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HYBRID FEATURES FOR FINGERPRINT RECOGNITION BASED ON INVARIANT MOMENTS AND GLCM

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ABSTRACT

The process of verification of the most important processes in security applications and many applications that are special and depends on the identification of the person to ensure privacy. The process of identifying people is done through several things, but the most important of these are biometrics, where people are distinguished by behavioral characteristics (such as gait, signature, sound) or biologic (such as the fingerprint, iris, and vein print).The fingerprint is one of the most important biometrics in humans, because it does not change and be easy to capture in addition to that the human has many fingers, if a problem got a finger can use another finger. In this research a method was proposed to identify the fingerprint by the texture features. Hybrid properties are used by using invariant moments that extract features from a new proposed model is a double thinning model DTM, and GLCM that extracts features from the binary model. The matching process was performed using the Euclidean distance. The system was tested on a database of 40 people. The results were very impressive above 98%. This research opens the horizon to the use of hybrid properties to identify biometrics.

Keywords: *Fingerprint, DTM, GLCM, Invariant Moments, Recognition, Authentication.*

1. INTRODUCTION

Personal identity is used to identify people, but it is still one of the most important problems. It is used in many fields such as criminology and forensic identification, control of access, payment, computer use in identification, and so on[1].

Identity management plays a key role in building and establishing an association between a person and his identity. One must have the ability to identify someone's identity or verify a certain identity allegation of an individual whenever required[2].

The process of identifying people takes place in three main ways: First what he knows, secondly what he own extrinsically, and the third who is he intrinsically. In the first method we rely on some confidential information that is defined by the individual exclusively (such as the identification number of the person, password, cryptographic key, and so on), In the second method, the individual is identified by what he owns or externally carries (e.g. passport, identification card, physical key, license of the driver, or personal device such as a mobile phone). In the third method, individuals are identified by physical or behavioral characteristics, this is recognition by biometric information [2], [3].

The biometrics definition (if we separated the word "bio" that mean life and "metric" which mean measure) refers to identify individuals by using measurements of unique biological [4]. The identification system identifies people through identity analysis using identification methods, which is a critical task. Using of simple methods of identifying the identity, such as the use of passwords or passport is inadequate and is very dangerous because the password can be detected or the passport can be lost[5], [6].

Biometrics is the identify individuals automatically based on their biological or behavioral characteristics or both. Using biometrics, a person is identified and recognition based on who he is rather than what he knows as a password or what he owns, such as an identity card[5], [6].

Fingerprints are a very important biometric feature among the biometric attributes in the hand. It's used in criminal investigation cases by forensic experts because it has a high level of reliability. The fingerprint is formed by flowing ridges patterns at the end of the finger [5]. Finger prints are widely used in many areas [7].

There are several techniques to identify people but fingerprints are used significantly compared to other types of biometrics, for several reasons such as having multiple sources available for measurement (ten fingers), ease of capture[8], it does not change over time, there is a high distinctiveness besides that the fingerprint capture devices are of small size and low price compared with sensors for other biometric measurements [9].

Fingerprint recognition is a procedure of comparing a fingerprint with other fingerprints to determine whether or not it is from the same finger [8].

2. RELATED WORK

Yang et al., in **2008** [10], proposed system for fingerprint verification depends on invariant moments. After enhance the print image, then extract the fingerprint core, next select a region around this point, this point will divided to four parts. The properties are then extracted from each of these four parts. All properties will be stored in a single vector representing the person in the recognition process. The researcher used the type of features, to overcome the disadvantages of traditional methods. The results were very good. This type of research opens the horizon for the expansion of fingerprint recognition through tissue properties.

Sang et al., in **2017** [11]**,** this work suggests a method to identify fingerprints based on the minutiae in addition to invariant moments. After processing the fingerprint and extracting the minutiae, a certain number of them are chosen. These points are considered as a region of interest, since each point of minutiae will be considered the center of the region of interest, that be around it. The invariant moments will then be extracted from these areas where invariant moments considered as features to identify the fingerprint. Use the cosine similarity to measure similarity. The results were very good, with an accuracy up to 96.67%.

Minutiae selection processes require many complex calculations. Many of these points are not reliable in determining the region of interest due to their presence in the edges of the fingerprint. In such cases the surrounding areas of these points will be smaller than the size specified for other regions of interest and thus affect the features Extracted from them.

Ali et al., in **2011** [12]**,** suggested a method for distinguishing fingerprints by extracting texture properties. At first the core of the fingerprint is found where the area around this point is the region of interest. The fingerprint image is then enhanced by the use the Diffusion Coherence Technique. Next, the features are extracted from this area using the Gray level Co-occurrence Matrix (GLCM). Finally, K-Nearest Neighbor (KNN) is used to check the similarities and identify the input fingerprints. The proposed work was tested, and the results were good.

Benazir et al., in **2012**[13]**,** They proposed a method to identify fingerprints by extracting texture features. After fingerprint images are processed for the purpose of noise disposal, the point of reference point determination that will represent the center of the ROI comes. The core is selected as a reference point and then an area around this point is cropped to an area of 100 * 100 pixels. GLCM is used to extract features from the previously identified ROI. The features are extracted in four angles (0, 45, 90, 135). Each fingerprint has 16 features. These features are used in the matching process. The results indicate that the proposed system is good.

