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Hand Gestures Expressing Numbers and Its Application to Personal Identification

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Abstract

This paper proposes a personal identification method to express numbers by using hand gestures. A new set of hand patterns has been devised to express each number to decrease the recognition errors and for each user to easily memorize them. The normalized correlation value between a registered grayscale image and an input grayscale image is used for recognizing each hand pattern. Threshold values are used to distinguish each number expressed by each hand pattern. FAR (False Acceptance Rate) and FRR (False Rejection Rate) are defined and calculated by using the experimental data and they can be used to decide a set of threshold values to judge each number and each person at the same time. Registration and identification procedures for personal identification are shown. A prototype for personal identification is implemented and evaluated. The identification scheme using a genetic algorithm is investigated.

1 Introduction

Personal identification is very important in our society. A password for personal identification has the risk that the user forgets it or the other persons use it. Biometric technology that uses human body information can decrease the risk [1]. Hand patterns can be used without the feeling of dislike in comparison with fingerprints, faces, and irises. So far, only one fixed hand pattern has been used for the personal identification using hand patterns [1]. This paper investigates a personal identification method to express each number (i.e., digit 0-9) by using each hand pattern [2], [3]. A prototype for personal identification is constructed and evaluated. The identification scheme using a genetic algorithm [4] is investigated.

(Note: To describe a number expressed by a hand gesture, when 'number' is ambiguous in a sentence, 'digit' or 'digit number' is used for clarification in this paper.)

2 The Expression of Numbers by a Hand

It is possible to consider many sets of finger usages to indicate each number by means of each hand gesture. The requirements are as follows. All numbers (0-9) should be available. Almost every user can easily express all numbers, and learn how to express numbers. The system should be easily implemented. The error rate should be low for personal identification.

Considering these requirements, the usages of fingers are defined as follows. All numbers are expressed by using only one hand, because if both hands are used simultaneously, the CCD camera's photographic range to obtain a hand image will become large. At the time of registration, a user chooses the left hand or the right hand. The easiness to simultaneously extend and / or bend one or more fingers is taken into consideration. The correspondence between each digit number and each total number of one or more extended fingers is also taken into consideration. To reduce the difference of each hand gesture, the extended fingers are attached. When the thumb is not used, it is put on the palm. As for the number of five, the thumb is extended and attached to the index finger, and all of the second joints of remaining fingers are bended. The proposed set of hand gestures to express numbers is shown in Fig. 1.

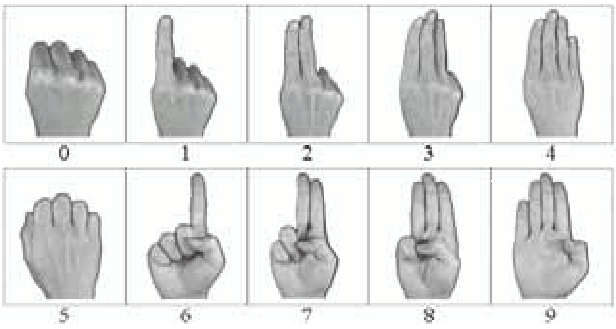


Figure 1. The proposed set of hand gestures.

3 Normalized Correlation for Matching

Normalized correlation values are used to check the similarity degree between a registered grayscale hand image and an input grayscale hand image. Normalized correlation value M is defined as follows.

$$M = \frac{\sum_{i,j}\left[\left(f_{ij} - f_m\right)\left(g_{ij} - g_m\right)\right]}{\sqrt{\sum_{i,j}\left(f_{ij} - f_m\right)^2}\ \sqrt{\sum_{i,j}\left(g_{ij} - g_m\right)^2}} \qquad (1)$$

where f_{ij} is the brightness value of pixel address (i , j) of the registered grayscale hand image, g_{ij} is the brightness value of pixel address (i , j) of the input grayscale hand image, f_m is the average brightness value of the registered grayscale hand image, and g_m is the average brightness value of the input grayscale hand image. When the normalized correlation value between two grayscale hand images is greater than the threshold value, these two grayscale hand images are regarded as the same hand pattern expressing the same digit number of the same person.

4 Evaluation

4.1 Error rates

(1) False rejection error

The false rejection error means that the registered user is falsely determined as a non-registered user and expressed by FRR (False Rejection Rate). The false rejection error of the proposed method occurs in one of the following cases.

