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Biometric Identification by Fingerprint Image Based Minutiae Detection

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الخلاصة

تعد الوثوقية الشخصية تطبيق مهم من تطبيقات الحوار بين الإنسان والحاسبة والتي نتجت من خلال التطور في عالم الرقميات وان احد أمثلة هذه التطبيقات هي تكوين الهوية الشخصية . يعرف علم المقاييس الشخصية بأنه علم تحديد الصفات الشخصية من خلال المقاييس الفسيو لوجية (الوظائفية) والصفات السلوكية . تو فر المقاييس الشخصية مثل بصمة الأصبع، الوجه وطبعة الصوت أسلوب للوثوقية الشخصية . تعتبر بصمة الأصبع نوع مهم من أنواع المقاييس الشخصية التي من الممكن استخدامها في التطبيقات المدنية والقانونية.

اختيرت قاعدة بيانات لبصمة الإصبع من قاعدة الصور العالمية FVC2000/DB2 لبصمة الأصبع. ومن ثم تم إجراء معالجة أولية للصور من خلال إجراء عمليات التحويل من الصور الملونة إلى الصور ذات التمثيل الثنائي باستخدام أسلوب المشتقة لمرشح كاوس وذلك لامتياز هذا الأسلوب بتحديد الحواف . اعتمدت مشتقة Sobel الأفقية والعمودية لحساب زاوية القوس وتحديد اتجاهه، من ثم لتحديد التفاصيل بدقة استخدمت عمليات المورفولوجي للصور في عملية التنحيف . قطعت هذه الصور بشكل مقاطع صورية ممثلة بمربعات لفصل خلفية الصورة عن صورة البصمة وكذلك لتقطيع البصمة إلى مقاطع صورية تتضمن تفاصيل تتمثل بنهاية الأقواس الموجودة فيها إضافة إلى الأقواس المتفرعة. أخيراً، لتحديد تفاصيل البصمة اعتمدت طريقة Crossing Number م ع المقاطع الثنائية الناتجة لاختبارها إذا كانت تمثل أقواس متفرعة أم أقواس نهائية. اثبت العمل المقترح نتائج كفوءة تجاوزت نسبة ٨٢ % مقارنة بأنظمة أخرى في نفس المجال.

Abstract

In an increasingly digital world, reliable personal authentication has become an important human computer interface application, some

examples where establishing a person's identity. Biometrics is the science of verifying the identity of an individual through physiological measurements or behavioral attributes. Biometrics such as fingerprint, face and voice print offers means of reliable personal authentication. Fingerprints were one of the important forms of biometric identification to be used for law and civilian applications.

Data base images for fingerprint images are selected from the First International Fingerprint Verification Competition FVC2000/DB2. Then a primary processing to these images are performed through the transformation from RGB color to binary form using the derivative of Gaussian filter scheme because, the excellence of this scheme in edge detection. The Sobel horizontal and vertical gradient are relied to compute the ridge angle and to detect its orientation, then to detect the details accurately image morphological operations are used for thinning operation. These images are segmented to image portions represented by blocks also to segment the finger tip to image portions contain details assimilate by ridges ending as well ass ridges bifurcation. Indeed, to detect the details of the fingerprint Crossing Number method is relied with the resultant binary portions to test them if they represent ridge ending or ridge bifurcation. The proposed work shows efficient results exceeds 82% compared with other system on the same field.

1. Introduction

Accurate automatic Biometric identification is an important field to the operation of our increasingly automated information society [3]. Biometrics is defined as "reorganization of a person by determining the authenticity of a specific physiological and/ or characteristic posse by the person" [9].