Suharjito et al., in **2017**[14]**,** They suggested a way to find out the correlation of the child with his/her parents through a fingerprint. Fingerprints are initially captured for the child and parents. A specific portion of the footprint is cut at 150 x 150 pixels depending on the core. The footprint is then improved to be clearer for the next stage. Next, features are extracted from the fingerprint using GLCM. In the end, the correlation ratio is measured by using the method of correlation coefficient. The proposed work was examined on 30 families and the results were very good in distinguishing between the families of the child and the different families.

3. PROPOSED WORK FINGERPRITN VERIFICATION SYSTEM

In the second stage of the verification process, a fingerprint is used to verify the identity

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of the person. The fingerprint verification is in two steps: in the first step, the registration stage (offline), where the person's data are recorded, the person's fingerprint is captured by the fingerprint sensor, and then several operations are carried out, where the fingerprint is processed for the purpose of improving and noise disposal, and also to deal with the cuts and distortions that occur during the capture of the fingerprint, and other fingerprint preparation processes so that it will be ready to extract features from them, then selecting a specific area of the fingerprint, called region of interest ROI and extract the features from it. These features are stored as a template in the database for use in matching operations in the next step.

Direct verification step (online), during this step, the same steps are performed at the registration stage. The fingerprint is read using the fingerprint sensor, and pre-processing steps are applied, after that select ROI. Features are then extracted from the ROI and these features are finally used to match with the features in the database. If the matching ratio is higher than the threshold limit, the person will be considered authorized. if the proportion of the match did not exceed the threshold limit, the person will be considered unauthorized. Figure 1 explains the fingerprint matching process.

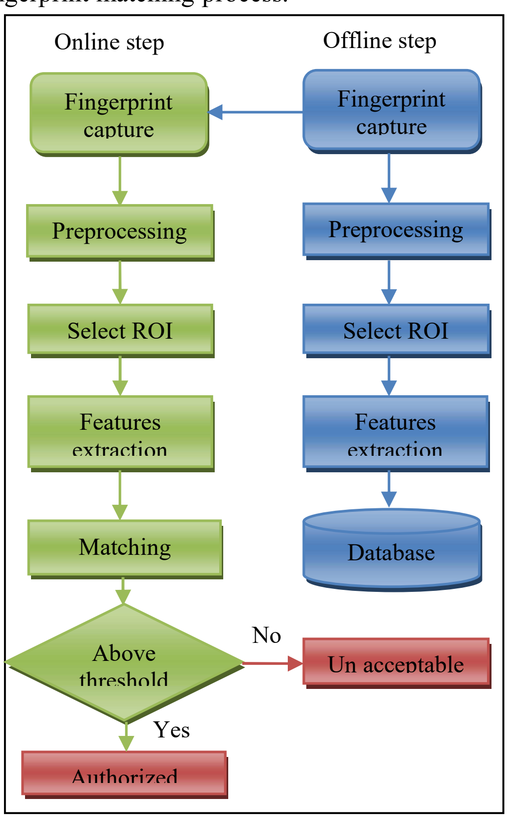

Figure 1. Fingerprint matching process.

3.1 Fingerprint Pre-processing

Fingerprint capture is done by a fingerprint sensor. There are many types of devices that perform this task. The fingerprint image is gray. Several operations are performed on the images of the fingerprint for the purpose of preparation them to extract features from them. Pre-processing operations consist of several stages, as in Figure 2 where the first step begins with improving the image, then the image is converted to the binary mode in the second step. In the last step, the image is converted to the thinning model. We will explain each stage separately.

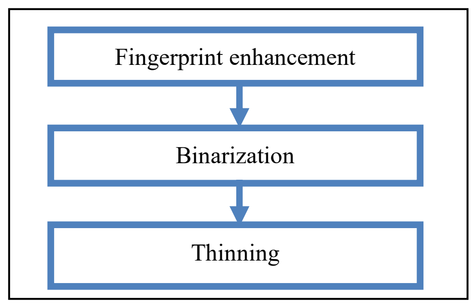

Figure 2: Pre-processing operations.

3.1.1 Enhancement

When fingerprints are captured through the use of the optical reader or other methods, the image of the fingerprint may become blurred and sometimes the hills in the fingerprint may become intermittent due to dry skin, sweating or wounds. In order to get real features that work on good fingerprint matching, we need fingerprint processing and optimization to eliminate noise and also to connect the incorrect interruptions in the hills and eliminate the incorrect connections. There are many methods of improvement in the spatial and the frequency domain. In our search we will use the short time Fourier transform described in[15]. It gives great results and does not take long. The result of enhancement appears in Figure (3).

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Figure (3): Fingerprint enhancement , a. Original image b. Enhanced image.

3.1.2 Binarization

After the image enhancement phase is completed, we move on to the next stage. This phase involves converting the image from gray scale to a binary image. The pixel in the gray image represents a gradient ranging from 0 to 255. The process of converting this type of image into binary images, each pixel in the image is converted to one of the two values, 0 or 1, depending on the threshold value as in equation (1).

$$H(x,y) = \begin{cases} 1 \text{ if } & f(x,y) \geq T \\ 0 & otherwise \end{cases} \quad (1)$$

Where T represent threshold, *H(x,y)* is the value of pixel at point *(x,y)*.