(a) The system cannot correctly recognize the hand gesture expressing the number.

(b) The user cannot correctly show each number by using a hand gesture that depends on the person's skill level. It is not difficult for an ordinary person to have a high skill level of hand gestures in a small preparation time.

(c) The user forgets the number. This case should be excluded for the evaluation because the system can regard the user as a non-registered user.

(2) False acceptance error

The false acceptance error means that the system falsely determines a non-registered user as a registered user and expressed by FAR (False Acceptance Rate). The false acceptance error of the proposed method occurs only when the other person knows the correct number, shows the number by using hand gestures and the person's individuality data of the hand gesture is very similar to the registered user. It is very difficult to satisfy these conditions at the same time. Therefore, the FAR of the proposed method will become lower in comparison with that of other biometric methods such as a fingerprint.

(3) How to decrease the error rates

In order to decrease the values of error rates, the system should correctly determine the number shown by the hand gesture and extract correctly the individuality from the hand gesture. These depend on the image processing of the system. The user should correctly show each hand gesture.

(4) Experimental results

We have obtained multiple hand patterns from five persons. Each person show 10 digit numbers, and 5 patterns for each number by hand gestures. Therefore, there are 250 hand gesture images. These hand patterns are used for input images and registered images to obtain the error characteristics of the proposed method. Figure 2 shows the relationship between the threshold values and the FAR (False Acceptance Rate) to decide the number and the identity by using hand gestures expressing numbers. Figure 3 shows the relationship between the threshold values and the FRR (False Rejection Rate) to decide the number and the identity by using hand gestures expressing numbers. The numbers in Fig. 2 and Fig. 3 indicates each digit number expressed by each hand gesture. By using the data of Fig. 2 and Fig. 3, we obtain Table 1 and Table 2. Table 1 shows FRR and threshold values when FAR = 0. Table 2 shows the threshold values when FAR = FRR.

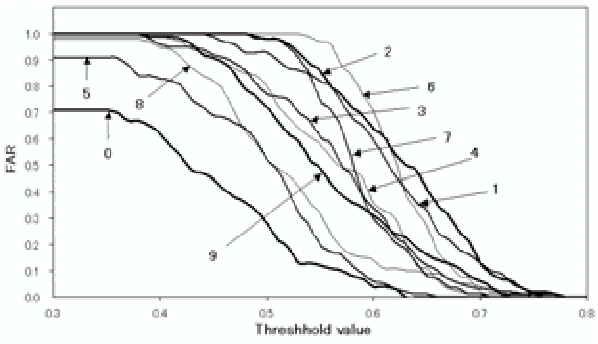


Figure 2. FAR versus threshold values.

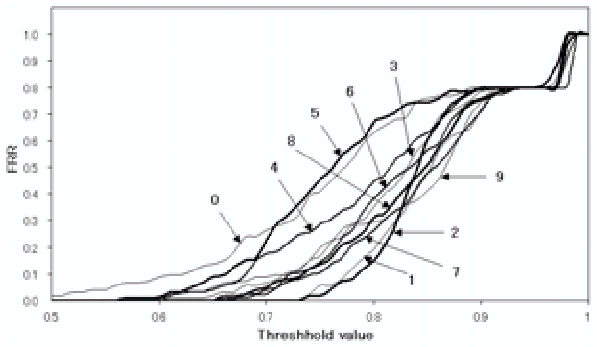


Figure 3. FRR versus threshold values.

Table 1. FRR and threshold values when FAR = 0.

Numbers expressed by each hand gesture.	FRR when FAR = 0.	Threshold values.
0	0.112	0.63
1	0.056	0.76
2	0.080	0.78
3	0.080	0.71
4	0.288	0.75
5	0.096	0.66
6	0.104	0.73
7	0.136	0.76
8	0.088	0.73
9	0.280	0.78
Average value	0.132	0.73

Table 2. Threshold values when FAR = FRR.