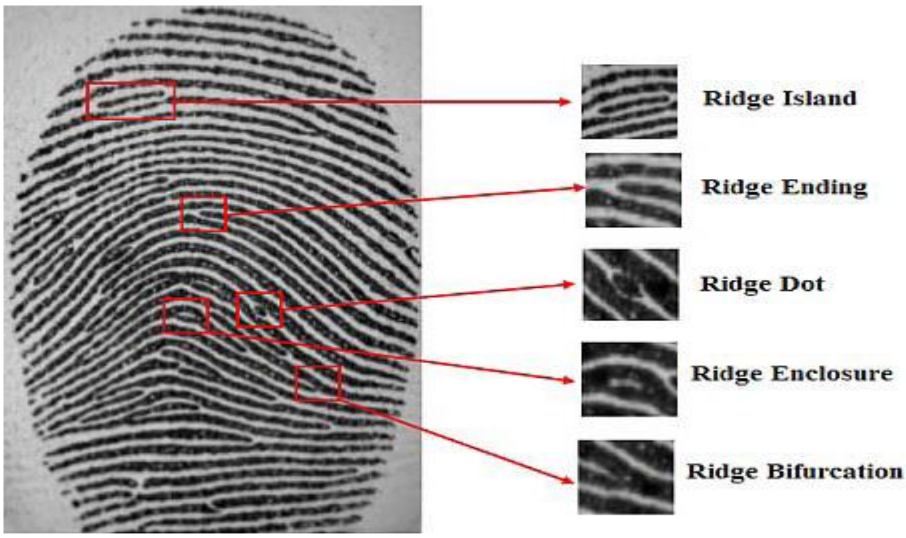
Fingerprint identification has become the most important than other characteristics such as face, retina, iris, voice and handgeometry biometric due to its university, performance and accuracy [3][4]. Fingerprint identification has been started since eighteen century by (Edward Henry), who establishes the "Henry system" for fingerprint classification. The progress of this field was continued by the early 20 century. Various fingerprint identification systems that based on fingerprint classification, matching and detection were developed. These systems were used in forensic agenesis as well as civilian applications [9][2].

This rapid increase in fingerprint detection requires feature extraction algorithm. These features are minutia that includes the ridge and bifurcation [4][8]. Automatic fingerprint identification systems (AFIS) are a class of biometric information systems widely used based on minutiae matching. Another system was based on segmenting the fingerprint image into ridge zone and background. Statistical analysis is used such as moment other system used three zone such as ridge, valley and background with histogram. Also Fourier and Gabor filter to enhance the fingerprint images before any segmentation [11][10].

The proposed work use RGB fingerprint images then these images are transformed to gray-scale images. The gray-level images in turn are converted to binary images to facilitate minutiae extraction. Thinning process is performed to the fingerprint binary images. The thinned images are segmented into blocks to isolates the foreground from background. Also to extract minutiae features locally per-block. Finally minutiae features such as ridge and bifurcation were extracted based on blocks.

2. Fingerprint features overview

Fingerprint represents the image of skin of finger tip. Fingerprint included ridge (black line) separated by valleys [3]. The type of ridge such has ridge ending, bifurcation, crossover represents the local features and known as minutiae used in fingerprint analysis. Commonly different 150 type of minutiae were recognized and defined a sample is shown in figure (1-a). The most important ones are ridge and ridge bifurcation used commonly in fingerprint identification as shown in figure (1-b) [11].



(a) **(b)**

Figure (1): fingerprint overview
(a): Different minutiae type
(b): Ridge ending and bifurcation

Ridge ending are the points were the ridge curve terminates, and bifurcation were the ridge split from a single path into two paths as Y-junction as shown in figure (2-a) and figure (2-b) respectively [1].

