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HAND GEOMETRY: A New Method for Biometric Recognition

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Abstract- This research method demonstrates a study about personal verification and identification using hand geometry. Hand geometry used in this research consists of the lengths and widths of fingers and the width of a palm. Users can place their hands freely without the need for pegs to fix the hand placement. In this method, six different distance functions were tested and compared. Test data obtained were from different users. Among the six different distance functions, S_1 gives the best results in both verification and identification.

Keywords: Biometric, Hand geometry, Recognition, Identification

I. INTRODUCTION

The need to identify people is as old as humankind. People have used some various systems to identify an individual. Conventional identification systems are based on knowledge that people have to memorize some passwords and the systems that the people have to own some photo IDs or coded cards

The important drawbacks of these methods are as follows: (i) possessions can be lost, stolen or easily duplicated; (ii) knowledge can be forgotten; and (iii) both possessions and knowledge can be shared or stolen.

Biometric is gaining more attention in recent years. There are many biometric systems based on different characteristics and different parts of the human body. Each biometrics has its strengths and weakness depending on its application and use. A system that uses hand and finger geometry is one of the effective ways for identification purposes. The physical properties of a human hand contain some information that is useful for authenticating the identity of an individual. Each human hand has its own characteristics and unique. Finger length, widths of the fingers, palm width, thickness or locations of fingers distinguish a human being from the others.

Biometric recognition systems can eliminate these problems. Biometrics deals with identification of individuals based on their biological or behavioral characteristics. A number of biometric characteristic exist and are use in various applications including hand and finger geometry, voice, face, fingerprint, iris, gait, DNA, retinal scan, odor, keystroke, signature, and infrared facial and hand vein thermo grams.

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The advantages of a hand geometry system are that it is a relatively simple method that can use low resolution images and provides high efficiency with great users' acceptance. [1,2]

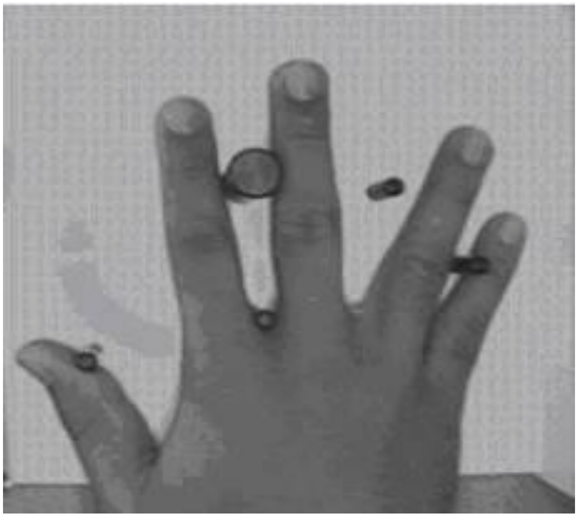

Fig 1: Incorrect placement of a hand

Traditional hand geometry system always uses pegs to fix the placement of the hand [3,4,5,6]. Two main weaknesses of using pegs are that pegs will definitely deform the shape of the hand silhouette and users might place their hands incorrectly as shown in Fig. 1. These problems can certainly reduce the performance of the biometric system.

Many researches about personal recognition based on hand geometry have been examined and studied. Jain et. al. [7] developed a hand geometry based verification system and used it for a prototype web security system. Sanchez-Reillo et. al. [8] selected finger widths at different latitudes, finger and palm heights, finger deviations as a feature vector. Oden et. al. [9] implemented a system using implicit polynomials. Sidlauskas [10] discusses a 3D hand profile identification apparatus used for hand recognition. Kumar et. al. [11] uses both hand geometry and palm print; on the other hand, Han et. al. [12] used only palm print information for personal authentication. In this research, the proposed algorithm is based on digital image processing including hand segmentation, feature extraction, and recognition.

II. METHODOLOGY

Hand geometry features are extracted from an image by 3 steps as follows: image acquisition, image pre-processing and feature extraction.

