

## Hand Authentication System Using Invariant Moment

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### Abstract

Hand authentication is one of an important biometric authentication technique. In this paper a method for verification is proposed depending on the features that exist in the hand which can easily extracted using the invariant moment. Hand shape can be used for authentication because of the two important properties uniqueness, and stability. From these two important characteristics it became easier to recognize one person from another depending on the features of each one. It is important to extract those features from the hand of a person by using one of the features extraction methods, where the invariant moment method was used to extract those features. Using these features an authentication system depending on a hand shape known as (HAS) was designed, implemented, and tested.

Keywords: Biometric, Authentication, hand shape, computer security, personal authentication, and Invariant Moment.

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## **1. Introduction:**

In computer security, personal identification and authentication is one of the main aspects to prevent an unauthorized access to computer assets. The two known approaches in personal identification and authentication are fingerprint and hand geometry, these approaches are based upon the measurement and comparison of the features extracted from the person's hand.

Hand shape is a new biometric solving technology that could help the police to solve thousands of more crimes per year, and it is also be used in access control or in a bank to authenticate the person identity.

In this research we propose an authentication system that is based on the hand shape features which is used as an access control mechanism. The proposed authentication system depends on the seven features that moment can be extracted from the hand of a person, by calculating the statistical features for each image of hand's person. To scan the hand of a person it must use one of the scanners (optical readers or digital camera) that are suitable for hand authentication and then build the image for further processing [1].

## **2. The Proposed System Design:**

The proposed system is known as the Hand Authentication System (HAS). It is designed to accept an interior view image of human hand and attempt to authenticate a person's identity by capturing (his, her) hand image.

### **HAS Design:**

Hand of a person is very useful to identify individuals because they vary slowly from time to time, and it is unique for each person [1]. Hand features of a person can be used to authenticate the identity of that person. Features extraction involves computing the widths, lengths, and thickness of the fingers at various locations using the captured image [2]. The proposed system uses the statistical features of the hand which is obtained from applying the moment to the hand to authenticate a person.

HAS authenticate a person identity by using the seven features of moment that extracted depending on the external (boundary) and internal details founded in the hand. In general the proposed system is suitable for authentication more than identification. To show the hand will be ready to extract the features, figure (1-a,b) shows the inner and external surfaces of the hand.

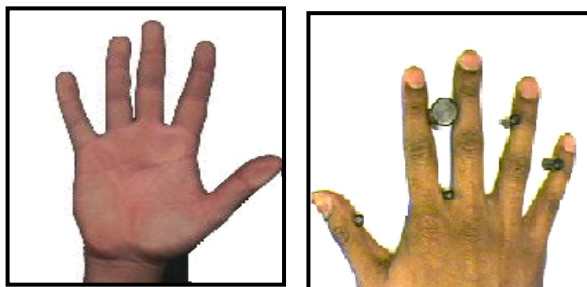


Fig (1-a) Inner surface of the hand

Fig (1-b) External surface of the hand

### 2.1 The Proposed System Modules:

HAS system consist of three main modules (Enrollment, Features Extraction, and Authentication modules) as shown below.

**Module(1):** Enrollment module: which is responsible for the enrollment or the insertion of hand image of a known (who was identified before) person, with the person's name (ID) (to be used later as an index or reference). The hand will be treated in this module and in the other modules as shown in Fig (1-b). By using some pegs to fixed the shape of hand in standard form every time enroll the hand in the images database.

**Module(2):** Features extraction module this module is used to get the required information of the interior hand to create a suitable template of each person. This module depends on the method that is used to extract the features from the hand. In the proposed system, the hand features are extracted using the moment method. In order to make the process of feature extraction easy and suitable for the moment functions a sub-process stage is carried out. A sub-process includes transformation, smoothing, edge detection, thresholding, and thinning (as shown in figure 3).

**Module(3):** Authentication Module: which is responsible for authenticating (verifying) a hand image of a known person whose identity requires being authenticated by using hand shape features. The features of the input hand image that was extracted in the previous module (module 2) will be fed to this module, and then those features will be matched with hand features that stored in a database file and

belong to that person whose identity must be authenticated. Authentication process is accomplished by matching the temporary template with the template that has the same ID in the database.

The representation of the whole system design is illustrated in Fig (2). From Fig (2), it is obvious that either module 1 or module 3 will be selected to process the input hand image of an identified person. This selection will depend on whether the hand image is fed to the system for enrollment or for authentication.