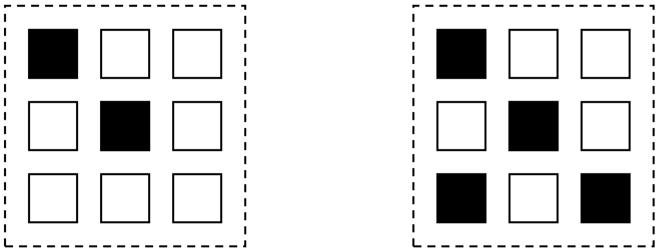


Figure (2): minutiae pixel representation
(a): Ridge ending pixels
(b): Ridge bifurcation pixel

3. The proposed work

A sample of 33 color fingerprint data set images are applied as a visual database in this work. These images are selected from FVC2000/DB2 figure (3) shows some images from the sample. The proposed work differs from others work in two points. The first one is that the proposed work uses the block-wise operation instead of pixel-wise scheme which is widely used in fingerprint analysis. The second is that, the segmentation process is performed not only to isolate background and foreground but also to segment the fingerprint tip as blocks with details while others isolate the foreground and background only.

Figure (3): sample from FVC2000/DB2

In order to extract Minutiae features easily and clearly these RGB images are converted to the gray-scale images then to binary images. The gray-scale images is regarded as an intermediate step, because there is no command that directly converts the RGB images to the Binary images. Minutiae detection algorithm is described briefly in the following steps:

1) Pixel orientation.
2) Image binarization
3) Thinning
4) Segmentation
5) Minutiae detection.

These steps are shown in figure(4). A detailed description to each step is discussed in the follows:

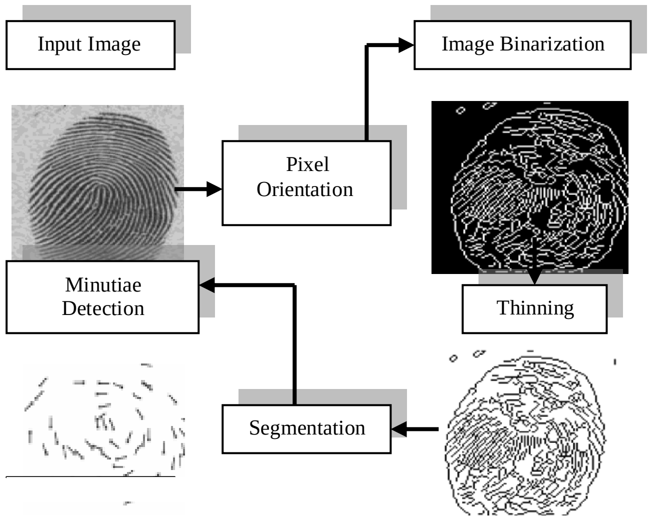


Figure (4): minutiae detection algorithm

3.1 Pixel Orientation Computation

The orientation field in fingerprint image defines the local angle of the ridge contained in fingerprint. It is an essential step in fingerprint analysis. These orientations are estimated in block-wise scheme and its computation is performed as follows:

1) A block of 3x3 is centered at pixel (i,j) which represent the angle of the associated block.
2) The gradient *dx(i,j) and dy(i,j)* for each pixel in the block are computed that represents the gradient magnitude in x (horizontal) and y (vertical) directions [10]. This computation is done using Sobel gradient operators. The horizontal mask sobel operator

$$Sh = \begin{pmatrix} 1 & 0 & -1 \\ 2 & 0 & -2 \\ 1 & 0 & -1 \end{pmatrix}$$

And the vertical mask sobel operator

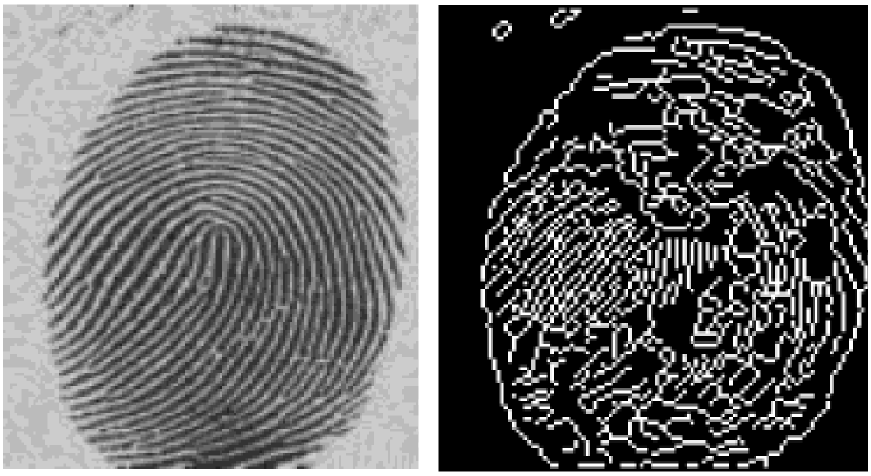
$$Sv = \begin{pmatrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{pmatrix}$$

