Babylonian Journal of Artificial Intelligence
Vol. 2024, **pp**. 102–117
DOI: https://doi.org/10.58496/BJAI/2024/013 ISSN: 3006-5437
https://mesopotamian.press/journals/index.php/BJAI

Research Article

Authentication System Based on Fingerprint Using a New Technique for ROI selection

Wisam K. Jummar [1,*], Ali M. Sagheer [1], Hadeel M Saleh [2]

1 College of Computer Sciences and Information Technology, University of Anbar, Ramadi, Iraq
2 Continuing Education Center, University of Anbar, Ramadi, Iraq

ARTICLE INFO

Article History

Received 02 May 2024
Revised: 03 Jul 2024
Accepted 03 Aug 2024
Published 25 Aug 2024

Keywords

Data analytics

Bi-LSTM

Traffic management

Bus passenger

Urban mobility

ABSTRACT

Through the analysis of biological, behavioral, or a combination of both traits, biometrics entails the identification of specific persons. Finger veins, iris patterns, fingerprints, and DNA are examples of common biometric qualities. Of these, fingerprints are the most commonly utilized since they are highly distinctive, simple to obtain, and can be obtained from a variety of sources (because each person has ten fingers). In addition to introducing a method for identifying the region of interest (ROI), which is a specific area selected from the fingerprint image to improve feature extraction, this research focuses on several models for extracting fingerprint features. The study suggests a novel technique known as the flexible region of interest (FROI) for extracting a wider region of interest. Using the GLCM algorithm and invariant moments, features were retrieved from four fingerprint models (gray, binary, ridges thinning, and valleys thinning) using this FROI.

The highest performance was obtained with invariant moments recovered from the valleys thinning model, according to experimental results from a verification system. This led to a false rejection rate (FRR) of 7.5% and a false acceptance rate (FAR) of 0.3846%

1. INTRODUCTION

One of the basics of security systems is to verify the identity of the user whether he/she is an authorized user or not. The authentication process is used to detect the impersonation of an authorized individual of the security system. This breach is one of the most serious threats facing computer systems[1]

Using an identity card, key or password is considered traditional techniques that is used to prove a person's identity. On the other hand, biometrics are characterized by their association with the person where they cannot be lost or forgotten and are difficult to steal. Therefore biometrics are used in identity verification systems based on an individual's behavioral or physiological characteristics[2]. Identity recognition is a sensitive process for all identity management systems. The use of technologies such as an identity card or password as a procedure to verify the identity of the person does not provide high reliability for easy loss or theft it or that the person may share it with other people[3].

Some parts of the human body, such as fingerprints, iris, vein prints, palm print, and so on, are adopted to extract the person's biological characteristics. These measurements are used in many applications such as border management system and airports, access control, law enforcement, and other military and civil applications[4]. These characteristics will be used to distinguish between individuals because they are unique and permanent do not change[5]. The behavioral characteristics of human depend on some behaviors he/she does, such as speech, walking, signing and type rhythm[4]. The behavioral characteristics of the persons my change over the time[6].

One of the most widely used methods of biometric identification at present is the fingerprints recognition[7], [8]. In fact, the fingerprint is one of the first biometrics used in identity recognition. Fingerprint recognition is a system characterized by high speed and high accuracy, so it has a very good performance[2].

Permanence, this characteristic indicates that fingerprints never change over time. While the uniqueness refers to excellence in the form of the fingerprint so that no one else in the world carries the same configuration even among the twins, whose DNA is identical, each of them has a different fingerprint[9].

Corresponding author. Email: wisamkhalid6@uoanbar.edu.iq

There are many types of biometrics as mentioned earlier, the fingerprint is one of the most important types of these used to identify the identity of individuals. The fingerprint has been used for more than a century[10]. The science of forensic is one of the most important examples of using fingerprints for support of the investigation. The fingerprint is also used in commercial transactions and civic life[11].

The fingerprint contains multiple features that are generally divided into three main levels. The shape of the hills and their flow and patterns are considered the first level of the characteristics of the fingerprint. The second level consists of certain points distributed on the hills, these points are the minutiae. The most important types of the minutiae are ridges endings and bifurcations. Third-level features are obtained by dimensional features in the hills such as the width of the hills, edges, pores, scars, shape, deflection of the hills, and the details that be permanent[12].

2. LITERATURE REVIEW

Enhance the fingerprint by using short time Fourier transform, the invariant moment features use for fingerprint verification. A specific area of the image called the region of interest is determined depending on the core point of the fingerprint where the area is cropped around this point, after that divides this area into four parts. Depending on enhanced gray model of the image, the features are extracted for each region separately[13].

The fingerprints are processed using the short time Fourier transform (STFT), and then the image is converted into a binary model, after that convert it to thinning model by using the morphological operations, next, extract minutiae. Minutiae features integrates with features extracted by invariant moments. A certain number of these minutiae is selected, and each point of the selected minutiae is considered as the center to the region of interest (ROI). The image is then cropped around each point Which were selected, finally, the invariant moments used to extract the features from these areas, these features are used to match the fingerprints[14].

The Gray level Co-occurrence Matrix (GLCM) apply on a specific area of the fingerprint, this area selected by extract the core point who will be the center of the crop area, after enhance this area by the Diffusion Coherence, the features will extracted, finally use these features for recognition operation through K-Nearest Neighbor (KNN)[15].

3. TYPES OF MODELS

Fingerprint identification, need to the matching between features that extracted from images. There are multiple types of features that can be used for matching. Every type of features depends on some steps to reach it.

The techniques of features extraction, depends of type of images, where it is my in gray scale mode or binary that also can be in (normal type or in thin mode). The research will talk about multiple techniques that can be used to get image, ready to extract the features, also we will suggest new models of the image that can be useful to extract different features, or to get more number of features.

3.1. Enhanced Model

Firs type of the images that can be used to extract features is the gray scale image. The features that get should be very good to help in identification process, therefor must do enhancement steps, to prepare the image for next step.