There are many ways of converting from gray to binary images, in this work we use adaptive binarization. The image is divided into blocks, and the threshold value of each block is calculated to help give an accurate picture. Adaptive binarization gives great results especially in images that are of poor quality or when parts of the image are not clear, each block is processed separately. If the block contains poorly visible parts, an appropriate threshold value will be calculated in order to be converted without real parts of the image being canceled, due to poor selection of the threshold or use a fixed threshold for all parts of the image as in the global binarization.

It's possible to implement the binarization on original image, but to give an excellent result, will apply it on the enhanced image, using equation (2), look at figure 4, where apply an adaptive threshold binarization, used a block size (16X16), and constant (0.03).

$$T = \frac{\sum_{(x,y)} \sum_{\in B} f(x,y)}{N_B} - C \quad (2)$$

Where *B* represent the processed blocks, N_B is the number of pixels at each *B* block, and *C* consider a constant that can be defined freely.

Figure 4: Fingerprint binarization.

3.1.3 Thinning

The thinning phase is used to turn the fingerprint hills into one pixel width as shown in Figure 5. This process is used to facilitate the extraction of features from the image and reduce the time required. The thinning process depends on the threading of the pixels in the image, this window called crossing number. Each black pixel with 8 pixels adjacent to it is checked as in Figure 6. The pixels $x_1 ... x_8$ are called the eight neighbors, p is the pixel being examined and the pixels x_1, x_3, x_5 and x_7 are called the four neighbors.

The thinning process begins by deleting the pixel p from the image depending on the crossing number window. In the first step, pixel p is deleted, if the conditions C1 and C2 are satisfied. In step 2, pixel p is deleted if satisfy the conditions C1, C2 and C3. The first and second steps together represent one iteration in the thinning process.

Condition C1:

$$x_H(p) = 1 \quad (3)$$

Where:

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$$x_H(p) = \sum_{i=1}^{4} b_i \quad (4)$$

$$b_i = \begin{cases} 1 \; if \; x_{2i-1} = 0 \; and \; (x_{2i} = 1 \; or \; x_{2i+1} = 1) \\ 0 \quad otherwise \end{cases} \quad (5)$$

Condition C2:

$$2 \leq \min\{n_1(p), n_2(p)\} \geq 3 \quad (6)$$

Where:

$$n_1(p) = \sum_{k=1}^{4} x_{2k-1} \vee x_{2k} \quad (7)$$

$$n_2(p) = \sum_{k=1}^{4} x_{2k-1} \vee x_{2k+1} \quad (8)$$

Condition C3:

$$(x_6 \vee x_7 \vee \bar{x}_4) \wedge x_5 = 0 \quad (9)$$

After applying the thinning process, Some impurities appear on the resulting image, so we will remove the single isolated pixels, removes H-Breaks and removes spikes. Finally, we got the result in figure 5.

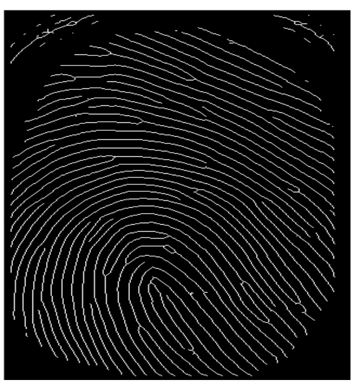

Figure 5: Fingerprint thinning

x_4	x_3	x_2
x_5	p	x_1
x_6	x_7	x_8

Figure 6: Crossing number

A. Double thinning model (DTM)

The fingerprint recognition process requires an appropriate number of features, in many cases. This means that the greater number of features which be clearer, leads to greater recognition rate. Therefore, we propose a new model based on the thinned images, but unlike normal thinned images. The proposed model does not only rely on ridges alone or valleys alone, but integrates the two models into a new model rich in features that can be acquired. The algorithm (1) shows the steps to obtain the proposed model. Eventually, the result is shown in Figure 7.

Algorithm 1: Double Thinning model (DTM)

Input: Fingerprint image
Output: Fingerprint in double thinning model

Step1:
Acquire fingerprint image.

Step2:
Fingerprint enhancement: using STFT.

Step3:
Image binarization: using adaptive threshold equation (2).

Step4:
Ridges thinning : using morphological operations described above.

Step5:
Inverse the binary image from step (3):
we will get valleys by black color and ridges by white color.

Step6:
Valleys thinning: using morphological operations described above.

Step7:
Sum the output of step (4) with output of step (6).

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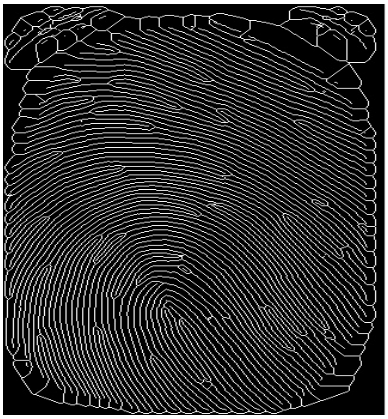

Figure 7: Double Thinning Model (DTM)

3.2 Select region of interest

After processing the fingerprint and obtaining the image model, whether in binary model or in double thinning pattern, the image contains areas that are not useful in fingerprint recognition. These parts of the image do not contain useful information, but on the contrary, sometimes confuse the process of recognition and make the extraction of features need to take longer. So should focus on the part of the image which be fixed between the images, called region of interest ROI.

There are researchers who use the core as a region of interest. Where a specific size is cut around the core and then the features are extracted from this area only, which leads to speed in performance and quality in the recognition process. There are researchers based on minutiae, after find the minutiae and select a specific number of them, then cut a part by certain size around each point of these minutiae. Finally the features of these areas are extracted. In this research, we will use the core, and crop around it, then will extract the features from this area.