The angle of the block is estimated by equation (1) [7].

$$\theta(i,j) = \tan^{-1}\frac{dy}{dx} \qquad \ldots\ldots (1)$$

3.2 Binarization

It is a process that converts a gray-level image into a binary image [4]. This process enhances the contrast between the (ridge and bifurcation) best than other attributes in fingerprint image as shown in figure (5-a) and (5-b). This process facilitates the extraction of minutiae. We apply canny method to detect the strong and weak edges. This is performed by calculating the gradient of derivative of a Gaussian filter. The advantage of canny method than others like prewiett, Robert is it is robust to noise and it is powerful in edge detection.



(a) **(b)**

Figure (5): Binarization Process
(a): Original image
(b): Binarization image

3.3 Thinning

The last step in fingerprint image enhancement is the thinning process [3][7]. The binary image is thinning by a morphological operation to simplify minutiae extraction this process erodes the foreground pixels until they become a single pixel in width, but bifurcation that is wider than one pixel. The behavior of the thinning morphological operators is determined by a structuring element. The binary structuring elements used for thinning are of the extended type described under the hit-and-miss transform (they can contain both ones and zeros).

The thinning operation is related to the hit-and-miss transform and can be expressed quite simply in terms of it. The thinning of an image A by a structuring element B is described in equation (2) and (3), where the subtraction is a logical subtraction [7].

$$\left.\begin{aligned} A \otimes B &= A - (A * B) \\ &= A \cap (A * B)^c \end{aligned}\right\} \quad \ldots\ldots (2)$$

$$A \otimes \{B\} = ((\ldots((A \otimes B^1) \otimes B^2)\ldots) \otimes B^n) \quad \ldots\ldots (3)$$

$\{B\} = \{B^1, B^2, \ldots, B^n\}$

The same thinning algorithm principle is applied in proposed work, by iteratively use the thinning morphological operation. The thinning operation is calculated by comparing the structure element origin with the image pixels. If the foreground and background pixels in the structuring element exactly match foreground and background pixels in the image, then the image pixel associate with the origin of the structuring element is set to background (zero). Otherwise it is left unchanged. This process repeatedly examines each pixel in the image and it is connectivity. It checks whether the neighbor pixel could be detected or not. It continues until no more pixels could be detected.

3.4 Segmentation

The segmentation is the process of dividing the image into several regions with same attributes [10]. As known the details of fingerprint are found in ridge (foreground), while the background contains no useful information so it is discarded. In order to extract minutiae the gray image is segmented to blocks of 40x40 with 3x3 pixels per block. The mean per block is used for segmentation as in equation (3) [7]:

$$\mu(k) = \frac{1}{N}\sum_{i=j=1}^{3} P(i,j) \qquad k = 1,2,...,40 \qquad \text{.......(3)}$$

Where μ *represents mean, N equals the number of pixels in the block and P is the image pixel with it is coordinates i for row and j for column,*

Since there is large mean of intensity in regions of ridges, opposite to uniform background. The mean principle is that the less mean value means the dark region with no details(background) and vise versa. If the value of mean is greater than determined threshold T. The block is considered to be in ridge region, otherwise it is regarded as background so that the block is discarded from next calculation.