There are many ways for enhancement, but the most popular enhancement step is the short time Fourier transform (STFT) described in[16],where it will give great results, it also does not take long. after finish the enhancement step, now the image like in figure 1 ready to extract features, using some algorithms that can extract features from gray images like the invariant moments [13], [17], and Gray Level Co-occurrence Matrix GLCM.

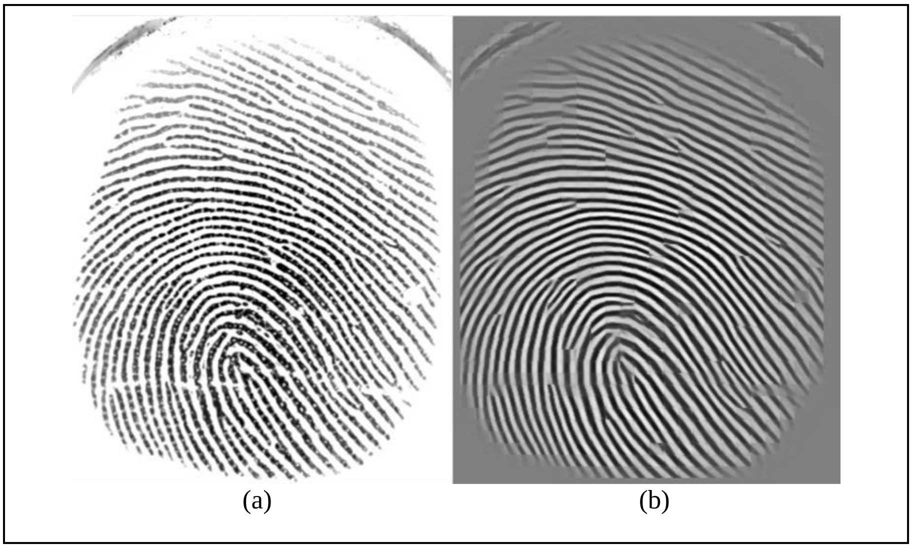

Fig 1. Fingerprint enhancement by STFT, (a) original image, (b) enhanced image.

This steps of enhancement, used to process the images which damaged due to poor image capture, or disappearance of parts of the image, by connect the incorrect break of ridges, also remove an incorrect connection of ridges, to prepare the image for the next step. As in figure 1, now the image is great and can use it to extract features.

3.2. Binary Model

Gray scale image convert to the binary image where the pixels represent either one or zero. In general, this operation compares each pixel in the image with a threshold value, if the pixel value is higher than the threshold, this pixel converts to white, which represents by 1. If the pixel value is less than the threshold, this pixel converts to a black color, which is 0. As in equation (1).

$$\boldsymbol{g(x,y)} = \begin{cases} \mathbf{1}\ \boldsymbol{if}\ \boldsymbol{f(x,y) >= T} \\ \mathbf{0}\ \boldsymbol{otherwise} \end{cases} \qquad (\mathbf{1})$$

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

There are two general types of binarization, global binarization and local binarization, in global binarization the threshold calculate depends on the whole image while in local binarization the image divide to blokes and choose the threshold for each block. Different algorithms will give different binarization results on different data, so the difficult is how to choose optimal algorithm. Examples of global binarization: (Fixed Thresholding Method, Otsu Method, and Kittler Method). Examples of local binarization: (Adaptive Method, Niblack Method, Sauvola Method, and Bernsen Method) [18].

Adaptive binarization, this method use a window of a certain size (N X N), this window moves across the entire image to extract a threshold for each area you pass through. This method produces better results than the fixed threshold. we can calculate the local threshold value by one of three ways which is[19]:

$$Th = \frac{\sum_{(x,y)} \sum_{\in V} f(x,y)}{N_V} - C \qquad (2)$$

$$Th = median\ \{f(x,y), (x,y) \in V\} \qquad (3)$$

$$Th = \frac{\max\{f(x,y), (x,y) \in V\} + \min\{f(x,y), (x,y) \in V\}}{2} \qquad (4)$$

Where V indicate the processed blocks, N_V represents the amount of pixels at each V block, and C is the constant.

The binarization can be implemented on the image without enhance. But to guarantee an excellent result, first we will enhance the image after that will apply the binarization, using equation (2), by the constant (0.03) and the block size (16X16). Figure 2 showing the binarization operation result.

Fig .2. Image binarization.

3.3. Thinning Model

Thinning model, works at the binary images, and apply thinning operation on it. Thinning operation is to remove all pixels of ridges except one pixel of the ridges, so the width of the ridge will be one pixel. Zhang-Suen thinning algorithm is the most famous in this field [20], in this research we use the morphological operations Which are included in the Matlab, to obtain the thinning image. There are some researchers use valleys instead of ridges[21], so they are make thinning operation on the valleys. Figure 3 explain the output of the thinning operation.

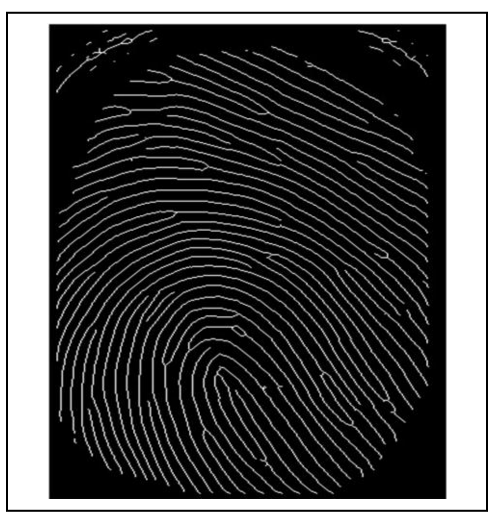

Fig .3. Image thinning.

The most famous features that can be extracted from this type of image is minutiae[22], [23], It considers one of the most distinctiveness features of the fingerprint.