3.2.1 Core region of interest

Extracting the reference point (Core) in the fingerprint, enables the system to obtain similar areas between the fingerprints, before moving to the stage of features extraction. The core is the most curved point in the hills, to extract this point complex filter is applied to the orientation of the hills. The orientation of the hills was obtained at the stage of the enhancement (STFT).

Core point extract by using the complex filter is done through multiple steps apply on each overlapping block from the image. firstly apply the complex filter as equation (10) centered at the pixel orientation in the orientation image, where m and g(x, y) = the equation (11), indicate the order of the complex filter and a Gaussian window, respectively. Secondly, for m=1, the filter response of each block can be obtained by a convolution as equation (12). finally, reconstruct the filtered image by composing filtered blocks.

$$h = (x + iy)^m \, g(x, y) \quad (10)$$

$$g(x, y) = \exp\left\{-\left(\frac{x^2 + y^2}{2\sigma^2}\right)\right\} \quad (11)$$

$$h * O(x, y) = g(y) * \left((xg(x))^t * O(x, y)\right) + ig(x)^t * \left((yg(y) * O(x, y)\right) \quad (12)$$

where O(x, y) represents the pixel orientation in the orientation image.

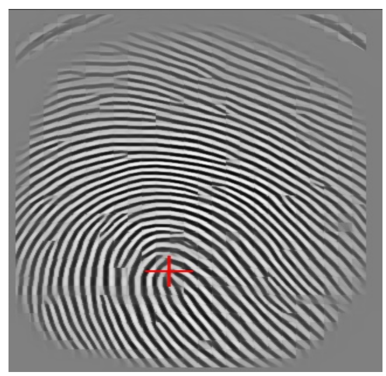

Figure 8:Core point at enhance image.

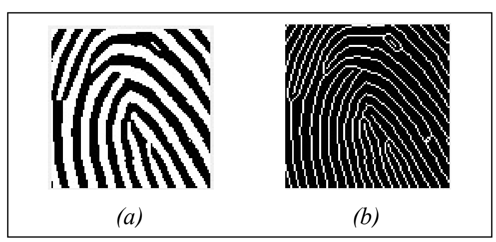

*Figure 9: Core ROI with dimensions (96 * 96) pixels, a. binary image, b. DTM image.*

In Figure 9 we note a region of interest, according to experience, the good results were obtained when the region of interest was (96*96) pixels. For the purpose of extracting features from this region, it divided into four sections as in Figure 10, and the features of each section are extracted to

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avoid nonlinear distortions as well as noise. Each of the four sections is (48 * 48) pixels space.

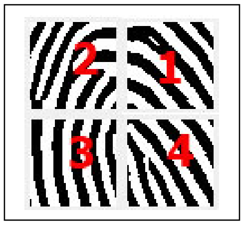

Figure 10: divide the ROI

3.3 Features extraction

Common features in fingerprint recognition are minutiae. To extract these points accurately, we need accurate processing, which results in inaccurate, especially in images with poor accuracy, and must align the fingerprints in order to obtain similar characteristics for the same person. These reasons make using algorithms to extract texture properties better, as they give good results in poor quality images, also it do not need to align the fingerprints.

The feature extraction process is done using two methods and then these features are combined into a single vector to form the features of the fingerprint image through which the person can be identified. The first method extracts features from the double thinning model DTM by the invariant moments where 7 features of the image are extracted. In the second method we extract the features from the binary model using Gray Level Co-occurrence Matrix GLCM, which produces 4 features of the image. Algorithm 2 explaining all steps of features extraction. The steps of the algorithm shown in figure 11.

A. Algorithm 2: Features extraction using core ROI

Input: Enhanced fingerprint image
Output: Features vector

Step1:
Converting the enhanced image to the binary image using equation (2).

Step2:
Converting the binary image to the DTM using algorithm (1).

Step3:
Using complex filters to extract the core point from enhanced image.

Step4:
Crop the ROI to 96 * 96 pixels from binary and DTM, the center of this area is the core point.

Step5:
Divide the ROI to 4 parts.

Step6:
1- Extract the invariant moments' features from the 4 parts of DTM.
2- Extract the GLCM features from the 4 parts of the binary model.
3- Combined the invariant moments' and GLCM features in one vector.

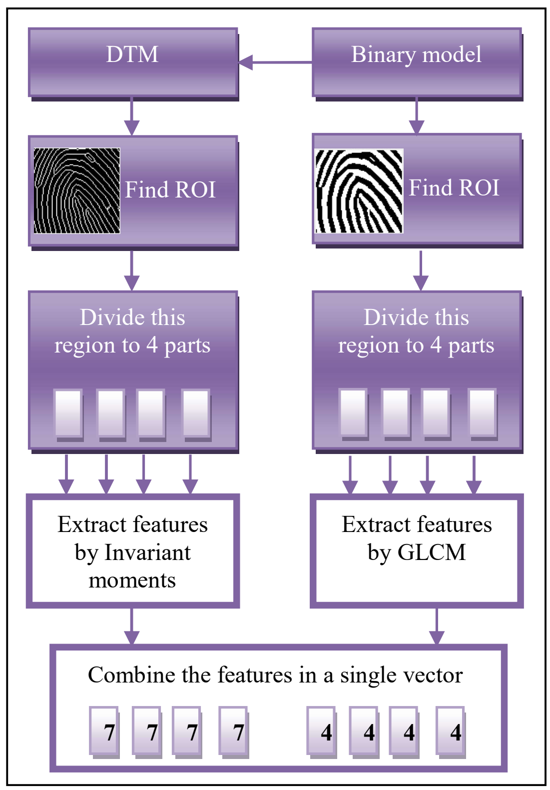

Figure 11: Features extraction flowchart.

