Hand Identification Using Fuzzy Logic

Ali M. Mohammed, Dr. Loay E. George, Dr. Ban N. Dhannoon

ABSTRACT— Biometrics refers to the automatic identification of a living person based on physiological or behavioral characteristics. Hand identification involves an analysis and measures of the features of the hand. In this work, an authentication system based on hand geometry (i.e., fingers' features) and non-geometry (central moment) are proposed and implemented. The features of the fingers are extracted from the binary figures sub-images which are producing after passing through a sequence of preprocessing stages. The authentication process consists of two phases, enrollment phase were image capture, binarization, edge detection, chain coding and feature extraction were implemented. In the verification phase, feature vector to the unknown person is extracted from its hand image were Euclidian method is used.

Keywords— Hand Identification, feature Extraction, geometrical features, non-geometrical, and trapezoidal membership function features.

1 Introduction

Person identification and verification using biometric methods are getting more important in today's information society. Hand recognition is a promising biometric because of its simplicity and fairly good performance of identification. The personal and institutional security requirements increase. The person has remember lots of passwords, pin number and other security codes. In the future, the biometric systems will take the place of this concept since it is more convenient and reliable [1].

Hand geometry involves analyzing and measuring the shape of the hand. This biometric offer a good balances of performance characteristics and is relatively easy to use. It might be suitable where there are more users or where users access the system infrequently and are perhaps less disciplined in their approach to the system [2].

2 Previous works

Several researches in the field of hand recognition were developed and published in the literature including:

- Slobodan Ribaric [3] who describe the design and development of a prototype system for the automatic identification of an individual based on the fusion of palm and hand geometry features.
- In 1999, Milan Markovic [4] dedicate his research on the problem of two-dimensional shape recognition from the point of view of possible optimization, regarding feature extraction and classification methods. Two types of moments were used; they are central moment and moment invariant.
- In 2003, the research of Hiba Zuhair [5] involves several proposed methods based on extracting the hand geometry features from the captured hand images, and compare the extracted features with the template of claimed user, which should previously enrolled to the system and stored in a database.
- In 2007, a thesis submitted by Saraf Ashish [6] involve hand geometry based identification systems which utilize the geometric features of the hand. The system accepts a grayscale handprint from which it extracts the finger lengths, finger widths, diameter of the palm and the perimeter.
- In 2012, a new scheme for hand recognized method based on the extension neural network for biometric authentication was presented [7]. It applied a thermal imaging camera to capture the palmar images to develop the person's recognition system; the main advantage of the thermal image is that it can reduce errors and noise in the features extracted stage, which is most important to increase the accuracy of recognition systems.

3 Proposed System Layout

Figure (1) presents the layout of the proposed system, it consists of two modules:

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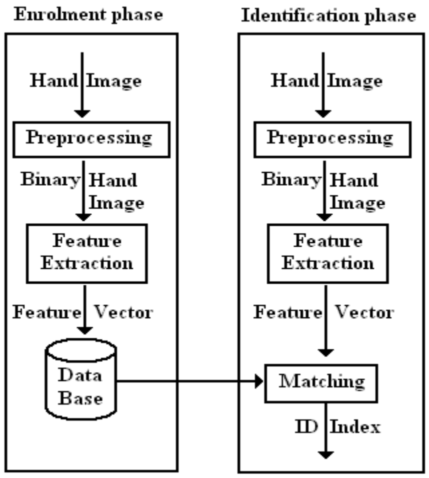

Fig. (1) The main system

Module1: the input to this module is the hand's image. The first stage in this module performs the preprocessing operation (it includes image binarization, edge detection, and chain code). The second stage is for feature extraction. Two types of feature extraction were used, they are geometrical features (length of fingers, width of fingers, hand span, distance between joints) and the non-geometrical features (find central moment of the shape of each finger). The result of this module is creating feature vector for each input image.

Module 2: the input to this module is the feature vector. The system will apply the feature analysis to decide which of these features have a good recognition. After finding the good discriminating features, then the matching step is performed between the unknown person features with the representative feature vectors listed in the database which contains the required template features for number of hand image samples taken for each person. The result of this module is person ID (index).

A colored hand image BMP is input to the system, figure (2) shows a typical hand image.

Figure (2) Color image

3.1 Design of Enrolment phase

This phase implies all the processing or steps required to determine the features vectors for an input image. The extracted features vectors in this phase are stored in a database, to be utilized latter in the identification phase. Figure (3) shows the implementation steps of the enrolment stage.