3.4. Selecting the Region of Interest (ROI)

The computational operations that will take place on the image need considerable time and consume computing resources because the size of the image is large. There are many parts of the image that do not contain useful information, and may contain noise and incorrect information that negatively affect the identification process so it's not useful in the process of extracting features, to reduce the calculations, will determine a specific area of the image to extract the features called: region of interest (ROI), this area must be identical in all images. In this type of images, some researchers go to determine ROI by the reference point (core and delta). The core represents the maximum curvature in the ridges. Extract the reference point of the image, using the complex filters explained in [24]. After extracting this point, we crop the image around this point where this point will be the center of the cropped image, as shown in Figure 2, where the area is smaller and faster in extracting the features. There are other researchers who rely on the minutiae to identify ROI. the minutiae is extracted and a section of these points is selected. Each point of the minutiae is considered being the center of the ROI, where these areas are cut, and extract the features from them, as suggested in[14]. The size of the area of interest is determined by experiment to see which size gives the best results.

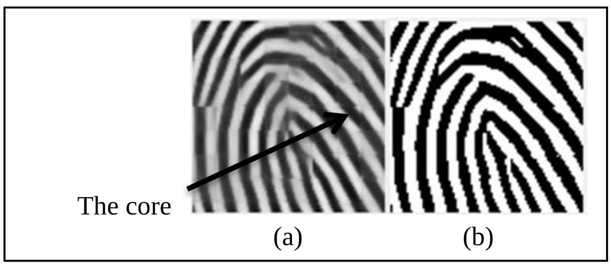

Fig .4. Crop ROI, (a) enhanced model (b) binary model.

The above figure shows how a specific area was cut around the area of the core. This area can be cut from any model, whether be enhanced, binary or thinning, depending on the location of the core.

3.5. Gray Level Co-occurrence Matrix GLCM

GLCM algorithm is used to extract the texture features of the image. Where it is used to extract features from gray images. GLCM will extracts 4 features from the image. These features are Correlation, Contrast, Homogeneity, Energy, which are explained in equations (5,6,7, and 8).

$$\text{Correlation} \qquad C = \frac{\sum_u \sum_v (u-m_u)(v-m_v)p(u,v)}{\sqrt{\sigma_u \sigma_v}} \qquad (5)$$

Where u represent rows, v represent columns, and p is GLCM matrix.

$$\text{Contrast} \qquad S = \sum_u \sum_v (u-v)^2\, p(u,v) \qquad (6)$$

$$\text{Homogeneity} \qquad H = \sum_u \sum_v \frac{p(u,v)}{1+|u-v|} \qquad (7)$$

$$\text{Energy} \qquad E = \sum_u \sum_v \mathrm{p}(u-v)^2 \qquad (8)$$

3.6. Invariant Moments

Hu moments, is one of the invariant moments types that can be used for patterns recognition. Seven features will be extracted from the image. The process of extracting features is as follows:

The moment of order (p + q) for the 2-D continuous function f(x,y), can be defined as:

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

$$for\ p,q = 0,1,2,\ldots \quad (9)$$

Also can be defined the central moments as:

$$\mu_{pq} = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} (x-\bar{x})^p (y-\bar{y})^q f(x,y)dxdy \quad (10)$$

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 (10) becomes

$$\mu_{pq} = \sum_x \sum_y (x-\bar{x})^p\ (y-\bar{y})^q\ f(x,y) \quad (11)$$

And the normalized central moments, denoted Z_{pq} , are defined as

$$Z_{pq} = \frac{\mu_{pq}}{\mu_{00}^{y}}, \qquad where\ \ y = \frac{p+q}{2} + 1, \qquad for\ p+q = 2,3,\ldots. \quad (12)$$

The seven invariant moments can be derive from the second and third moments, which proposed by Hu[25]. 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 the result appears as a series of absolute orthogonal moment invariants that can be used for rotation, position, and scale invariant pattern recognition.

$$\begin{gathered}
mo_1 = Z_{20} + Z_{02},\\
mo_2 = (Z_{20} - Z_{02})^2 + 4Z_{11}^2,\\
mo_3 = (Z_{30} - 3Z_{12})^2 + (3Z_{21} - 3Z_{03})^2,\\
mo_4 = (Z_{30} - Z_{12})^2 + (Z_{21} - Z_{03})^2,\\
mo_5 = (Z_{30} - 3Z_{12})(Z_{30} + Z_{12})[(Z_{30} + Z_{12})^2 - 3(Z_{21} + Z_{03})^2]\\
+(3Z_{21} - Z_{03})(Z_{21} + Z_{03})[3(Z_{30} + Z_{12})^2 - (Z_{21} + Z_{03})^2],\\
mo_6 = (Z_{20} - Z_{02})(Z_{30} + Z_{12})[(Z_{30} + Z_{12})^2 - (Z_{21} + Z_{03})^2]\\
+4Z_{11}(Z_{30} + Z_{12})(Z_{21} + Z_{03}),\\
mo_7 = (3Z_{21} - Z_{03})(Z_{30} + Z_{12})[(Z_{30} + Z_{12})^2 - 3(Z_{21} + Z_{03})^2]\\
+(3Z_{12} - Z_{30})\ (Z_{21} + Z_{03})\ [3(Z_{30} + Z_{12})^2 - (Z_{21} + Z_{03})^2]
\end{gathered} \quad (13)$$

4. PROPOSED WORK

ROI can be extract by use the core to crop the image as in the Enhanced model. The size of the crop is fixed for all images, so if they're some images hold smaller print than the original fingerprint, may give a little different ROI, which may affect the identification process. In this paper a new method was proposed to solve this problem, namely Flexible region of interest (FROI).

4.1. Flexible Region of Interest (FROI)

The research proposes a new type of ROI is the Flexible ROI technique, suppose that the size of print is changeable, so to handle with this point, firstly will enhance the fingerprint image through the enhance model and convert the enhanced image to the binary model, then specifying the boundaries of the fingerprint, top point and bottom point of rows, first left and first right points of columns, that represent the boundaries of the fingerprint, by find first ridges pixel in the rows and the columns, after that we will crop this image which be in binary or enhanced model or other model until these points, as in figure 5.

(a) (b)

Fig .5. First crop of FROI, (a) binary image (b) first crop.