3.3.1 Invariant moments

Features extracted using the invariant moments, produce 7 features. These features are not affected if the size, rotation, or location of images is changed. The following section describes the extraction of properties in this way.

For a 2-D continuous function f(x,y), the moment of order (p + q) is defined as:

$$m_{pq} = \int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty} x^p y^q f(x,y)\,dx\,dy$$

$$for\ p,q = 0,1,2,\ldots \quad (13)$$

The central moments can be defined as:

$$\mu_{pq} = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} (x-\bar{x})^p (y-\bar{y})^q f(x,y)\,dx\,dy \quad (14)$$

Where $\bar{x} = \frac{m_{10}}{m_{00}}$ and $\bar{y} = \frac{m_{01}}{m_{00}}$

If f(x,y) is a digital image, then (14) becomes:

$$\mu_{pq} = \sum_x \sum_y (x-\bar{x})^p (y-\bar{y})^q f(x,y) \quad (15)$$

and the normalized central moments, denoted η_{pq}, are defined as:

$$\eta_{pq} = \frac{\mu_{pq}}{\mu_{00}^{y}}, \quad where\ y = \frac{p+q}{2} + 1, \quad for\ p+q = 2,3,\ldots \quad (16)$$

The second and third moments which Hu[16] proposed, can be use to derive the seven invariant moments. Hu derived the expressions from algebraic invariants applied to the moment generating function under a rotation transformation, like the equations explained below. This expressions consisting of groups of nonlinear centralized moment. Finally get the result as a series of absolute orthogonal moment invariants that can be used for position, rotation, and scale invariant pattern identification.

$$\emptyset_1 = \eta_{20} + \eta_{02},$$

$$\emptyset_2 = (\eta_{20} - \eta_{02})^2 + 4\eta_{11}^2,$$

$$\emptyset_3 = (\eta_{30} - 3\eta_{12})^2 + (3\eta_{21} - 3\eta_{03})^2,$$

$$\emptyset_4 = (\eta_{30} - \eta_{12})^2 + (\eta_{21} - \eta_{03})^2,$$

$$\emptyset_5 = (\eta_{30} - 3\eta_{12})(\eta_{30} + \eta_{12})[(\eta_{30} + \eta_{12})^2 - 3(\eta_{21} + \eta_{03})^2] + (3\eta_{21} - \eta_{03})(\eta_{21} + \eta_{03})[3(\eta_{30} + \eta_{12})^2 - (\eta_{21} + \eta_{03})^2], \quad (17)$$

$$\emptyset_6 = (\eta_{20} - \eta_{02})(\eta_{30} + \eta_{12})[(\eta_{30} + \eta_{12})^2 - (\eta_{21} + \eta_{03})^2] + 4\eta_{11}(\eta_{30} + \eta_{12})(\eta_{21} + \eta_{03}),$$

$$\emptyset_7 = (3\eta_{21} - \eta_{03})(\eta_{30} + \eta_{12})[(\eta_{30} + \eta_{12})^2 - 3(\eta_{21} + \eta_{03})^2] + (3\eta_{12} - \eta_{30})(\eta_{21} + \eta_{03})[3(\eta_{30} + \eta_{12})^2 - (\eta_{21} + \eta_{03})^2]$$

Using this algorithm, seven characteristics are produced for each area. Since the region of interest is divided into four parts, the invariant moments are extracted from each of these parts. To calculate the number of features extracted from the four parts we will multiply the seven features with the number of parts (4 * 7), will produce 28 feature.

3.3.2 Gray Level Co-occurrence Matrix GLCM

GLCM, extract 4 features from the image that is (Correlation, Contrast, Homogeneity, Energy) as in equations (18, 19, 20 and 21). The region of interest will also be divided into four parts, to calculate the number of features extracted from the four parts, the system will sum the four features from the four parts, will produce 16 feature.

$$\text{Correlation} \quad C = \frac{\sum_i \sum_j (i-m_i)(j-m_j)p(i,j)}{\sqrt{\sigma_i \sigma_j}} \quad (18)$$

Where i represent rows, j represent columns, and p is GLCM matrix.

$$\text{Contrast} \quad S = \sum_i \sum_j (i-j)^2 p(i,j) \quad (19)$$

$$\text{Homogeneity} \quad H = \sum_i \sum_j \frac{p(i,j)}{1+|i-j|} \quad (20)$$

$$\text{Energy} \quad E = \sum_i \sum_j p(i-j)^2 \quad (21)$$

Later, the features extracted from DTM by the invariant moments, will be combined with the extracted features from binary model using GLCM, in a single vector, holding 44 features. This vector saves as a template in the database to be used in the recognition process.