3.5 Minutiae Detection

In this section the details of minutiae detection is discussed. The Crossing Number (CN) method is used [1]. This method uses a 3x3 thinned image window produced from previous step. We use the center pixel within a block and examine if it represents minutiae. Also to examine the local neighborhood pixels if they represent a ridge ending or bifurcation. The CN formula is given in equation (4).

$$CN = 0.5 \sum_{i-1}^{8} |p_i - p_{i+1}| \qquad \text{.....(4)}$$

Pixel P is the center of the window, its 8 neighbor pixels are scanned clock wise as follows:

2	3	4
1	P	5
8	7	6

After CN calculation the ridge pixel can be classified to only a 2 categories. The first CN=1 that corresponds to ridge ending as shown in figure (2-a). The second is CN=3 which correspond to bifurcation as shown in figure (2-b).Other values of CN are excluded.

For every minutia the following information is recorded:
1- Block position in the image.
2- Orientation of the block associated with ridge.
3- Type of minutiae.

Finally, the fingerprint image is displayed with the minutiae detection.

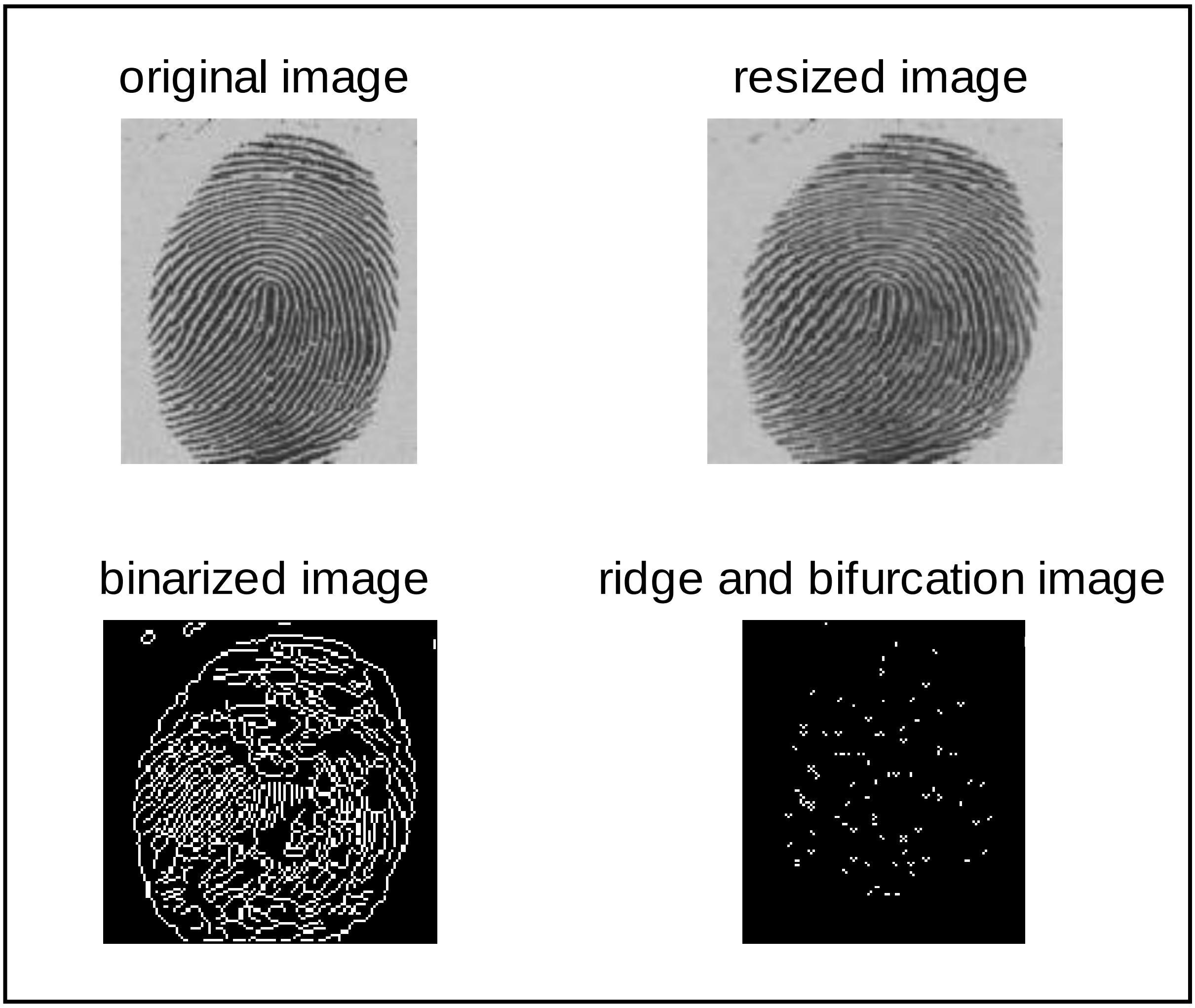
4. Experimental Results

This work aim in to detect and analyses the fingerprint images. These are done selecting 33 fingerprint images from FVC2000/DB2.

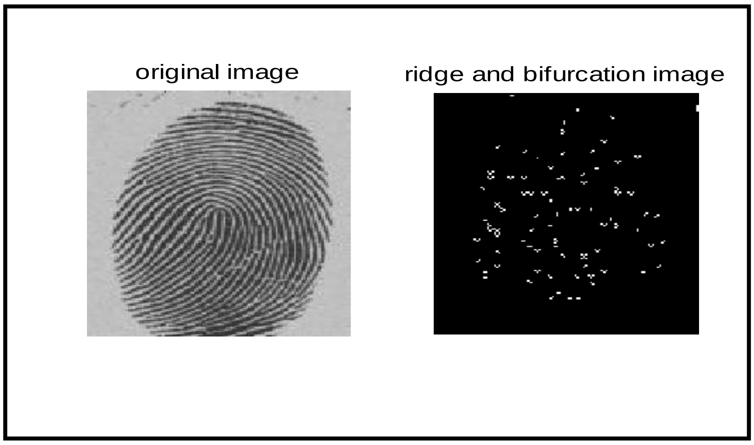
The results of the proposed work are described as values shown in table (1) the Minutiae includes ridge ending and bifurcation associated with each fingerprint image. Also the results are shown as images in figure (6-a) and (6-b).