In the second step of finding RIO, will calculate the size of the image that result through first crop, extract the number of rows and columns. After that will extract three-quarters of the columns number, suppose this number represent by Q as in Equation (14), that will represent the size of the crop box. To extract the ROI points that will be cropped from the image, will apply two steps. The first step is to subtract the number of rows R from Q and then divide the output by two to extract the pixel which represent the first point of the ROI, and then sum the output of the first point with Q to extract the pixel which represent the second point, as in Equations (15) and (16). In the second step, applied the same processes but with the number of columns C, as in Equations (17) and (18), to find the remaining two points of the ROI. Finally, using these four points to crop the image, will produce the image in Figure (6). All steps of finding FROI, are Clarified in algorithm (1).

(a) (b)

Fig .6. Last step of FROI, (a) first crop (b) last crop.

A. Algorithm 1: Flexible region of interest (FROI)

Input: Binary fingerprint image

Output: FROI

Step1:

Find first black pixel of the top and bottom row from the ridges

Step2:

Find first black pixel at the first left and first right column from the ridges

Step3:

Crop the image until the pixels from steps 1 and 2

Step4:

Calculate the number of columns C and rows R for the resulting image from step 3

Step5:

Calculate the numbers of the four pixels which will represent the main points of the ROI by:

A. Calculate Q : $Q = C - \frac{C}{4}$ (14)

B. Use equations (6, 7, 8 and 9) to calculate the main four pixels that represent ROI:

$$first_{point} = floor\left(\frac{R-Q}{2}\right) \quad (15)$$

$$second_{point} = first_{point} + Q \quad (16)$$

$$third_{point} = floor\left(\frac{C-Q}{2}\right) \quad (17)$$

$$fourth_{point} = third_{point} + Q \quad (18)$$

Step6:

Crop the fingerprint image (enhanced, binary, thin, etc..) until these points

This method will give a similar ROI to all images even if they are different in size, because the cropping process depends on the size of each image separately. The researcher can choose the appropriate size for the used ROI through increase or decrease Q value. There are another advantage with flexible ROI, where it results a big ROI, comparison with other type of ROI, and As a result we can reach more features. The figure 7 shows the main four points that specify the FROI.

Fig .7. The main four points, for FROI

4.2Fingerprint Recognition System

To see what results can be obtained from FROI, we design a fingerprint recognition system. The system consists of two stages: the first stage is the registration stage (off line), where the features of each user are saved in the database. The second stage is the stage of testing (on line), by extracting features and matching them with information in the database. Each stage consists of several steps. The first step is the fingerprint acquisition through a scanner or camera, then enhancement, after that change it to the binary model, then select the ROI, during the last step the features are extracted. After this stage, the matching process begins to determine whether the person is authorized or not. Figure 8 explain the recognition system.

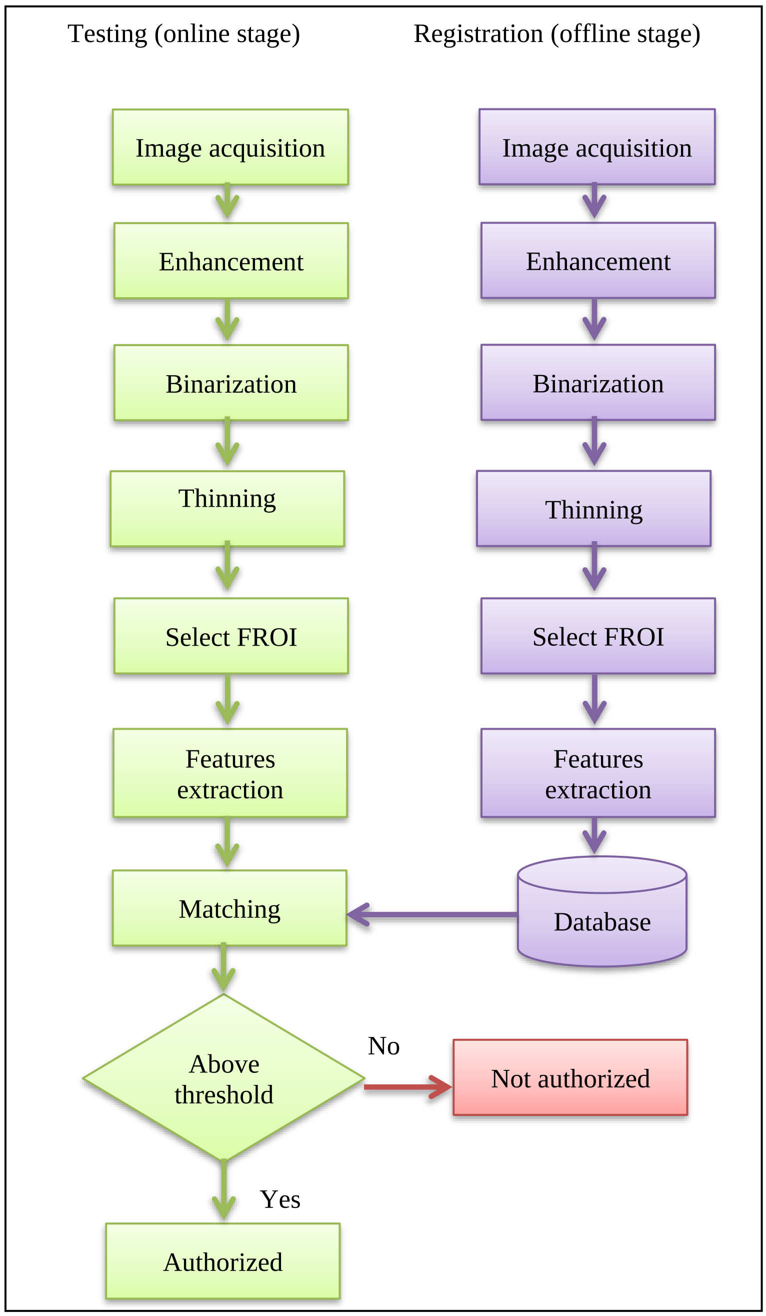

Fig 8. Fingerprint verification system flowchart.