Numbers expressed by each hand gesture.	FAR and FRR.	Threshold values.
0	0.0815	0.56
1	0.0260	0.74
2	0.0355	0.77
3	0.0395	0.68
4	0.0525	0.67
5	0.0360	0.62
6	0.0385	0.70
7	0.0590	0.66
8	0.0445	0.70
9	0.0875	0.69
Average value.	0.0501	0.68

4.2 Matching time

The matching process needs the coordinate transformation such as the image position (horizontal, vertical, and rotational movements) and the image size (expansion or shrinking) to find the maximum normalized correlation value between two grayscale hand images. The software matching time between two hand images is about 0.17 seconds when the clock time of the CPU of the personal computer is 1.8Ghz. This matching time is small enough for practical applications

5 Personal Identification

5.1 Procedures for personal identification

The procedures for personal identification consist of the registration and identification procedures. At first, a user registers the personal identification data to the system by means of the registration procedure. Hereafter, the user can be identified by means of the identification procedure. When one digit of identification number is used (it is easily possible to extend the procedures that uses more than one digits of the user number), the procedures are described as follows.

Registration procedure:

Step R1: The administrator of the system inputs the user ID (identification) number with more than one digit by using the keyboard.

Step R2: The user shows a hand gesture expressing the last digit of the user ID number, and the CCD camera of the system captures the hand image. The system sets the file name of the hand image as the user ID number.

Step R3: The system moves the hand image file with the ID number as the file name to the folder with the folder name that is equal to the last digit of the ID number.

(Therefore, there are ten folders and each folder name is one of ten digits (0-9)).

Identification procedure:

Step P1: The user shows a hand gesture expressing the last digit of the user ID number, and the CCD camera of the system captures the hand image.

Step P2: The system judges the digit number expressed by the input hand image by comparing each standard hand image expressing each digit number (from 0 to 9) to the input hand image. (In this step, only the digit number is decided and the individuality is not judged.)

Step P3: The system compares the input hand image to each hand image in the folder indicated by the number expressed by the digit number of the input hand image. When a registered hand image in the folder is coincided with the input hand image, the system obtains the ID number of the input hand image from the file name of the registered hand image. (In this step, both of the digit number and the individuality are judged.)

5.2 Prototype

We have constructed a prototype for personal identification. The prototype consists of a personal computer, a CCD camera, the image input board, and the personal identification software to implement the proposed method. The prototype system can check a person by using a hand gesture that represents one of the digits of the user ID. Figure 4 shows the prototype.

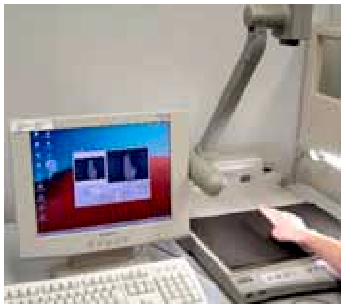
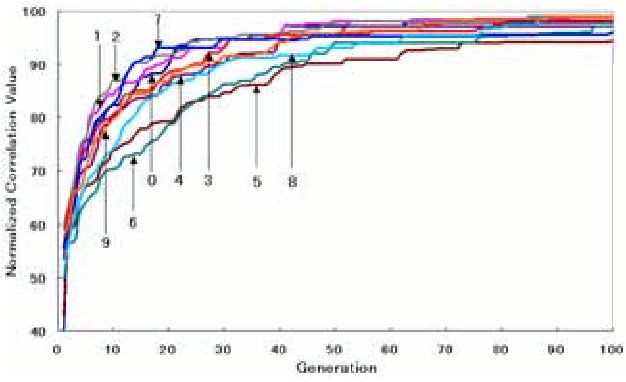


Figure 4. The prototype to identify a person by using a hand gesture.

5.3 Identification with using a genetic algorithm

Let us investigate how to use a genetic algorithm (GA) for judging both of the digit number and the person expressed by the input hand image. Each individual of GA corresponds to each hand pattern. Each chromosome that corresponds to each individual is a set of bits that includes each name of a person, each digit number of a hand pattern of the person, and each identifier of the hand pattern. A person can store one or more registered hand patterns for each digit number of the person. The population of GA that corresponds to the selected registered images consists of individuals. When a chromosome is obtained, we can calculate the fitness value (i.e., the normalized correlation value) between the input hand image and the individual with the chromosome. To produce a new generation for the population of GA, such techniques as the crossover, the mutation and the roulette selection are used for each population of GA.

Let us suppose a population consists of 5 individuals. The registered hand images for experiments consist of 250 images that are obtained from 5 persons, 10 digit numbers for each person and 5 hand patterns for each digit number. Figure 5 shows an example of the average normalized correlation value between the registered hand image and the input hand image, versus each generation of GA. According to Fig. 5, we need about 80 generations to obtain the converged normalized correlation value.