Table (1): the results of the proposed work

File Name	Ridge ending	Bifurcation	Minutiae
T1.jpg	30	33	63
T2.jpg	38	78	116
T3.jpg	6	114	120
T4.jpg	20	85	105
T5.jpg	52	51	103
T6.jpg	29	52	83
T7.jpg	27	68	95
T8.jpg	44	66	110
T9.jpg	34	120	154
T10,jpg	10	98	108
T11.jpg	29	104	133
T12.jpg	22	90	112
T13.jpg	35	120	155
T14.jpg	30	74	104
T15,jpg	25	84	109
T16.jpg	30	84	114
T17.jpg	18	61	79
T18.jpg	17	74	91
T19.jpg	26	68	94
T20.jpg	15	104	119
T21.jpg	23	61	84
T22.jpgp	23	61	84
T23.jpg	27	95	122
T24.jpg	21	100	121
T25.jpg	26	57	83
T26.jpg	33	52	85
T27.jpg	19	54	73
T28.jpg	19	58	77
T29.jpg	25	137	162
T30.jpg	16	91	107
T31.jpg	43	164	207
T32.jpg	41	116	157
T33.jpg	30	43	73



(a)



(b)

Figure (6): the results of the system
(a): The steps of the proposed work
(b): First and final step of the system

5. Results Analysis

In order to measure the enhancement of the proposed work. The sensitivity and specificity were measured over the entire database [11]. These measures indicate the ability of the algorithm to detect the true minutiae and reject false minutiae respectively as given in equation (4) and (5) respectively:

$$\text{Sensitivity} = 1 - \frac{\text{Missed minutiae}}{\text{Ground truth number of minutiae}} \quad \ldots\ldots.(4)$$

$$\text{Specificity} = 1 - \frac{\text{False minutiae}}{\text{Ground truth number of minutiae}} \quad \ldots\ldots.(5)$$