The online stage begins with the process of capturing the image which is done using a scanner as mentioned earlier. Then starting the image enhancement step by the STFT. Then we convert the image from gray to the binary by adaptive binarization. After that the image will thinning by use morphological operations that embedded in Matlab. Next we will use algorithm 1 to extract the FROI. The next step is the features extraction by using GLCM or the invariant moments. finally, the features are saved as a template in the database. In the online stage we apply the same steps and after extracting the features will matched them with the features in the database by the Euclidean distance. If the matching rate exceeds the threshold specified, the person is deemed to be authorized, and if he does not exceed the threshold, he is deemed to be not authorized.

4.2.1. Features Extraction

There are many algorithms and techniques that can be used to extract features from images. During this research we will rely on the texture properties of the images, so we will use two algorithms to test the system and clarify the best results obtained. The first algorithm is GLCM, and the second one is the Hu invariant moments.

GLCM will use during this research to extract the features from the gray or binary or thinning images. To get rid of nonlinear distortions and the noise, the FROI is divided into equal parts and we extract features from each part and then these features are collected in one vector. Through this paper the FROI is divided into 16 parts, GLCM will extract 4 features from each part, meaning 16 * 4 = 64 feature for each fingerprint. In case divide the FROI to 4 parts then, 4*4=16 feature for each fingerprint.

Hu moments also used to extracts the texture properties of the gray or binary or thinning images, if the FROI is divided into 16 parts the number of properties will be 16 * 7 = 112 per fingerprint, but if the FROI is divided into four parts, the number of features will be 4 * 7 = 28 per fingerprint.

4.2.2. Matching

Matching is a process of comparing the properties saved in the database with properties extracted from the fingerprint. A threshold value is specified. If the matching rate exceeds the threshold, the person is considered acceptable, if the matching proportion does not exceed the threshold, the person is considered inadmissible. The Euclidean distance is used in the matching process as in equation (19)

$$ED(f1, f2) = SQRT\left(\sum_{i=1}^{N}(f1_i - f2_i)^2\right) \quad (19)$$

Where f1 and f2 represent fingerprints ' features. N is the number of features.

During this research the results will be tested if the FROI is divided into 4 parts or to 16 parts. The testing process will be done through two factors: the false acceptance rate FAR and the false rejection rate FRR as in Equations (20) and (21).

$$FAR = \frac{Number\ of\ unauthorized\ persons, admitted}{The\ total\ number\ of\ authentication\ attempts} \quad (20)$$

$$FRR = \frac{Authorized\ persons, who\ were\ rejected}{The\ total\ number\ of\ authentication\ attempts} \quad (21)$$

5. RESULT

The system is designed using Matlab 2015a environment on a laptop HP, running Windows 10. the main specifications is: 8 GB memory, and Intel processor corI 7-4500U 1.8GHz. A local database has been built. Fingerprint was captured using the fingerprint scanner Futronic FS80H. The number of people whose fingerprints were captured was 40, 15 females and 25 males, aged between 19 and 38 years old, where 8 images were taken for thumb from each person, 6 images were used in the training process, and two images were used to examine the accuracy of the system. The image capture process was in room temperature.

5.1. The First Stage

GLCM using to extract the features from the FROI. The features will be extract through four models: the gray model, the binary model, the thinning hills model, and the thinning valleys model. Then will test the system in each model to see the best results obtained from any model. System testing in this type of features will be through two phases:

5.1.1. The First Stage

The first stage where the FROI will be divided into four parts where the features are extracted from each part. The number of extracted features is 4 * 4 = 16. Table 1 shows the values of FAR and FRR in each model used. Figure 9 describes the data in Table 1.

TABLE I. SYSTEM RESULTS FOR GL CM FEATURES, FOR 4 PARTS OF FROI.

Type of model	FAR	FRR	Threshold
Gray	1.3782 %	33.75 %	0.76
Binary	1.5812 %	28.75 %	0.95
Ridges thinning	1.3942 %	26.25 %	0.89
Valleys thinning	1.469 %	26.25 %	0.89

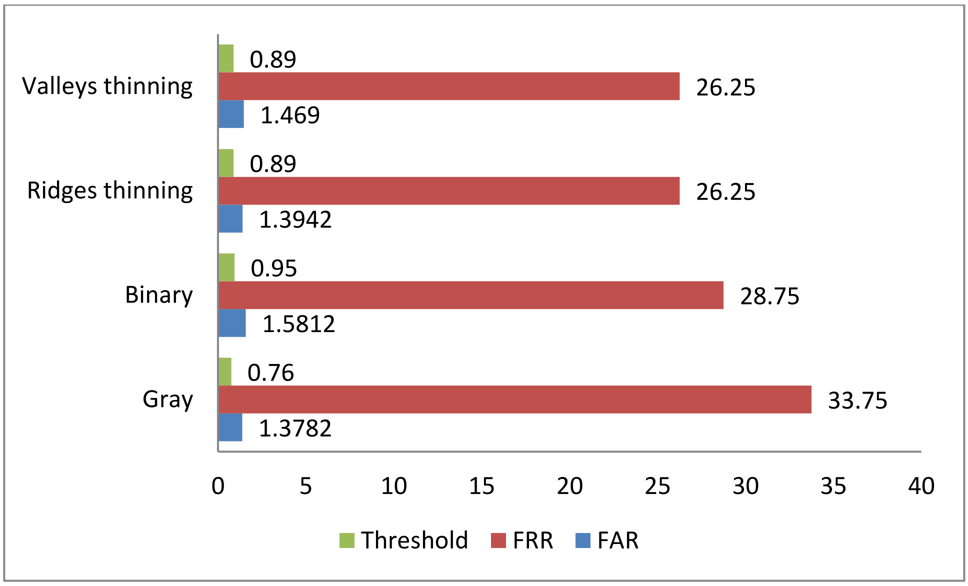

Fig .9. Comparison of the results of the GLCM algorithm where the FROI is divided into 4 parts.

The results were not good as the FRR was high with the four models, and the FAR also appeared to be the high rate. The best result obtained in this experiment is through ridges thinning, where it would produce the best FAR almost, with an equal proportion of FRR with the valleys thinning.

5.1.2. The Second Stage

The second stage where the FROI is divided into 16 parts after extracting the features of each part the number of extracted features will be 16 * 4 = 64. Table 2 describes the FAR and the FRR in each model used. Figure 10 explains the data in Table 2.