A. Image Acquisition

The image acquisition system comprises of a light source, a CCD digital camera, and a black flat surface used as a background. A user places one hand, pointing up, on the flat surface with the back of the hand touching the flat surface. The user can place a hand freely since there is no peg to fix the position of the hand. Then an image is acquired by using a CCD digital camera.

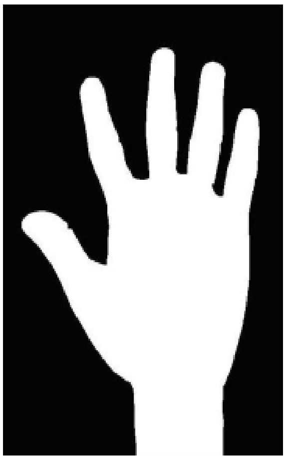

Fig.2: Example images from image preprocessing process.

Fig.3: Example images from Image Acquisition.

Users are only requested to make surethat their fingers do not touch one another and that the back of the hand lies flat and stays on the flat surface. In our experiments, only the left hand images of the users are acquired.

B. Image Preprocessing

Since the acquired image is a color image, it is converted to a grayscale image. Median filter is applied to remove noise in the image. Because of the black background, there is a clear distinct in intensity between the hand and tha background. Therefore, the histogram of the image is bimodal. The image can be easily converted to binary image by thersholding. The threshold value is automatically computed using Otsu method [13,14]. Then the border of the hand silhouette is smoothed by using morphological opening and closing. The result is shown in fig. 2.

Firstly, the reference position on a wrist, as shown in Fig. 4, must be found. By scanning the pixels at the bottom of the image from left to right, the left-most pixel of the hand image, S1, and the right-most pixel, E1 are located.

Fig.4: Example images from image preprocessing process.

The reference point is simply the middle point between S1 and E1. The next step is to find all the fingertips and valley points of the hand. The distances between the reference point and each contour point of the hand , from S1 to E1, are measured by Euclidean distance as defined in equation 1.

$$D = \sqrt{(x - xr)^2 + (y - yr)^2}$$

Where (x, y) is a point in the contour and (x_r, y_r) is the reference point.

Comparing the distances with those of other neighbor points' on the hand contour in some distances, the fingertips are the points that have the most distances, and the valley points, the least. The result positions of fingertips and valley points are marked as circles and shown in Fig. 4.

The extracted features used in our research are the lengths of each finger, the widths of each finger at 3 locations and the width of the palm. This results in 21 features all together. These features can be found as follows.

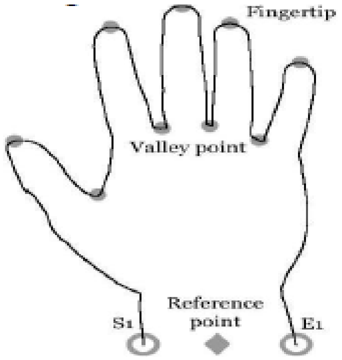

Fig.5: Fingertips and valley points of a hand.

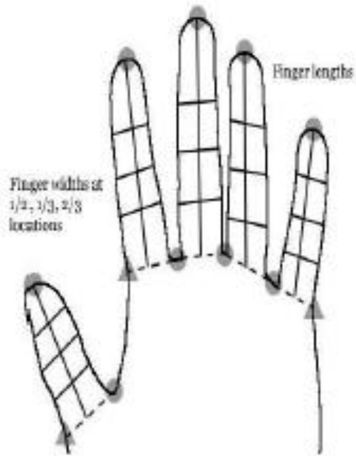

Fig.6: Definitions of finger lengths and widths.