3.4 Matching

The matching process is a comparison of the characteristics extracted from the fingerprint with the properties saved in the database. If the similarity ratio is greater than or equal to the threshold limit, the person will be considered acceptable, but if the similarity ratio is below the threshold, the person is rejected. The Euclidean distance is used to measure the similarity ratio. The

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Euclidean distance of the two fingerprint features is calculate by the equation (22).

$$ED(f1, f2) = SQRT\left(\sum_{i=1}^{N}(f1_i - f2_i)^2\right) \qquad (22)$$

Where N is the number of features. $SQRT$ denotes the square root.

4. EXPERIMENTAL RESULTS

The system is designed using a laptop HP that has an Intel processor corI 7-4500U 1.8GHz, and 8 GB memory, and is running Windows 10. The main system was built in the Matlab 2015a environment.

Fingerprints were captured and a local database of thumb images was created for 40 people. 25 males and 15 females, ages 19 to 38. I was capture the image at room temperature. We captured 8 pictures for each person, 6 pictures used for training as templates in the database and two images used to check the accuracy of the system. Through fingerprint capture the fingerprint scanner Futronic FS80H was used. This scanner gives a good quality of the image, it is use 4 infrared LEDs, the image with size of 16*24mm with resolution of 320*480 pixels, 500DPI, and format 8bit gray scale.

The efficiency of the system was based on two factors, the false rejection rate FRR, and the false acceptance rate FAR, in addition to the time.

FAR is the proportion of unauthorized counterfeit persons considered by the system as authorized persons, to the total number of counterfeit persons. we can calculate it as in equation (23). The false reject rate (FRR), this type of errors occur when refuse authorized person. we can calculate it in equation (24).

$$FAR = \frac{Number\ of\ fraudsters\ admitted}{The\ total\ number\ of\ authentication\ attempts} * 100\% \quad (23)$$

$$FAR = \frac{Number\ of\ genuine\ people\ who\ have\ been\ rejected}{The\ total\ number\ of\ authentication\ attempts} * 100\% \quad (24)$$

4.1 ROI parts

When extracting the core and using the surrounding area as a ROI, this area can be used to extract the features directly from them, or this area can be divided into four parts and then extract the features from each part as suggested by some researchers. These features are then collected in one vector and saved as a template in the database. During the recognition process, the same steps are applied and the resulting template is compared with the saved templates in the database. To find out which method gives better results, do we use the entire area of interest to extract the features directly or divide this area into parts, the results are shown in Table 1. Note the obvious difference by dividing the area of interest into four parts that give better results than using the entire region once, since the image division reduces nonlinear distortions as well as noise.. Figure 12 shows the difference in results if properties are extracted from a four-part divided area or if features are extracted without dividing the image.

Table 1. FAR, FRR for core ROI.

Number of parts for ROI	FAR	FRR	Threshold
1	0.9669	15	0.986
4	0.2457	3.75	0.9

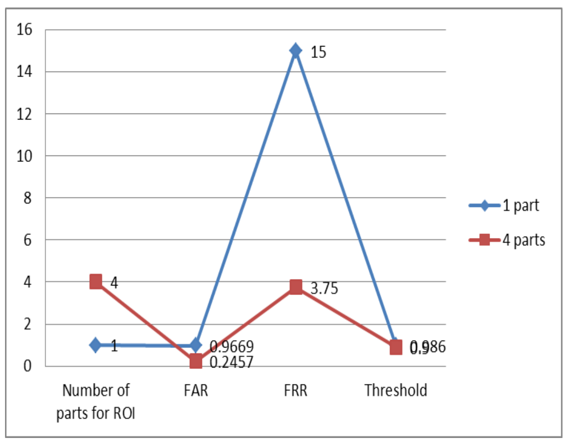

Figure 12. FAR and FRR for core ROI if we divide the region into 4 parts or without divide.

4.2 Select the size of ROI

The area of interest around the core is cropped, the size of this area must be determined. The size of this area is very important as the success of the identification system depends on the selection of an appropriate size for the ROI. A small area may be chosen that does not give enough features to build an efficient system, or the selected area is too large and also results in negative results due to noise or some distortion. This is a very critical area and must be carefully chosen. This area is divided into four equal parts. The size of these parts depends on the size of the region of interest

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that has been cropped. The size of ROI was selected based on experience. Where several sizes of the area of interest were tested in order to know the appropriate size of the ROI to ensure the best results. The best results was obtained when the region of interest was a crop to (96*96) pixels and each part of the four parts is (48*48) pixels. We will compare the resulting results, for the features extracted from different sizes of the region of interest. As shown in Table 2, these results are explained in Figure 13.

Table 2: FAR, FRR for different sizes of core ROI.

The size of the core ROI	FAR	FRR	Threshold
16*16	1.0897	47.5	0.73
24*24	1.1165	30	0.82
32*32	0.9936	13.75	0.845
40*40	0.844	12.5	0.86
48*48	0.8547	11.25	0.864
56*56	0.6197	6.25	0.87
64*64	0.5662	5	0.87
72*72	0.3526	3.75	0.88
80*80	0.2671	5	0.89
88*88	0.3472	3.75	0.89
96*96	0.2457	3.75	0.9
104*104	0.3152	5	0.9

As shown in the table above, the results are improved as the size of the area of interest increases. We started with the ROI of 16 x 16 pixels, where the results were not good, with a high rate of false rejection and false acceptance. After we cropped a larger area, the results started to improve but still remain unsatisfactory. Results continued to improve gradually with the size of the cutting area increasing, with the area being increased 8 pixels every time until we reached the maximum results obtained from a 96 * 96 pixel ROI. Where the false acceptance rate is low and also the percentage of false rejection is very good. Then, when we increased the cutting area, the results began to decline because the cutting area began to exceed the fingerprint in some parts, which negatively affected the results. Therefore, the size of the area of interest is chosen by testing several sizes and selecting the size that generates the best results to be the size adopted in the recognition system.