TABLE II. SYSTEM RESULTS FOR GL CM FEATURES, FOR 16 PART OF FROI.

Type of model	FAR	FRR	Threshold
Gray	1.0684 %	27.5 %	0.45
Binary	1.0417 %	20 %	0.84
Ridges thinning	0.6624 %	22.5 %	0.72
Valleys thinning	0.6944 %	25 %	0.72

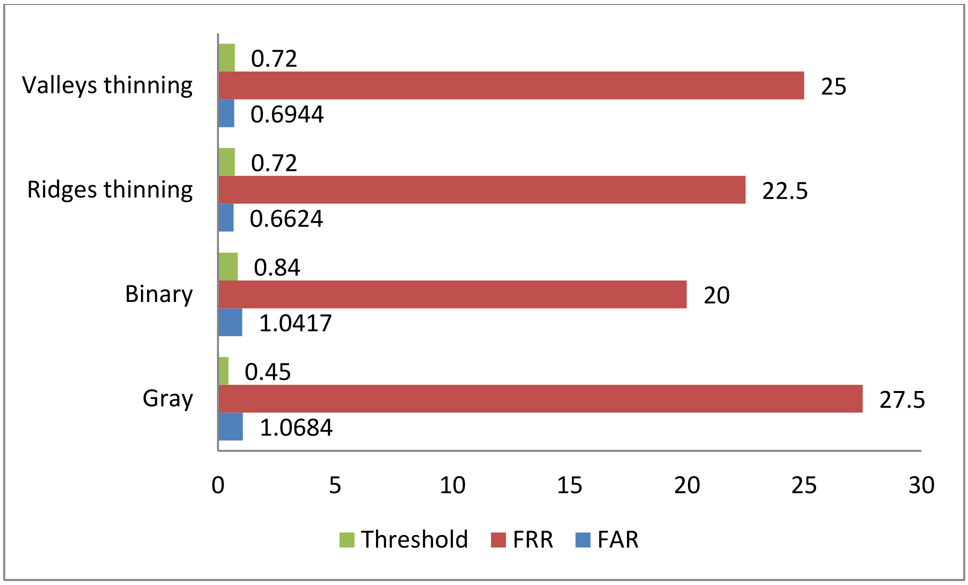

Fig .10. Comparison of the results of the GLCM algorithm where the FROI is divided into 16 part.

During Table 2, we see a clear improvement in the results after dividing the area of interest into 16 parts. Increasing the number of parts of the image leads to increased features and makes the system more accurate, but the system still not considered as a good system. The best results were obtained through ridges thinning. The FAR was the best among the models while the FRR was slightly less than the binary model.

5.2. Hu Moments

Hu moments can be used to extract features from the fingerprint image after select the area of interest. Also, we will use four models to extract the properties of the image: the gray model, the binary, the hills thinning, and the valleys thinning. The system will also be tested in two phases, with the number of parts of the area of interest varying at each stage.

5.2.1. First Stage

During this phase the area of interest will be divided into four parts. The Hu moments extract the properties of each part of the image, so the number of resulting properties is 7 * 4 = 28. Table 3 shows the results of each model. Figure 11 shows the data for Table 3.

TABLE III. SYSTEM RESULTS FOR HU MOMENTS FEATURES, FOR 4 PARTS OF FROI.

Type of model	FAR	FRR	Threshold
Gray	8.5043 %	22.5 %	0.99998
Binary	1.688 %	36.25 %	0.992
Ridges thinning	0.7212 %	25 %	0.89
Valleys thinning	0.9989 %	27.5 %	0.89

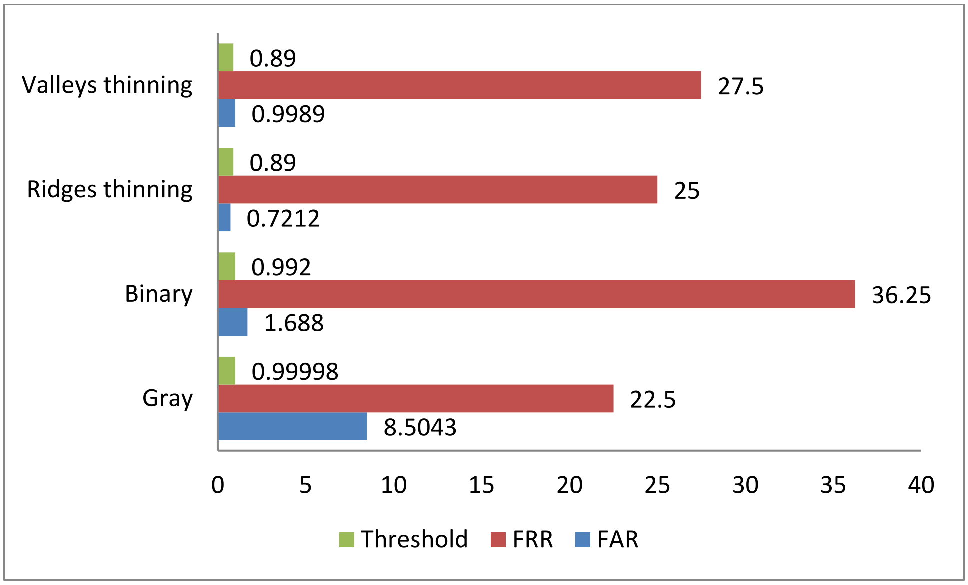

Fig .11. Comparison of the results of the Hu moments algorithm where the FROI is divided into 4 parts.

By comparing the first phase of the Hu moments with the first phase of the GLCM, will find that the results from the gray and binary model became worse while the results of the ridges thinning model and the valleys thinning model has improved. The best result was obtained from the ridges thinning model. The results of the system are still not up to the required level.

5.2.2 The Second Stage

The FROI will be split into 16 parts during this phase. The Hu moments will be extracted from each part, meaning that the number of features to be extracted is 7 * 16 = 112. Table 4 presents the results of the system at this stage. Figure 12 explains the data in Table 4.

TABLE IV. SYSTEM RESULTS FOR HU MOMENTS FEATURES, FOR 16 PART FROI.