These measures required a computation of the ground truth value of the database images. This value needs some automatically calculations offered by the system, a selected randomly 10 images from the 33 images are shown in Table 2. Where *M* represents number of minutiae determined by the expert, *N* is the number of automatically extracted minutiae, *P* is the number of correct minutiae, *I* is number of missing minutiae that could not be recognized by the system and *L* is the number of false minutiae.

Table 2: Comparison of number of minutiae before and after applying proposed method.

File name	*M*	*N*	*P*	*I*	*L*
T1.jpg	63	73	55	8	18
T2.jpg	116	114	98	18	16
T3.jpg	120	135	117	3	18
T4.jpg	105	119	100	5	19
T5.jpg	103	102	100	3	2
T6.jpg	83	81	77	6	4
T7.jpg	95	94	92	3	2
T8.jpg	110	111	105	5	6
T9.jpg	154	149	140	14	9
T10.jpg	108	127	97	11	30

The ground truth minutiae for these images were determined automatically as shown in figure (7). This figure shows the minutiae distributions for three sets. These sets are automatically extracted minutiae extracted from the images, number of matching minutiae in the images, and the number of missed minutiae. We see that in this data set images, the ground truth is equal 60.

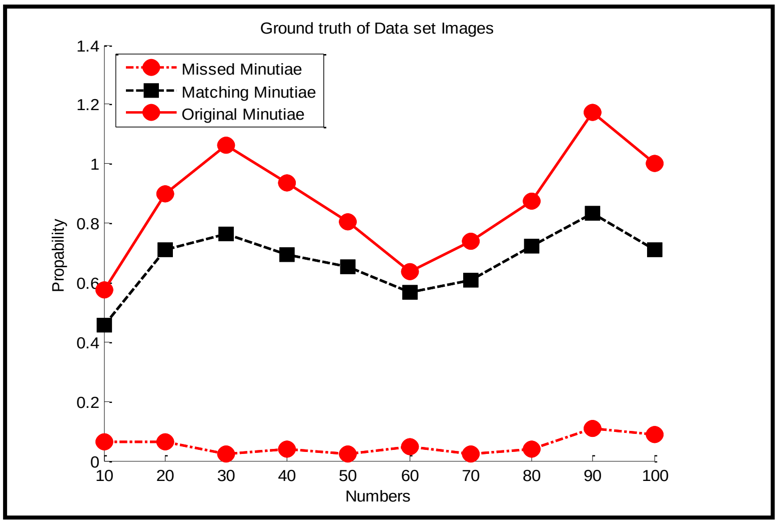


Figure (7): the ground truth of dataset image

We compared our performance of the proposed work with another related work titled "A systematic approach for feature extraction in Fingerprint Images" [5]. We found that the number of true positives due to the proposed methods exceeds the number of true positives found by that approach as shown in table(3).

Table (3): Performance Evaluation over data set image

Value	Proposed work		Systematic work	
	Sensitivity	Specificity	Sensitivity	Specificity
Mean Value	82	75	79.40	85.29
Std Deviation	17.27	21.11	7.86	12.91

Conclusion and future work

We have proposed a bioinformatics system through the minutiae detection for biometrics verification. The difference between the procedures we proposed than others is that we segment the thinned image, while the others segment the gray-scale image. Also minutiae are the foreground based block-wise scheme is indicated as a region of interest(ROI). The block-wise is performed faster than others method that used pixel-wise scheme. The reliability of the detection depends on the analysis used.

Future work we will try to use HSV color spaces. Also this system will be used for matching with other fingerprint images and with frequency multiresolution. Finally an idea of online minutiae detection with fingerprint sensor connected with the computer will be applied.

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