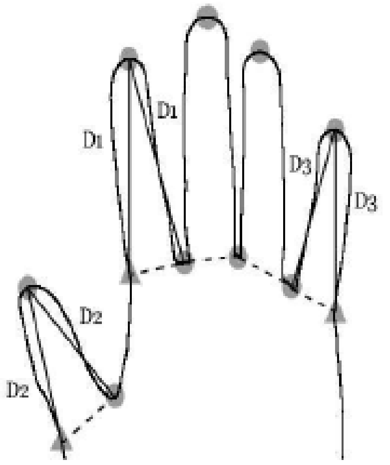

Fig.7: Definitions of finger baselines.

B. 1 Finger Baselines

The finger baselines of a middle finger and a ring finger are obtained by connecting the valley points which are on both sides of that particular finger. However, for a thumb, an index and a little finger; each has only one adjacent valley point. Thus, in our research, the other valley points are assumed to be on the opposite side of the finger with the same distance from the fingertip to the existing valley point. For example, the located valley point of an index is on the right of the index contour with a distance D1 from the index fingertip as shown in Fig 5.

Therefore, the assumed other valley point of the index must be D1 distance on the left of the index contour as well. All valley points are located and shown in Fig. 5. Baselines are the lines connected between two valley points, also shown in Fig. 5 as dashed lines.

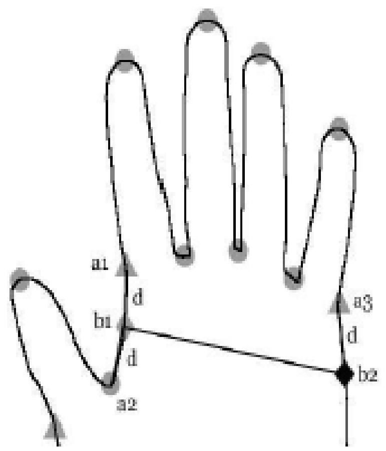

Fig.8: Definitions of a palm width.

B.2 Finger Lengths

The "finger lengths" are obtained by measuring the distances from the fingertips to the middle points of the finger baselines. These finger lengths are shown in Fig. 6.

B.3 Finger Widths

In this research, the "finger widths" are the widths of a finger measured at 3 locations as shown in Fig.6. The first one is measured at the middle of the finger length, the second one, at the one-third, and the last one, at the two-third of the finger length. All the finger widths are shown in Fig. 6.

B.4 Palm Width

The "palm width" is the distance from b1 to b2 in database. The matching process can be divided into two types based on the application. They are verification and identification. Distance functions are utilized in the matching process to help differentiate the authorized and unauthorized persons. More details of this process are described in this section.

III. PERSONAL VERIFICATION AND IDENTIFICATION

A biometric system is like other authentication systems in that an authorized user has to register oneself to the system before verification or identification can be accomplished. The extracted bio data of the registered person is stored as a template in a database. In order to authorize an individual, the system matches the claimer's bio data with the template(s) in the database.

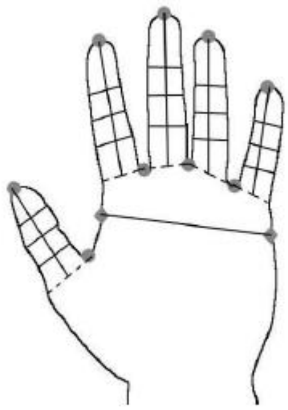

Fig.9: Hand geometry features

The matching process can be divided into two types based on the application. They are verification and identification. Distance functions are utilized in the matching process to help differentiate the authorized and unauthorized persons. More details of this process are described in this section.

B.1 Verification and Identification

For a verification system, an individual claims as one of the authorized users previously registered to the system. The system confirms or denies the claimer by matching the individual's extracted data with those of the claimed person which is stored in a database. Therefore, a verification system does a one-to-one matching process. For an identification system, the claimer's extracted data are matched with those of all registered persons. The system then establishes or recognizes the identity of the individual. Identification is therefore a one-to-many matching process.