Module 3 may be used as an authentication process or identification process, but the main process of the system is authentication process. Module 2 will be needed after scanning stage in all cases. If the image is required for enrollment, the features must be extracted and saved in database as a template. If the image is required for authentication/identification, the features must be extracted for the matching process with the template that called from the database.

## **2.2 Input Stage:**

In the proposed system, the hand image will be captured by a colored traditional scanner or digital camera; (this is due to the unavailability of the special hand reader). One point to be taken in consideration is the way the hand is positioned on the surface of the reader. In the proposed system we used the traditional scanner where some fixed points (pegs) was found to enforce putting the hand in specific position as shown in figure (1-b). the pegs will ensure the positioning of the hand on the surface of the scanner in a standard form.

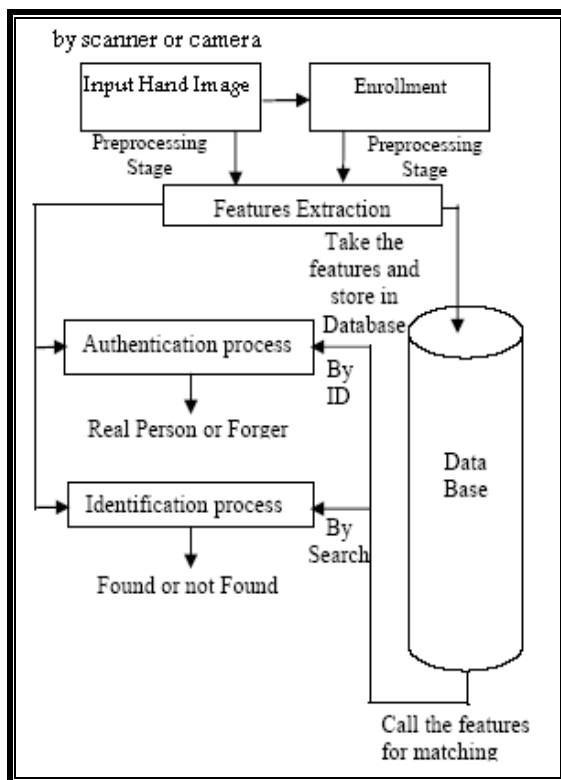


Fig (2) The Block Diagram of the Proposed System

In the input stage, a colored hand image in a BMP format will be fed to the system, as shown in Fig. (1.a) but with using a pegs (inner surface with all the boundaries of the hand, including palm boundary and fingers boundary, then will deal with the hand shape as a result).

This step includes the process of reading the header information of BMP image file format. Bitmap image (also called raster images) can be represented by our image module  $I(r,c)$ , where we have pixel data and the corresponding brightness values stored in some file format [4,6].

The input colored images must convert to a gray level (256 level image). In the input stage the image will be entered for Authentication purpose or for Enrollment purpose.

### 2.3 Enrollment Module:

The main operation of this module is to enroll hand image of a known person.

After the input stage operation was finished, hand image will be saved in a temporary folder. The hand image named by the name of the person (ID) to be used as an identifier.

The important notice that we must considered is, this module will not be completed only if the features extraction module be completed to save the values in the data file (reference data base file).

### **2.3.1 The Preprocessing Stage**

The enrollment module includes all the preprocessing operations required for ease the features extraction during the features extraction module, and available for authentication module. Preprocessing stage is required for the image when this image is for authentication or enrollment purposes.

The proposed hand authentication system use the preprocessing stage because, it is too difficult to extract features directly from the original colored input hand image, so it is necessary to use the preprocessing stages in order to reduce the complexity of computation and computational time of the further processing.

Preprocessing stage includes algorithms that concerned with the operations used to find the object of interest (in the proposed system, the hand is considered to be that object) to be prepared for the next module (feature extraction module).

The operations of the preprocessing stage are: Transformation from colored image to gray level image, Smoothing, Edge detection, Thresholding, and Thinning. Fig (3) shows a block diagram of preprocessing operations.

#### **2.3.1.1 Transformation Color Image to Gray Level Image:**

In this operation, the colored image of the hand that entered by scanner to the proposed system will be transformed to gray level image. Each colored input hand image will be converted to a gray-scale image by using the intensity relationship:

$$I=(R+G+B)/3 \quad \dots(2.1)$$

Where I is the intensity, and R, G, and B are the corresponding Red, Green, and Blue components. This relationship is performed on each pixel in the colored bitmap image. This intensity relationship will convert 24-bit/pixel bitmap images to 256 gray-level images.