Type of model	FAR	FRR	Threshold
Gray	3.4722 %	28.75 %	0.99995
Binary	1.0737 %	23.75 %	0.968
Ridges thinning	0.5609 %	8.75 %	0.60
Valleys thinning	0.3846 %	7.5 %	0.61

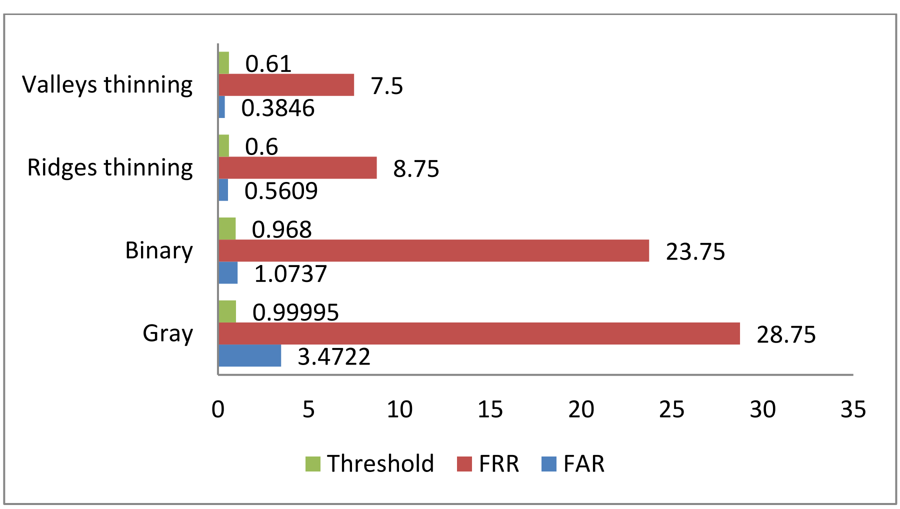

Fig .12. Comparison of the results of the Hu moments algorithm where the FROI is divided into 16 part.

As seen from the above figure, the results obtained from the gray and binary models are still not good, but the results from the hills thinning model and the valleys thinning model have improved significantly. The best result obtained was from the valleys thinning model, where the FAR was very good, with an acceptable percentage of the FRR. So the Hu moments can be used to extract the fingerprint properties from the valleys thinning model to build a fingerprint recognition system

5.3. System Run Time

Runtime is a key and important element in biometric identification systems. The system must be fast. The system has been tested using four fingerprint models: the gray model, the binary, the ridges thinning, and the valleys thinning. Features of fingerprint images were extracted by two algorithms: GLCM and the Hu moments. The time spent at each stage of the system for each of the four models was measured.

Table 5 represents implementation time if the ROI is divided into 4 parts and GLCM is used to extract the features. While Table 6 represents implementation time if the ROI is divided into 16 parts and GLCM is used to extract the features. Table 7 shows the details of implementation time when the ROI is divided into 4 parts, while the features are extracted by the Hu moments. Finally, Table 8 explains the execution time when dividing the ROI into 16 parts and using the Hu moments to extract features.

TABLE V. SYSTEM RUNTIME USING GL CM FEATURES WITH 4 PARTS ROI.

Operation type	Time required to every model			
	Gray	binary	Ridges thin	Valleys thin
Preprocessing	0.2234	0.2241	0.2274	0.2262
Select and divide ROI	0.3161	0.3131	0.3156	0.3149
Features extraction	0.1831	0.1831	0.1831	0.1831
matching	0.00080767	0.00082896	0.00079090	0.00077320
Total	0.723408	0.721129	0.726891	0.724973

TABLE VI. SYSTEM RUNTIME USING GL CM FEATURES WITH 16 PARTS ROI.

Operation type	Time required to every model			
	Gray	binary	Ridges thin	Valleys thin
Preprocessing	0.2234	0.2241	0.2274	0.2262
Select and divide ROI	0.3158	0.3119	0.3183	0.3145
Features extraction	0.1840	0.1840	0.1840	0.1840
matching	0.00064349	0.00075990	0.00064157	0.00067432
Total	0.723843	0.72076	0.730342	0.725374

TABLE VII. SYSTEM RUNTIME USING HU MOMENTS FEATURES WITH 4 PARTS ROI.

Operation type	Time required to every model			
	Gray	binary	Ridges thin	Valleys thin
Preprocessing	0.2234	0.2241	0.2274	0.2262
Select and divide ROI	0.3161	0.3131	0.3156	0.3149
Features extraction	0.1837	0.1837	0.1837	0.1837
matching	0.00070537	0.00067753	0.00073321	0.00069673
Total	0.723905	0.721578	0.727433	0.725497

TABLE VIII. SYSTEM RUNTIME USING HU MOMENTS FEATURES WITH 16 PARTS ROI.

Operation type	Time required to every model			
	Gray	binary	Ridges thin	Valleys thin
Preprocessing	0.2234	0.2241	0.2274	0.2262
Select and divide ROI	0.3158	0.3119	0.3183	0.3145
Features extraction	0.1840	0.1841	0.1841	0.1840
matching	0.00073518	0.00075485	0.00065140	0.00064614
Total	0.723935	0.720855	0.730451	0.725346

In the above tables, we notice that the implementation times of the system on all types of models are very close, with a slight increase in time in the case of using Hu moments to extract features, because the number of features extracted is 7, is almost twice the number of features extracted by GLCM. A slight increase in time is also observed when the ROI is divided into 16 parts, due to the large increase in the number of extracted features where more time is required for extraction and matching.

6. CONCLUSION AND FUTURE WORK

The process of fingerprint recognition can be implemented on several models of the image and with several algorithms, the researcher is free to choose one of these models and algorithms that can give good results. Addition to the type of model used, identifying the ROI for which the features will be extracted is considered one of the most important factors for the success of biometric identification systems. Most researchers rely on the core point to determine the ROI while others rely on the minutiae dots to determine the area of interest. In this research flexible region of interest (FROI) was proposed, through which to obtain a lot of features, where it is possible to have a significant impact in the recognition process. FROI can be easily extracted and used, and works well with fingerprints that are vertical and not highly slanted, since the significantly slanted fingerprint may result in little variation in the ROI between the images. The experimental results showed a good effect of the proposed work in the fingerprint recognition, which can be used with multiple recognition algorithms.