B.2 Distance Functions

As mentioned earlier, a personal verification system and an identification system compare the claimer's bio data with the templates in the database. Distance functions are used to decide whether the claimer is the claimed person or as whom the claimer is recognized. In this research, 6 distance functions are experimented as follows

1. Distance Function -I

$$D_I = \sum_{k=1}^{n} \left| u_k - d_k \right| \quad (1)$$

2. Distance Function-II

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$$D_{II} = \sqrt{\sum_{k=1}^{n} (u_k - d_k)^2} \quad (2)$$

3. Distance Function-III

$$D_{III} = \sum_{k=1}^{n} \frac{|u_k - d_k|}{u_k + d_k} \quad (3)$$

4. Distance Function-IV

$$D_{IV} \frac{1}{n} \sum_{k=1}^{n} \frac{\min(u_k, d_k)}{\max(u_k, d_k)} \quad (4)$$

where $U = \{u_1, u_2, u_3, \ldots, u_n\}$ is the feature vector of an unknown individual or a claimer, and $D = \{d_1, d_2, d_3, \ldots, d_n\}$ is the database vector.

Including the variances of the database vectors, two additional functions are also examined as follows:

5. Distance Function-V

$$D_v = \sum \frac{|u_k - d_k|}{v_k} \quad (5)$$

6. Distance Function-VI

$$D_{VI} = \sqrt{\sum \frac{(u_k - d_k)^2}{v_k^2}} \quad (6)$$

Where $V = \{v_1, v_2, v_3, \ldots, v_n\}$ is the variance vector having the entries of the variances of each features in the database vector. To measure the similarity and find the best match, a statistical method correlation is also used. Correlation is an effective technique for image recognition. This method measures the correlation coefficient between a number of known vectors with the same size unknown vectors with the highest correlation coefficient between the vectors producing the best match. There are two forms of correlations: autocorrelation and cross correlation. Auto-correlation function (ACF) involves only one vector and provides information about the structure of the vector or the data. Cross correlation function (CCF) is a measure of the similarities or shared properties between two vectors. Since there are two vectors as unknown input feature vector and known database vector in this study, cross-correlation is used. In the simplest form, the correlation between $f(x, y)$ and $w(x, y)$ is as the following:

$$c(x, y) = \sum_s \sum_t f(s,t) w(x+s, y+t) \quad (7)$$

IV. EXPERIMENTS AND RESULTS

In our research, we divide the tests into 2 operation modes, a verification mode and an identification mode. Six different distance functions, as shown in section 3.2, are used in the feature matching process. The data used in the experiments are described in section 4.1 and the experiments and results of a verification mode and an identification mode are illustrated in sections 4.2 and 4.3 respectively.

A. Data Used in Our Experiments

There are 96 test users in our experiments. Ten left-hand images are acquired from each user. These images are divided into 2 groups. The first group consists of the images of all 96 users, 5 images from each user. They are used for the enrolment process to define the users' templates, or feature vectors. The features are extracted as mentioned earlier in section 2.2. Five hand images from each user are used for forming the database feature vectors. The average values of each feature are kept as the database vectors, and also the variances of each extracted features are registered for recognition purposes. The other hand images are used for testing the performance of the proposed algorithm. The algorithm has been tested on both identification and verification tasks.

In identification, an unknown individual feature vector is matched with all the vectors registered in the database and the algorithm determines or makes a decision that the claimer is one of the registered users or not and the system identifies the claimer. The performance of the algorithm is evaluated by the system's percent error or by the correct identification rate. The algorithm used six distance functions and correlation function defined on the recognition section for matching the claimer vector with the vectors on the database. The results for identification task are given in Table-1.

TABLE-I Identification Performance Test Results

Matching Algorithm	Identification Rate
Distance-I	% 94.68
Distance-II	% 93.94
Distance-III	% 92.02
Distance-IV	% 94.04
Distance-V	% 56.64
Distance-VI	% 55.15
Correlation	% 91.71

Table-I shows that the matching algorithm using the Distance-IV function and the algorithm using the correlation have better correct identification rates. If these two functions can be combined with their weights, this new function can give better result. The performance of this matching algorithm is %97.44.