### 2.3.1.2 Smoothing Operation

Image smoothing is used for two primary purposes: to give an image a softer or special effect or to eliminate noise [4,6]. Image smoothing is accomplished in the spatial domain by considering a pixel and its neighbor and eliminating any extreme values in this group [6]. By using smoothing filter (mean filter) we can get the effect of smoothing and the blurring will remove the unneeded details from the hand image.

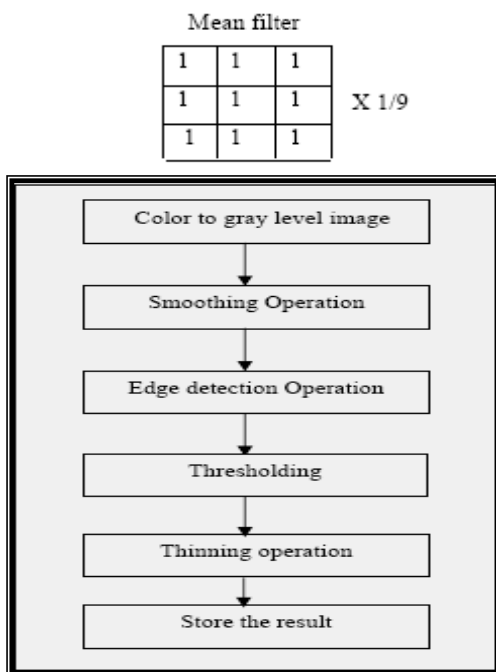


Fig.(3) The Block Diagram of Preprocessing Operations

### 2.3.1.3 Edge Detection:

After the smoothing operation was complete, the edge detection operation will be started to prepare the image for the next preprocessing stage. Where all preprocessing stages are used to prepare images for features extraction stage.

The main target from the edge detection is to shows the edge in the hand as clearly as possible. In the proposed system, the hand shape and all the features like fingers and palm that will resulted from the edge detection operation are treated as graphics lines, where these principle lines and other details will be used to extract the features from a hand.

### Sobel Operator:

In the proposed system, the Sobel operator is selected to be the edge detection method used for finding edge points of the hand shape because of its simplicity and produce wide edge and for this reason all the information of the hand will be not lost.

The Sobel edge detection masks look for edges in both horizontal and vertical directions and then combine this information into a single matrix [4].

| Row Mask |    |    | Column Mask |   |   |
|----------|----|----|-------------|---|---|
| -1       | -2 | -1 | -1          | 0 | 1 |
| 0        | 0  | 0  | -2          | 0 | 2 |
| 1        | 2  | 1  | -1          | 0 | 1 |

The masks that shown above are each convolved with the hand image. At each pixel location we now have two numbers:

$S_1$  corresponding to the result from the row mask, and  $S_2$ , from the column mask [4,7].

$$\text{Edge Magnitude} = \sqrt{s_1^2 + s_2^2} \quad \dots\dots 2.2$$

#### 2.3.1.4 Thresholding:

The aim of this stage is to isolate the hand shape from the background of the reader and other important details from the hand itself. For this reason the image is segmented in to two objects (background and edges of the external shape of the hand) that identify each person.

The result of this stage is a binary image (0,1) where 0's for background, and 1's for external shape of the hand and small details of a hand.

The way to extract the objects from its background is by selecting a threshold (T) that separates the modes. Then any point (x,y) for which  $f(x,y) > T$  is called an object point, otherwise, the point is called background point. Where  $f(x,y)$  is a gray level value at location (x,y).

In the proposed system, the threshold (T) is selected to be equal 40 as (default). This value was selected practically (using trial and error).

#### 2.3.1.5 Thinning (*skeleton*):

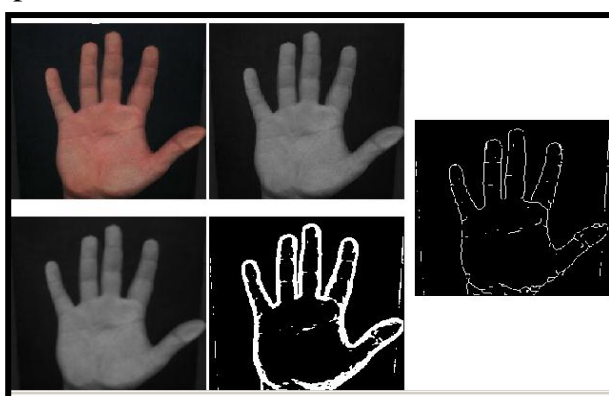
An important approach to representing the structure shape of an object region is to reduce it to graph. This reduction may be accomplished by

obtaining the skeleton of the region via a thinning (also called skeletonizing algorithm) [4].