4.3 Use two models for features extraction

After the image processing stages are completed and the area of interest is determined and divided this area into four equal parts, the next stage is the features extraction phase and a specific model of images must be chosen for extraction of the features. There is a lot of research that relies on extracting features from the gray model, also there is research that extracts the features from the binary fingerprint model, the last model from which we can extract properties is the thinning model. In the proposed work as explained earlier we suggested extracting fingerprint properties using two fingerprint image models.

The first model is to use the DTM described earlier where the features of this model are extracted using the invariant moments. Since the ROI is divided into four parts, seven features will be extracted for each part, so the number of features of this type is 7 * 4 = 28 per fingerprint. The second model used to extract properties is the binary model where the properties of this form are extracted by GLCM. The ROI in this model is divided into four parts. Four features are extracted for each of the four parts. The number of features of this type is 4 * 4 = 16 per fingerprint. Full number of features 28 + 16 = 44 feature for each fingerprint. If one type of feature is extracted for the recognition process, such as using invariant moments only or using the GLCM, we get fewer results than the current results. Table 3 shows the difference in results if the properties of the two models are used together or each model is used separately.

Table 3. The results for used different types of models for features extraction.

Type of model used	FAR	FRR	Threshold
Binary	0.6357	3.75	0.95
DTM	0.6784	11.25	0.94
Binary + DTM	0.2457	3.75	0.9

Figure 14 represents the table data above and we see the clear difference between using the extracted features from each model separately, and the features extracted from both models. The results show progress in the properties extracted from the two models together using the invariant moments and GLCM.

The FRR in the binary model is roughly similar to the FRR when both models are used together, but the difference is evident in the FAR. Where when using the properties of the two models together gives a much lower FAR than the use of binary model properties. We conclude from this that the advantages of both models are more advantageous even though the recognition time is increasing because it deals with two models instead of one, but it gives better protection which is the basic goal of the system.

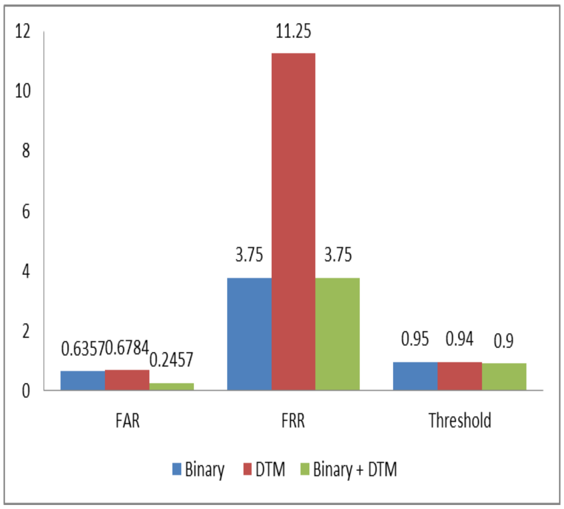

Figure 14: Different types of models for features extraction.

4.4 Choosing the double thinning model DTM

The double thinning model suggested in this paper gives very good features. But why this model? Why not only the hills are thinning, or thinning just the valleys? as they have been used in much research. After creating the DTM and extracting the properties from it, we find excellent results if compared to the results of just thinning the hills or just thinning the valleys. Table 4 illustrates the difference in results, where the difference in both the false rejection rate and the false acceptance rate is significant, as compared to the DTM, which shows a small fraction of the false acceptance rate and an acceptable rate of false rejection. The double lines in the proposed model will give further reinforcement to the identification process if there are deficiencies in the hill lines that will be compensated by the valleys lines. Figure 15 presents the results of the table 4.

Table 4. The results for used different types of thinning models.

Type of thinning model	FAR	FRR	Threshold
Ridge thinning	0.6143	13.75	0.8
valleys thinning	0.6036	13.75	0.8
DTM	0.2457	3.75	0.9

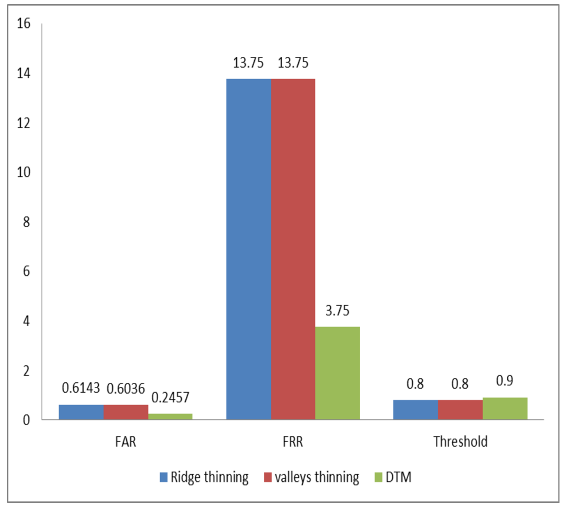

Figure 15: The results for different types of thinning models.