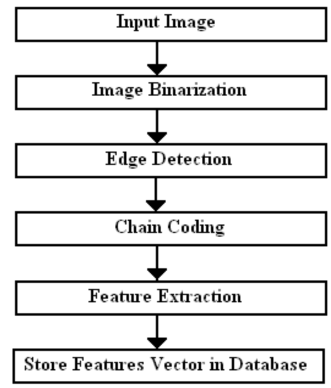

Fig (3) Implementation steps of the "Enrolment Phase"

3.1.1 Preprocessing Stage

Some preprocessing processes are used to make the data of the hand image more suitable for the primary data reduction and to make the analysis task easier [8].

The first step is converting the color image to binary image (black and white), the second step is finding the edge of the outer boundary of the hand's person, and the third step is determining the chain code of the boundary.

3.1.2 Image binarization

The first step of the image binarization process is converting the color image to gray image. The second step is converting the produced gray image to binary image. In this step, we compute histogram of the gray image and then determine the minimum value from histogram, this minimum value is used as a threshold value to binarize the gray image. Figure (4) shows the histogram value (0) and (255) is zero (minimum value). By test, we find that the minimum value between the value (55) and (80) in the histogram is the best threshold value to make the background of the image is black and set the hand's pixel white.

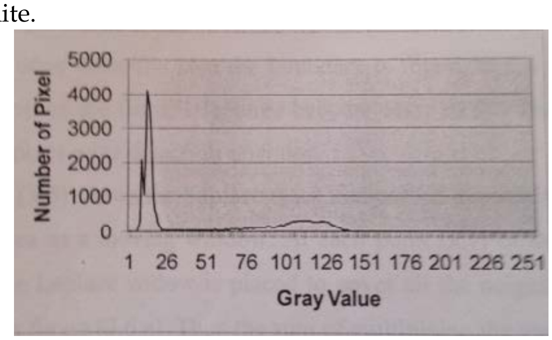

Fig. (4) Image Histogram

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3.1.3 Edge Detection

In the edge detection step, the boundary is found; this will make the determination of the finger's features become easy. Laplace edge detection operator was used, where at each point (x, y) of the image the center of the Laplace window is placed to cover all the neighbor pixels.

3.1.4 Chain Code

Chain code is used to represent the boundary as a connected sequence of straight line segments of specific length and direction [9]. So, the produced edge image contains only the boundary points of the hand as white points. Now we need to represent those boundary points as a sequence of adjacent points, in order to use this sequence to extract the hand features.

The main idea of chain code is constructing a one dimensional array of point type records, each contain the X and Y of the boundary pixel. The chain coding coding process begin by finding the start point of the hand edge as shown in figure (5) and check the 8-neighbors of the start point to detect the next connected (chain) point. The coordinates of the start point is registered in the boundary array, after that we start checking its neighbors in the clockwise manner, if one of them is an edge pixel (pixel value 255) then store this pixel in the boundary array and make it as a next test point and detect the old tested (start point, then represent this operation to find the new connect neighbor to the new start point.

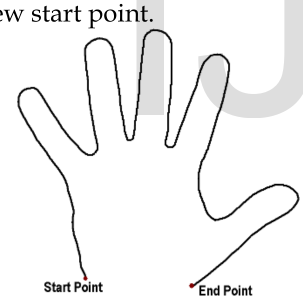

Figure (5) Boundary Hand Image

In the proposed work, after finding the start point and start searching its 8-neighbors to find out if any of them could be considered as a new edge point, in the case of non existence of the new neighbor connected point (i.e., whose value=255) then the detected start point should be ignored and not listed in the boundary array, in such case the step of searching for the start point should be continued until finding out another start point with connecting neighbors. In the case of finding out the correct start point then register the coordinates of the start point and all the connected adjacent points. The applied search method to check the 8-neighbors is circular.

3.1.5 Feature extraction

In the proposed work, we used two types of features (Geometrical feature and non geometrical feature). The geometrical features include the length of the fingers, width of the fingers at different vertical positions, hand span, and distance between joints of the fingers.

The non geometrical features include the central moment of each finger after determining the direction of that finger.

3.1.5.1 Geometrical Feature

The first step in the measurement of the geometrical features is to find the top points and joint points of the finger, as shown in figure (6).

After finding all top and joint points, we can compute all geometrical features.