The main goal of thinning operation is to get the exact representation of the edges that resulted from edge detection operation. Because the result from applying Sobel operator will be a wide edges that contain all possible details without any losing in principle lines features. So, thinning operation will reduced these edges of the hand shape as possible to generate the exact shape for the external boundary of the hand, and will reduce the calculations that required for features extraction (by using the moments calculations). All the next computations will depend on the results of this stage. The result of thinning operation will be a skeleton of the external boundary of the hand.

The skeleton can be determine as a set of pixels whose distance from the region's border is locally maximal, where thinning is iterative removal of region boundary pixels, and small changes in region (external boundaries of the hand) cause serious changes in the skeleton [4]. For this reason skeleton via a thinning operation will produce good and precise results for representing the template of person's hand, (graphically template not statistically template) because the last one will construct by feature extraction module (by invariant Moments).This algorithm (skeletonizing algorithm) is based on the idea of iteratively deleting edge points.

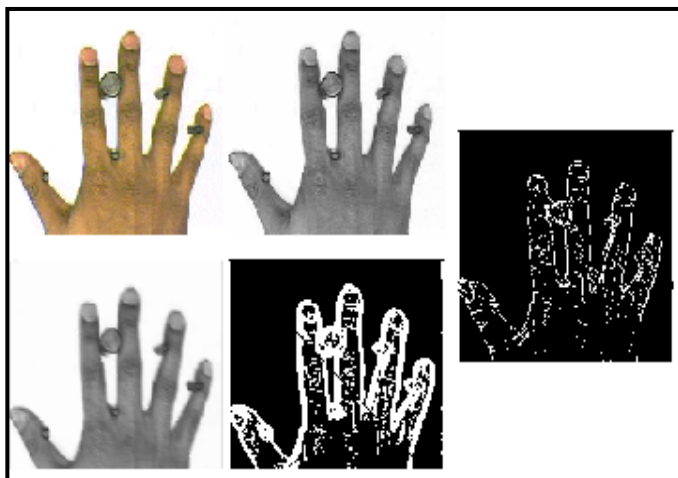
After all the preprocessing stages are executed, the features extraction operation is carried out. As an example, figure (4 and 5) shows all the preprocessing operations.



**Figure (4)**

Fig (4) shown the images of preprocessing when the reader scanned the hand from the outside, where we use the pegs to make the hand more stable for the reader.

Any way we can also put the hand on the surface of reader to scan the hand from the inside face. As shown in Fig (5).



**Figure (5)**

Fig.(4) The Results from the Preprocessing stages of a person (Original image, Gray level, Smooth, Edges, Thinning) respectively.(inner surface of the hand, where the system will depends on this positioning)

Fig.(5) The Results from the Preprocessing stages of a person (Original image, Gray level, Smooth, Edges, Thinning) respectively.(external surface of the hand)

## **2.4 Features Extraction**

After all the preprocessing stages that required for feature extraction, the proposed system is executed either in enrollment phase or in the authentication or identification phase. In the enrollment phase the hand features are stored in the person hand features data base, while in the authentication or identification phase a matching is required.

Invariant Moment will be the core strategy of hand features extraction, but we must not forget that there are many methods used to extract features from the hand but Moment is the more reliable and easy than the others as will be seen that from its computations.

Moment method depends on the region itself (binary image) to describe the objects.

For a 2-D continuous function  $f(x,y)$ , the moment of order  $(p+q)$  is defined as [4]:

$$m_{pq} = \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} x^p y^q f(x, y) dx dy \dots (2.3)$$

for  $p,q=0, 1, 2, \dots$

A uniqueness theorem states that if  $f(x,y)$  is piecewise continuous and has nonzero values only in a finite part of  $xy$  plane, moments of all orders exist and the moment sequence  $(m_{pq})$  is uniquely determined by  $f(x,y)$ . Conversely,  $(m_{pq})$  uniquely determines  $f(x,y)$ . The *central moments* can be expressed as

$$\mu_{pq} = \int \int (x - \bar{x})^p (y - \bar{y})^q f(x, y) dx dy \dots (2.4)$$

