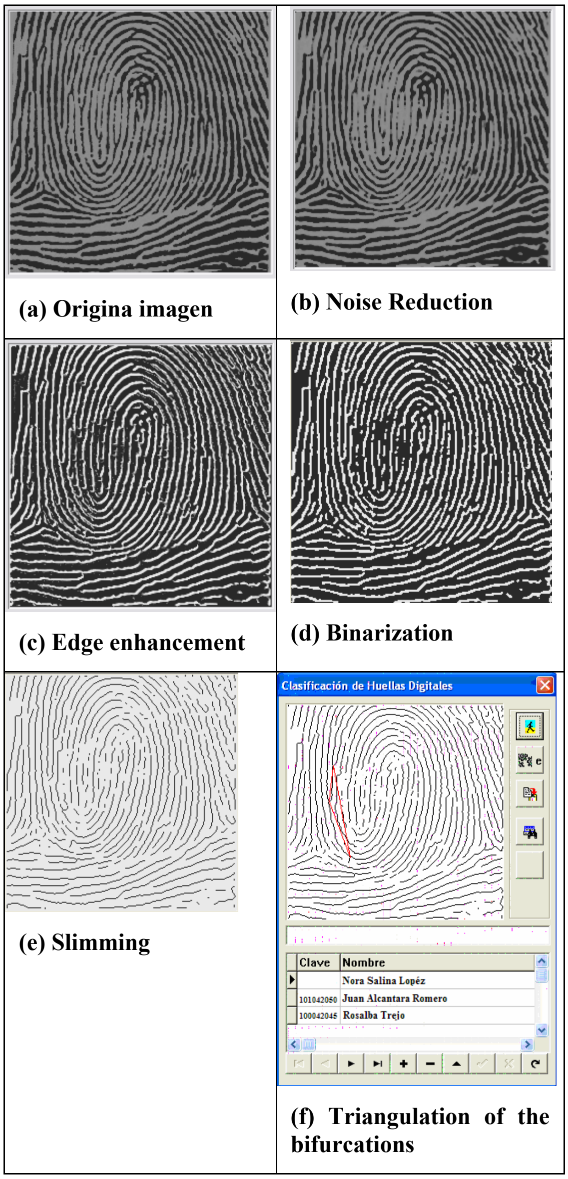
(a) Captured fingerprint in -20º

(b) Captured fingerprint in 0º

(c) Captured fingerprint in +20º

Figure 5. Three position of the fingerprint.

Figure 6 shows Steps in the case of gray image in (a) the original fingerprint is shown, in (b) the noise reduction is carried out by means of a Lowpass filter (applied to (a) across the processing frequencies), in (c) the edge enhancement is carried out by applying a unidirectional gradient of (a), in (d) a binarization is carried out on the criterion of the magnitude of the unidirectional gradient, in (e) the slimming of the crests is carried out to obtain a pixel width. Finally, (f) shows the graphic triangulation of three opposing bifurcations with the objective of finding the distances of the respective legs to form the biometric pattern.



(a) Origina imagen

(b) Noise Reduction

(c) Edge enhancement

(d) Binarization

(e) Slimming

(f) Triangulation of the bifurcations

Figure 6. Steps in the case of gray image.

4. CONCLUSIONS AND RESULTS

Every biometric technique has strengths and weaknesses; the selection of one depends on the application characteristics and on the biometric properties. Fingerprints possess the highest levels in reliability so they are one of the most comfortable ways for people to be identified. For that reason they are used in this I-AFIS. This I-AFIS can be adapted to a great number of applications. One good point of this system is that the features used in this system contain the following characteristics: Universality, all people have these characteristics. Uniqueness, there are no two people with the same features. Permanency, these features do not change with time. Quantification, the fingerprints admit quantitative measurements. It can be said that fingerprints are almost impossible to alter; they are different even in identical twins [16], and they remain unaltered during one's entire life (even when small wounds exist. If the skin is regenerated without scars, the new fingerprint is the same as the previous one) even after death or mummification.

The proposed system is original and can be used to identify or to verify people, due to the fact that it is flexible and can be adapted to the application context. Furthermore, this system has a method that is a simple technique for fingerprint identification, which is based on the calculation of only three minutiae (bifurcations). These minutiae are located, by preference, near the fingerprint nucleus. They form the triangulation of the biometric pattern according to Euclidian distances. The color characteristics of the captured fingerprint in each session provide additional information. This additional information (different for each person) allows the creation of an encrypted key for quick access to the fingerprint in database. It is important to note that two of the main problems encountered in this study and solved by this methodology, were:

1) The fact of finding an appropriate way for the color image binarization. 2) The triangulation searching accomplishment by considering situations, positions and type. It should also be mentioned that the results obtained in the process of statistical similarity were satisfactory, since in all the experimental tests performed the system offered a false acceptance (FA) rate of 0, and a false rejection (FR) rate of 1%, obtaining a global success rate (TE) of:

$$TE = 100\% - (FA + FR)\% = 100\% - (0 - 1)\% = 99\% \qquad (7)$$

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