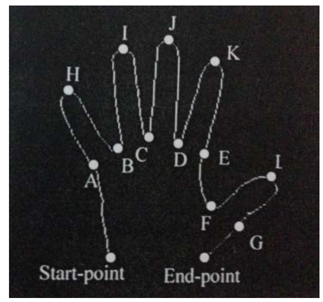

Figure (6) Top and Joint points

A. Finding Top and Joint points

By check the y-coordinates of all the boundary points all top and some of the joint points (**B**, **C**, **D**, and **F**) could be found. An additional method was used to find the remaining joint points (**A**, **E**, **G**).

i. By using a method based on checking the y-coordinates, the top points and joint points (**B**, **C**, **D**, and **F**) could be found. This method utilize the criteria that the top point has y-coordinate is less than the y-coordinates of the previous and next pixels. On the other hand the joint points have y-coordinate greater than those for the previous and the next pixels.
ii. To find the joint point **A**, a scanning to all the pixels that lay between the start-pixel and the top point **H** in the sequence of boundary points) is performed to find out point **A** (which is a pixel that has minimum distance with the joint point **B**).

The same above method could be used to find the joint points **E** and **G**. to find the joint point **E** we scan the boundary pixels between the top point **K** and the joint point F, and we take the pixel of minimum distance with pixel **D**. The joint **G** could be defined by scanning the pixel between the top point **L** and the end-pixel, where **G** is the pixel of minimum distance with the pixel **F**.

B. Extract the Geometrical Features

After extracting all top and joint points, the system now ready to measure the geometrical features. The geometrical features represent the length of the fingers, width of the fingers, hand span and distance between joints.

I. Finger's Length

The length of each finger represents the distance between the top of the finger and the middle point between joint points of that finger, as shown in figure (7).

The middle point could be computed from the equation (1):

$$\text{Middle point} = \left(\frac{\text{Joint A} + \text{Joint B}}{2}\right) \quad \dots (1)$$

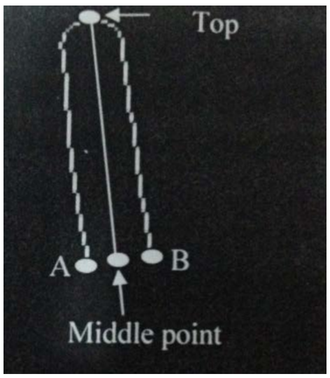

Figure (7) person finger

II. Finger's Width

It is represents the width of each finger at different vertical positions. The main idea of the width determination is select two corresponding pixels (left-pixel and right-pixel), such that the line passing through those should be perpendicular on the finger's longitudinal axis (i.e., the line passing through the finger's top point and it's middle point and intercept with it at certain mid point (i.e., the point cut the longitudinal line into 1/5, 2/5, 3/5, 4/5 of its length), as shown in figure (8). The slope value of the width line could be computed according to equation (2):

$$\text{Slope} = \frac{-\Delta y}{\Delta x} \quad \dots (2)$$

Where Δy is the vertical difference between the position of the finger's top point and its middle bottom point, and Δx is the horizontal difference between the top point and the middle bottom point.

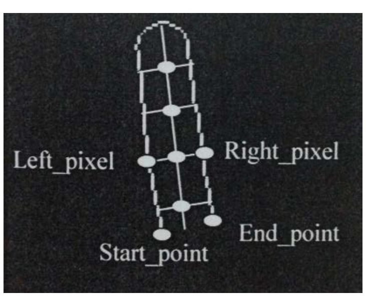

Figure (8) Finger width

III. Hand Span

The hand span represents the radius of the largest circle that can be drawn within the palm area of the hand.

The idea of determining the radius of the hand span that shown in figure (9), is based on allocating the Top and Bottom points. The radius of hand span represent the half of the distance between the Top and Bottom points.

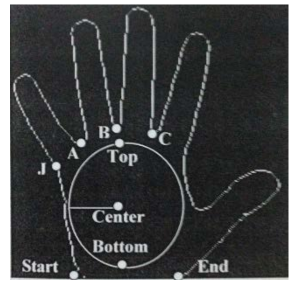

Figure (9) Hand Span

The Bottom point represents the middle of the distance between the Start and End points. The Top point could be computed as the average of the joint points **A**, **B**, and **C** as equation (3):

$$\text{Top} = \left(\frac{\text{Joint A} + \text{Joint B} + \text{Joint C}}{3}\right) \quad \dots (3)$$

The y-coordinate of the central point represents the middle distance between the Top and Bottom points. The radius of the hand span is represents the distance between the Top and the Center points.

Sometime the determined circle may draw out the hand boundary, this mean that the computed radius is not correct. The solution to this problem is done by scanning all the boundary pixels lay between the Start point and point **J**. For each scanned pixel compute the distance between that pixel and the hand center. If the distance is less than the computed radius we must decrease the radius by the half of the difference between the distance and radius. On the other hand, the hand center must be modified by the same value of the modifying the radius.