Where

$$\bar{x} = \frac{m_{10}}{m_{00}} \quad \text{and} \quad \bar{y} = \frac{m_{01}}{m_{00}} \quad \dots (2.5)$$

For a digital image,

$$\mu_{pq} = \sum_x \sum_y (x - \bar{x})^p (y - \bar{y})^q f(x, y) \dots (2.6)$$

The central moments of order up to 3 are:

$$\begin{aligned} \mu_{10} &= \sum_x \sum_y (x - \bar{x})^1 (y - \bar{y})^0 f(x, y) \\ &= m_{10} - \frac{m_{10}}{m_{00}} (m_{00}) = 0 \end{aligned}$$

$$\mu_{11} = \sum_x \sum_y (x - \bar{x})^1 (y - \bar{y})^1 f(x, y)$$

$$\mu_{20} = \sum_x \sum_y (x - \bar{x})^2 (y - \bar{y})^0 f(x, y)$$

$$= m_{20} - \frac{2m_{10}^2}{m_{00}} + \frac{m_{10}^2}{m_{00}} = m_{20} - \frac{m_{10}^2}{m_{00}}$$

$$\mu_{02} = \sum_x \sum_y (x - \bar{x})^0 (y - \bar{y})^2 f(x, y)$$

$$\begin{aligned}
 &= m_{02} - \frac{m_{01}^2}{m_{00}} \\
 \mu_{30} &= \sum_x \sum_y (x - \bar{x})^3 (y - \bar{y})^0 f(x, y) \\
 &= m_{30} - 3\bar{x}m_{20} + 2\bar{x}^2 m_{10} \\
 \mu_{12} &= \sum_x \sum_y (x - \bar{x})^1 (y - \bar{y})^2 f(x, y) \\
 &= m_{12} - 2\bar{y}m_{11} - \bar{x}m_{02} + 2\bar{y}^2 m_{10} \\
 \mu_{21} &= \sum_x \sum_y (x - \bar{x})^2 (y - \bar{y})^1 f(x, y) = m_{21} - 2\bar{x}m_{11} - \bar{y}m_{20} + 2\bar{x}^2 m_{01} \\
 \mu_{03} &= \sum_x \sum_y (x - \bar{x})^0 (y - \bar{y})^3 f(x, y) \\
 &= m_{03} - 3\bar{y}m_{02} + 2\bar{y}^2 m_{01}
 \end{aligned}$$

In summary,

$$\begin{array}{ll}
 \mu_{11} = m_{11} - \bar{y}m_{10} & \mu_{00} = m_{00} \\
 \mu_{30} = m_{30} - 3\bar{x}m_{20} + 2\bar{x}^2 m_{10} & \mu_{10} = 0 \\
 \mu_{12} = m_{12} - 2\bar{y}m_{11} - \bar{x}m_{02} + 2\bar{y}^2 m_{10} & \mu_{01} = 0 \\
 \mu_{21} = m_{21} - 2\bar{x}m_{11} - \bar{y}m_{20} + 2\bar{x}^2 m_{01} & \mu_{20} = m_{20} - \bar{x}m_{10} \\
 \mu_{03} = m_{03} - 3\bar{y}m_{02} + 2\bar{y}^2 m_{01} & \mu_{02} = m_{02} - \bar{y}m_{01}
 \end{array}$$

The normalized central moments, denoted  $\eta_{pq}$ , are defined as [4]:

$$\eta_{pq} = \frac{\mu_{pq}}{\mu_{00}^\gamma} \dots (2.7)$$

$$\gamma = \frac{p+q}{2} + 1 \dots (2.8)$$

For  $p+q = 2, 3, \dots$

A set of seven invariant moments can be derived from the second and third moments [4]:

$$\phi_1 = \eta_{20} + \eta_{02} \dots (2.9)$$

$$\phi_2 = (\eta_{20} - \eta_{02})^2 + 4\eta_{11}^2 \dots (2.10)$$

$$\phi_3 = (\eta_{30} - 3\eta_{12})^2 + (3\eta_{21} - \eta_{03})^2 \dots (2.11)$$