B. Experiments and Results from Verification Mode

In verification, the process involves matching a given hand to a person previously enrolled in the database. The claimer feature vector is then compared with the feature vector stored in the database associated with the claimed identity and the system decides that the claimer is right or not. Verification performance is measured from the two types of errors; False Rejection Rate (FRR) and False Acceptance Rate (FAR). FRR is the measure of the likelihood that the system will incorrectly reject a claimer. A system's FRR simply is stated as the ratio of the number of false rejections divided by the number of verification attempts. FAR is the measure of the likelihood that the system will incorrectly accept a claimer. FAR is stated as the ratio of the number of false acceptances divided by the number of verification attempts. The optimal performance of the system is obtained when the FRR equals FAR. If the threshold that the system decides according to is selected as FRR is equal to FAR, then the system's correct verification rate is obtained. The proposed algorithm was tested with eight matching algorithms. The results are summarized in Table-2.

TABLE-II Verification Performance Test Results

Matching Algorithm	Verification Error
Distance-I	% 97.23
Distance-II	% 96.06
Distance-III	% 95.88
Distance-IV	% 97.07
Distance-V	% 82.46
Distance-VI	% 71.18
Correlation	% 95.85
Sum of weighted Distance-VI and weighted-correlation	% 98.72

$$FRR = \frac{\sum_{i=1}^{n} f(x_i)}{N},$$

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$$f(x_i)=\begin{cases}1, D_i\left(F_i, Y_{ci}\right) > T \\ 0, \text{ otherwise}\end{cases} \quad (8)$$

Where Fi is the feature vector of the test image of the ith user. FCi is the feature vector template of the claimed identity that, in this case, the same person as the claimer.T is a predefined threshold. f (xi) is the function that equals one when the distance is higher than the threshold. Dx (Fi, YCi) is the distance measured from matching the feature vector with the template YCi .N is the total number of test claimers' images. In contrast with the FRR, the FAR is obtained by testing the system by matching the extracted features of a claimer with the templates of other registered persons'. In this research, the templates of other registered users' are randomly selected for matching. Distance (Dx) from the matching process is measured and compared with a predefined threshold. In order to make the FAR and FRR comparable, the predefined thresholds used for the processes of finding FRR and FAR must be set equally. The FAR is calculated by equation (9) as follows:

$$FRR=\frac{\sum_{i=1}^{N} f(x_i)}{N},$$

$$f(x_i)=\begin{cases}1, D_i\left(F_i, Y_{ci}\right) > T; i \neq j \\ 0, \text{ otherwise}\end{cases} \quad (9)$$

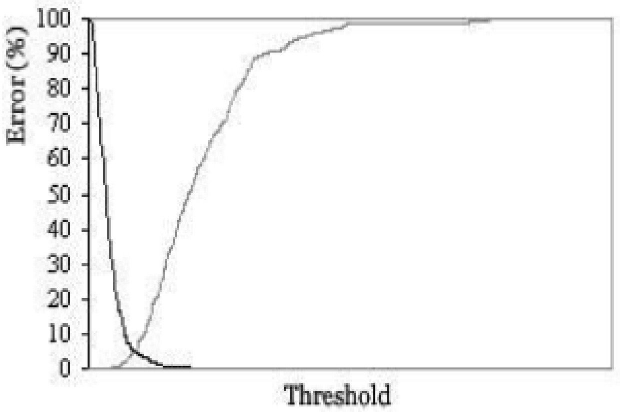

Fig.10: Graph FAR and FRR with vary threshold.

V. CONCLUSIONS

In this study, we presented an algorithm for recognizing the individuals using their hands automatically. We proposed a new thresholding algorithm for separating the hand from the background image. It gave better result. We compared and tested eight different functions for matching algorithm. In identification and verification processes, the weighted-combination of distance-IV and correlation functions yields the best performance. The identification rate for this algorithm is % 97.44 and verification rate is %98.72 giving the least error.

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