IV. Distance between Joints

One of the geometrical features set is the set of distances between the successive points of all fingers. These features were computed by scanning all fingers, and compute the distance between the previous and next joints points.

3.1.5.2 Nongeometrical Feature

After constructing all the geometrical features (fingers length, fingers width, hand span, distance between joints), the next step is constructing the nongeometrical features which are the central moments for each finger. This is done by:

A. Partition the image into subimages to separate the fingers from the hand and create five binary subimages each one content only one finger.

B. Find the direction of the principal axis of each finger.

C. Measure the central moment for each finger along the finger's principal axis.

A. Image Partitioning

In this step, the subimage for each finger is created to simplify extracting its feature. This image is drawn by using the finger's boundary from the boundary array, as shown in figure (10). Joint A and B are represents the start and end of the finger boundary.

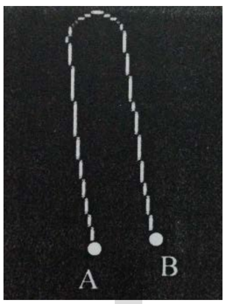

Figure (10) Person Finger

The produced subimages contain black background and white finger. By using the Bresenhan algorithm a line between the points A and B can be drawn to split the finger from the hand. The next step is filling the inside area bounded by the finger's boundary points to white color.

B. Compute Central Moment

For black and white image of size H*W, the nth order moment is defined as follows

$$m_{pq} = \sum_{i=1}^{H.W} x^p y^q \, M(x_i, y_i) \quad \text{-- (4)}$$

Where p,q = 0,1,2, … and M(xi, yi)=1 if the pixel i at position (xi, yi) is white pixel and 0 otherwise.

The central moment around the finger center is given in equation (5)

$$C_{pq} = \sum_{i=1}^{H.W} (x_r - x_c)^p (y_r - y_c)^q M(x_i - y_i) \quad ..(5)$$

Where xc, yc represent the central coordinates of the finger, and xr, yr are the rotated coordinates corresponding to their coordinated (xi, yi), see figure (11).

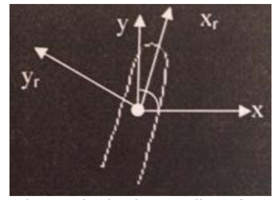

Figure (11) Finger direction

In the proposed work, the central moments up to sixth order were computed such that they produce for each finger 36 moments features. That means that for each hand person, 180 features were proposed. And the determined moments can be normalized by dividing the moments by their corresponding zeroth order moment.

3.2 Create Feature Vector

After finding all geometrical features, the feature vector is constructed which contains all features (fingers length, fingers width, hand span and distance between joints and central moments). The number of features is 211 feature. In the proposed work, a database of 13 person was established, for each person have 5 hand images were used as template samples to extract the hand features.

4 Fuzzification Features Vector

After construct the features vector, a trapezoidal member function was used to define the membership degree (MSF) for the feature. Figure (12) presents the shape of the trapezoidal function, where point M represents the mean of the features.

When feature value is between the points B and D, the membership degree (MSF) is equal to 1. The MSF between the points A and B could be expressed by using equation (6)

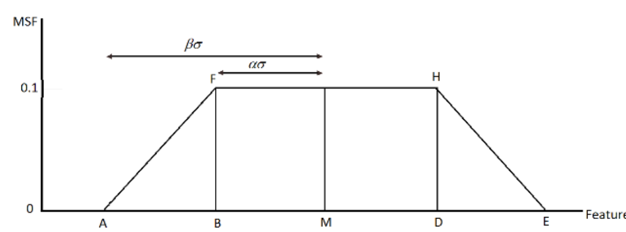

Figure (12) Trapezoidal Membership Function

$$MSF = \frac{feature + \alpha\beta - M}{\sigma(\beta - \alpha)} \quad .... (6)$$

While the MSF between the points D and E expressed by using the following equation

$$MSF = \frac{feature - M - \alpha\beta}{\sigma(\alpha - \beta)} \quad ..... (7)$$

The values of □□ and □□ are a real number.

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5. Matching Results

After extracting the geometrical (fingers length, fingers width, hand span and distance between joints) and non-geometrical features (central moments) of 13 persons, each one has 5 samples of their hand images, and using the trapezoidal membership function with the values of (α =2) and (β = 3), the recognition success was 100% for the training images and 86.538% for the tested images.

6 Conclusions

From the test results of the proposed system, the following remarks are stimulated:

- Combining the geometrical features with the non-geometrical features had improved recognition accuracy.
- The best order of the central moment is the sixth order that give mode discrimination information on the features of the finger's shape.
- The recognition success was 100% for the training images and 86.538% for the tested images.

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