$$\phi_4 = (\eta_{30} + \eta_{12})^2 + (\eta_{21} + \eta_{03})^2 \dots (2.12)$$

$$\begin{aligned} \phi_5 &= (\eta_{30} - 3\eta_{12})(\eta_{30} + \eta_{12})[(\eta_{30} + \eta_{12})^2 - 3(\eta_{21} + \eta_{03})^2] \\ &\quad + (3\eta_{21} - \eta_{03})(\eta_{21} + \eta_{03})[3(\eta_{30} + \eta_{12})^2 - (\eta_{21} + \eta_{03})^2] \\ \phi_6 &= (\eta_{20} - \eta_{02})[(\eta_{30} + \eta_{12})^2 - (\eta_{21} + \eta_{03})^2] + 4\eta_{11}(\eta_{30} + \eta_{12})(\eta_{21} + \eta_{03}) \\ \phi_7 &= (3\eta_{21} - \eta_{03})(\eta_{30} + \eta_{12})[(\eta_{30} + \eta_{12})^2 - (\eta_{21} + \eta_{03})^2] + (3\eta_{12} - \eta_{30})(\eta_{21} + \eta_{03}) \\ &\quad [3(\eta_{30} + \eta_{12})^2 - (\eta_{21} + \eta_{03})^2] \end{aligned}$$

This set of moments is *invariant* to translation, rotation, and scale change [4].

In all cases there is no problem of scaling, translation, rotation if the hand position as shown in Fig(1.b) (we use a peps), but the problem of those transformation types will be more seriously if we put the hand as shown in Fig (1.a).

### 2.5 Operation Matching and Authentication decision:

one of main principle of authentication is the matching *one to many* to make the final result and to know if the person is authentic or not, this will executed by matching the template that was saved in the database with the template that will created for authentication or identification (matching one to many ) operations. when the authentication process will needed from the proposed system the saved template will requested depending on the identifier of the template (ID and features record), but when the identification operation will needed from the system then the search operation will executed to find the person that has this template and then return the ID of this person with the ratio of matching, where authentication will return the ratio of matching directly with the same person.

If the ratio of matching equal or greater than 82% then the person is authorized otherwise the person is unauthorized.

### Features matching percentage calculation and total ratio:

In the beginning, the tolerance ratio for differences in matching process between the saved template and the template that will created for comparison (temporary template) will be determined.

From the “trial and error” method, the largest value of the tolerance ratio must not exceed the 5% (this value will enclose the seven values of moments).

“The difference is 5% between each coupled of the sevens values”

Suppose that,  $Ft[i]$  is any moment value of the template that created for comparison purpose (temporary template), and the  $Ftdb[i]$  is any moment value from saved template (from database) values. Where  $F$  is any value from the moments values,  $i$  is the sequence of moments values  $i= 1,2,3...7$ ,  $t$  is template, and  $db$  meaning the value from saved template (from database).

The matching ratio will be calculated as follows: -

- The tolerance value ( $T$ ) will be obtained from:

$$T = Ftdb[i] * tr \quad \dots\dots(2.16)$$

Where  $tr$ = tolerance ratio=0.05

- The  $T$  value will be added and subtracted to/from the  $Ftdb[i]$  for determining the permission range.

$$S1 = Ftdb[i] - T \quad \dots\dots(2.17)$$

$$S2 = Ftdb[i] + T \quad \dots\dots(2.18)$$

After getting the  $S1$  and  $S2$ , the  $Ft[i]$  must be greater than or equal to  $S1$ , and small than or equal to  $S2$ . As shown below:

$$S1 \leq Ft[i] \leq S2 \quad \dots\dots(2.19)$$

If Eq. (2.19) is satisfied, the two values ( $Ft[i]$  and  $Ftdb[i]$ ) will take into consideration when calculate the total ratio of matching the two image of hands, and the total ratio will calculated as follow:

The matching percentage between  $Ft[i]$  and  $Ftdb[i]$  will be calculated by:

As explain in section (2.6), there are seven moments values will be resulted from features extraction ( $F1, F2, F3, \dots, F7$ ). Any value from these values will takes  $1/7$  from the total ratio ( $1/7 * 100 = 14.285$ ).