4.5 Comparison of techniques and methods used for fingerprint recognition, with related research

The techniques used in the proposed work include steps and algorithms whose extracted features are integrated to increase fingerprint recognition. The methods used in this research are different if compared with relevant research. Table 5 presents a comparison of methods and techniques used in the proposed work and related research.

The first stage is the preprocessing phase. The most important stage is the enhancement stage. Short time Fourier transform STFT, is used. This technique has been used by many researchers and it improves the image of the fingerprint in a wonderful and fast manner. Two models were adopted instead of one model to extract properties from the fingerprint. The first model is the DTM, and the second model is the binary model. The method used to determine the ROI is through the point of Core. This method has also been used in several research, but the size of this area was chosen through the experiment to obtain the best Results, obtained from a 96 * 96 pixel return on investment. Through this work, the ROI is divided into four parts depending on previous researches. Through the features extraction operation the research adopted two techniques. The first technique is to use the invariant moments to extract the features from the DTM. The second technique is to use the GLCM to extract features from the binary model. After combining the features of the two models together we have a vector we can use it to recognize the fingerprint.

4.6 The required time for fingerprint recognition

Fingerprint recognition requires several stages. Steps to handle fingerprints need time. Table 6 shows the difference in time for each stage of identification, of the proposed work.

Table 6. The required time for every stage

Operation	The time
Preprocessing	0.4578
Crop and divide the ROI	0.1011
Features extraction	0.0065
Matching	0.000365
Total	0.5658

Consume the preprocessing phase, most of the time because it consists of several stages such as enhancement, binarization and convert to the DTM. Each stage of these stages need calculations are expensive in terms of time. While the shortest phase is the matching where the Euclidean distance is used to match the features. Since the number of features is not great, so it does not cost much time in the matching process

5. CONCLOSION

Fingerprint recognition process requires several steps of processing for the purpose of obtaining unique features through which we can identify people. In this research, we rely on the integration of features extracted from two models of the fingerprint image. The first model is the double thinning model DTM while the second model is the binary model. Features are collected in a single vector to represent the fingerprint. The combination of two types of features gives strength in fingerprint recognition and this was evident in experimental results where the recognition ratio in the system was excellent.

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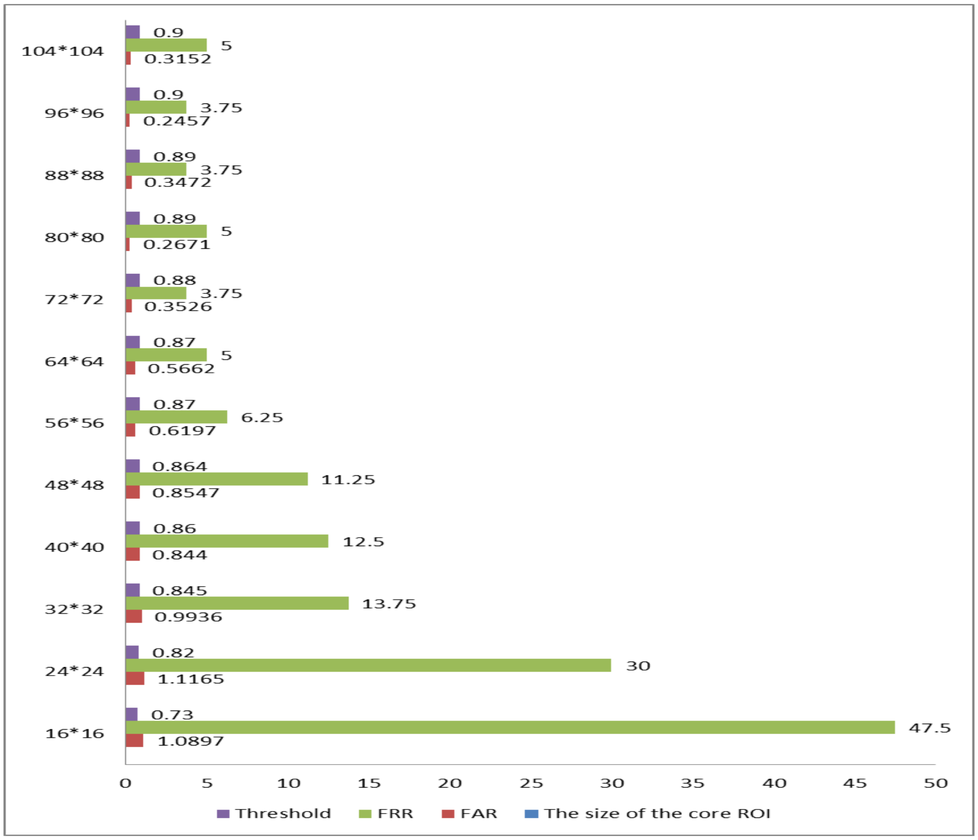

Figure 13: FAR and FRR for multiple sizes of ROI.

Table 5. Comparison of techniques and methods used for fingerprint recognition, with related research

Methods	The type of algorithm used	Number of parts that divide the ROI	The size of the ROI	Type of the model that used for features extraction
Invariant Moment Features [10]	Invariant moments	4	64*64 pixel	gray model
Minutiae and invariant moment [11]	Invariant moments	Depends on selected minutiae	Test several sizes	Ridges thinning
GLCM-based [12]	GLCM	1	100*100 pixel	gray model
Texture features [13]	GLCM	1	100*100 pixel	gray model
Proposed Methods	Invariant moments + GLCM	4	Best results when 96*96 pixel	DTM + Binary model