Conflicts Of Interest

The paper states that the author has no financial or non-financial interests that could be perceived as influencing the research or its interpretation.

Funding

No financial endorsements or contributions from institutions or sponsors are mentioned in the author's paper.

Acknowledgment

The author would like to thank the administrative staff at the institution for their assistance and logistical support throughout the duration of this research.

References

[1] I. Velsquez, A. Caro, and A. Rodrguez, “Authentication schemes and methods,” Inf. Softw. Technol., vol. 94, no. C, pp. 30–37, 2017.

[2] R. D. Labati, V. Piuri, and F. Scotti, Touchless Fingerprint Biometrics. CRC Press, 2015.

[3] D. R. Kisku, P. Gupta, and J. K. Sing, Advances in biometrics for secure human authentication and recognition. CRC Press, 2013.

[4] M. M. H. Ali, V. H. Mahale, P. Yannawar, and A. T. Gaikwad, “Fingerprint Recognition for Person Identification and Verification Based on Minutiae Matching,” in Advanced Computing (IACC), 2016 IEEE 6th International Conference on, 2016, pp. 332–339.

[5] J.-L. Chen, C.-H. Huang, Y.-C. Du, and C.-H. Lin, “Combining fractional-order edge detection and chaos synchronisation classifier for fingerprint identification,” IET Image Process., vol. 8, no. 6, pp. 354–362, 2014.

[6] M. S. Al-Ani, T. N. Muhamad, H. A. Muhamad, and A. A. Nuri, “Effective fingerprint recognition approach based on double fingerprint thumb,” in Current Research in Computer Science and Information Technology (ICCIT), 2017 International Conference on, 2017, pp. 75–80.

[7] D. Peralta, I. Triguero, S. Garc\'\ia, Y. Saeys, J. M. Benitez, and F. Herrera, “Distributed incremental fingerprint identification with reduced database penetration rate using a hierarchical classification based on feature fusion and selection,” Knowledge-Based Syst., vol. 126, pp. 91–103, 2017.

[8] D. Peralta, I. Triguero, R. Sanchez-Reillo, F. Herrera, and J. M. Ben\'\itez, “Fast fingerprint identification for large databases,” Pattern Recognit., vol. 47, no. 2, pp. 588–602, 2014.

[9] H. M. Daluz, Fundamentals of fingerprint analysis. CRC Press, 2014.

[10] Q. Zhao and A. K. Jain, “On the utility of extended fingerprint features: A study on pores,” in Computer Vision and Pattern Recognition Workshops (CVPRW), 2010 IEEE Computer Society Conference on, 2010, pp. 9–16.

[11] E. A. Azzoubi and R. B. Ibrahim, “AN ENHANCEMENT ALGORITHM USING GABOR FILTER FOR FINGERPRINT RECOGNITION.,” J. Theor. Appl. Inf. Technol., vol. 74, no. 3, pp. 355–363, 2015.

[12] A. K. Jain, Y. Chen, and M. Demirkus, “Pores and ridges: High-resolution fingerprint matching using level 3 features,” IEEE Trans. Pattern Anal. Mach. Intell., vol. 29, no. 1, pp. 15–27, 2007.

[13] J. C. Yang and D. S. Park, “Fingerprint verification based on invariant moment features and nonlinear BPNN,” Int. J. Control. Autom. Syst., vol. 6, no. 6, pp. 800–808, 2008.

[14] J. Sang, H. Wang, Q. Qian, H. Wu, and Y. Chen, “An efficient fingerprint identification algorithm based on minutiae and invariant moment,” Pers. Ubiquitous Comput., vol. 22, no. 1, pp. 71–80, 2018.

[15] A. Ali, X. Jing, and N. Saleem, “GLCM-based fingerprint recognition algorithm,” in Broadband Network and Multimedia Technology (IC-BNMT), 2011 4th IEEE International Conference on, 2011, pp. 207–211.

[16] S. Chikkerur, V. Govindaraju, and A. N. Cartwright, “Fingerprint image enhancement using STFT analysis,” in International Conference on Pattern Recognition and Image Analysis, 2005, pp. 20–29.

[17] L.-W. Chen and C.-R. Li, “Invariant moment features for fingerprint recognition,” in Wavelet Active Media Technology and Information Processing (ICCWAMTIP), 2013 10th International Computer Conference on, 2013, pp. 91–94.

[18] P. Grdiet and N. K. Garg, “Binarization Techniques used for Grey Scale Images,” Int. J. Comput. Appl., vol. 71, no. 1, 2013.

[19] M. Sudarma and N. P. Sutramiani, “The Thinning Zhang-Suen Application Method in the Image of Balinese Scripts on the Papyrus,” Int. J. Comput. Appl., vol. 91, no. 1, 2014.

[20] T. Y. Zhang and C. Y. Suen, “A fast parallel algorithm for thinning digital patterns,” Commun. ACM, vol. 27, no. 3, pp. 236–239, 1984.

[21] S. A. Sudiro, M. Paindavoine, and T. M. Kusuma, “Simple fingerprint minutiae extraction algorithm using crossing number on valley structure,” in Automatic Identification Advanced Technologies, 2007 IEEE Workshop on, 2007, pp. 41–44.

[22] R. Bansal, P. Sehgal, and P. Bedi, “Minutiae Extraction from Fingerprint Images - a Review,” Int. J. Comput. Sci. Issues, vol. 8, no. 5, pp. 74–85, 2011.

[23] R. Thai, “Fingerprint Image Enhancement and Minutiae Extraction,” vol. 7782, p. 63, 2014.

[24] K. Nilsson and J. Bigun, “Localization of corresponding points in fingerprints by complex filtering,” Pattern Recognit. Lett., vol. 24, no. 13, pp. 2135–2144, 2003.

[25] M.-K. Hu, “Visual pattern recognition by moment invariants,” IRE Trans. Inf. theory, vol. 8, no. 2, pp. 179–187, 1962.