The matching percentage between ( $Ft[i]$  and  $Ftdb[i]$ ) is:

If  $Ftdb[i] \leq Ft[i]$  then the matchin

$$\left(\frac{Ftdb[i]}{Ft[i]}\right) * 14.285$$

Else

$$\left(\frac{Ft[i]}{Ftdb[i]}\right) * 14.285$$

In general the total ratio of matching the two hands template is calculated as follows.

$$M = \sum_{i=1}^7 \left( \frac{\text{Smallvalue}}{\text{Larg evalue}} \right) * 14.285$$

if  $F_{tdb}[i] \leq F_t[i]$  then the total ratio will be

$$R = \sum_{i=1}^7 \left( \frac{F_{tdb}[i]}{F_t[i]} \right) * 14.285$$

Where R is the total ratio.

else

$$R = \sum_{i=1}^7 \left( \frac{F_t[i]}{F_{tdb}[i]} \right) * 14.285$$

The R-value must be greater than or equal 82% to accept the entered hand; otherwise the system will refuse the entered hand.

### 2.6 Experimental Results:

Table (1) shows some of the final results of invariant moment computations, where the hand's position is shown in Fig (1-a):

| Invariant (I) | Moment Value (Fi) |
|---------------|-------------------|
| I1            | 1.139339          |
| I2            | 2.455277          |
| I3            | 4.420444          |
| I4            | 4.146687          |
| I5            | 8.430147          |
| I6            | 5.419262          |
| I7            | 6.771801          |

Table (2) shows some of final results of invariant moment computations, where the hand's position is shown in Fig (1-b):

| Invariant (I) | Moment Value (Fi) |
|---------------|-------------------|
| I1            | 0.489878          |
| I2            | 1.344249          |
| I3            | 2.609810          |
| I4            | 2.281571          |
| I5            | 4.727228          |
| I6            | 2.953640          |
| I7            | 2.823264          |

Table (3) shows the results of matching each sample in temporary template with its likely and others in the database.

| Hs\Ht | P1    | P2    | P3    | P4    |
|-------|-------|-------|-------|-------|
| P1    | 97.37 | 0     | 0     | 14.12 |
| P2    | 28.57 | 85.22 | 0     | 0     |
| P3    | 0     | 0     | 98.28 | 42.07 |
| P4    | 0     | 0     | 0     | 96.78 |

Where, Hs is (saved hand template) and Ht (temporary hand template).

### **3. Conclusions and Recommendations:**

#### **3.1 Conclusions:**

Authentication is one of the main issues in computer security and many different methods were suggested for authentication and among them is the biometric approach.

There are many methods of biometric systems and hand shape (boundary) is one of them. In this research a biometric authentication system was designed and implemented using hand approach, the system is known as “Hand Authentication System (HAS)”.

We can conclude from the proposed system the following:

1. The proposed system can be used easily for authentication and/or identification and this is due to the acceptable results obtained from it.
2. Hand features can be used for authentication and/or identification and this due to the good results obtained from the proposed system.
3. Invariant moments shows a good approach for hand extraction features that may be used for human authentication or identification.
4. The proposed system can be used for access control.
5. Hand boundary used effectively in the proposed system for identification or authentication.

#### **3.2 Recommendations:**

The following recommendations and suggestions are proposed to enhance the HAS:

1. The proposed system depends in essential on the external shape of hand boundary, but there are many others information (features) like the length of fingers, color of skin, and compute the center circle of the palm.
2. In this proposed system feature extraction depends on the two dimensions of the hand, but there is a method of using three dimensions.

3. There are many methods may be used as feature extraction and may be able to help us to give good and accurate results.
4. Furthermore the hand shape technique can be integrate with another biometric techniques namely fingerprint or/and palmprint to make whole the system more integration because it will deal with all features of hand.

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## نظام التثبيت بواسطة اليد باستخدام العزم الثابتة

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### المستخلص

التحقق باليد هي واحدة من تقنيات المقاييس البيولوجية المهمة. في هذا البحث تم اقتراح طريقة للتثبيت (التحقق) اعتماداً على خصائص موجودة في اليد والتي يمكن وبسهولة استخراجها باستخدام طريقة العزم الثابت. شكل اليد يمكن ان يكون لغرض التثبيت من ادعاء الشخص لخاصيتين مهمتين هما: كونها فريدة لا يمكن تكرارها وكذلك مستقرة ، ومن هذه الخاصيتين اصبح من السهل تمييز شخص عن اخر اعتماداً على خصائص يد كل منهما. ومن المهم استخراج هذه الخصائص من يد الشخص باستخدام واحدة من طرق استخراج الخصائص، وان طريقة العزم الثابت قد تم استخدامها لاستخراج هذه الخصائص. وباستخدام هذه الخصائص المستخرجة قد تم تصميم وتنفيذ وفحص نظام التثبيت اعتماداً على شكل اليد للشخص.

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