Note: The numbers in the figure indicate each digit expressed by each hand gesture.

Figure 5. The average normalized correlation values versus the generations of GA.

When GA is used in the identification procedure, the input hand gesture image is directly compared to the registered hand image specified by the population that was selected from all of the registered hand images. Therefore, the standard hand images for judging each digit number to specify a folder with a digit number are not used, and the Step P2 of the identification procedure is not necessary. The identification procedure with using GA is described as follows.

Identification procedure with using GA:

Step GA-P1: The user shows a hand gesture expressing the last digit of the user ID number, and the CCD camera of the system captures the hand image.

Step GA-P2: The system compares the input hand image to each registered hand image in the folders. When a registered hand image in the folder is coincided with the input hand image, the system obtains the ID number of the input hand image from the file name of the registered hand image (or the chromosome of GA). Each threshold value has the same value as before (i.e. when GA is not used).

5.4 Discussions

(1) The identification time without using GA

In the identification procedure without (or with) using GA, the user need not input the user ID number from the keyboard. Let us examine the effect of the proposed method. Let m be the processing time for comparing and judging two hand images. Let N be the total number registered hand images. A user can store one or more registered images for the same digit number expressed by hand gestures to decrease the FRR (False Rejection Rate).

The maximum time for checking one input hand image in the identification procedure without using GA
= [The time for judging the digit number expressed by the input hand image]
+ [The time for finding the best registered hand image in the folder with the digit number expressed by the input hand image]
= 10・[The time for matching two hand images]
+ [The time for matching two hand images]
・[The total number of registered images] / 10
= 10m + m･N/10 = m･(10 + N/10). (2)

The maximum time for checking one input hand image in the identification procedure when the proposed method is not used (i.e., to check all registered images)
= [The time for matching two hand images]
・[The total number of registered hand images]
= m･N. (3)

The ratio of identification times between the schemes
= m･(10+N/10) / (m･N) = 10/N+1/10. (4)

When N is 50, 100, 200, 1000, or infinity, the ratio of identification times between above schemes becomes 0.30, 0.20, 0.15, 0.11, or 0.10 respectively. Therefore, we can remarkably decrease the time for identification by means of the proposed method using hand gestures expressing numbers.

(2) The identification time with using GA

The identification time with using GA is calculated as follows.

The maximum time for checking an input hand image in the identification procedure with using GA
= [The time for matching a set of two hand images]
・[The total number in a set of individuals of GA]
・[The converged generation number of GA]. (5)

The converged generation number depends on the total number of registered images. Since the digit number expressed by hand gestures has the effect to classify hand gesture images in ten categories, the converged generation number decreases in comparison with the case when the digit numbers are not used for hand gestures.

(3) To decrease the error in identification

When two hand gesture images that are originated from two different persons and each has a different digit number, the hand gesture patterns are clearly different. Therefore, the FAR (False Acceptance Rate) decreases by using the digit numbers expressed by hand gestures in comparison with the case when the digit numbers are not used for hand gestures.

To decrease the FAR in the identification procedure without (or with) using GA, it is possible to increase the number of digits expressed by hand gestures for each person (e.g., two or more digits extracted from the user ID number can be used). However, when the total number of digits to input in the identification procedure is increased, the time for identification is increased.

6 Conclusion

A new method for personal identification using hand gestures expressing numbers is proposed. The proposed method has excellent points in comparison with other personal identification methods. In the identification procedure, the user can input the ID number without using a keyboard. The identification time is remarkably decreased in comparison with the conventional case when only one hand pattern that does not expressing a number is used. The identification procedure with using a genetic algorithm is shown. The effectiveness of the genetic algorithm is for further study.

References

[1] J. Chirillo and S. Blaul: “Implementing Biometric Security”, Wiley Publishing Inc. 2003.

[2] T. Kobayashi: “Personal identification using hand information”, *Proceedings of the 2001 Symposium on Cryptography and Information Security*, IEICE, Oiso-machi, Japan, pp.725-726, Jan. 2001 (in Japanese).

[3] T. Kobayashi and K. Sugiyama: “Hand image recognition for code numbers”, *Proceedings of The First International Conference on Information Technology & Applications*, IEEE, Paper No. 225-5, pp.1-6, Australia, Nov. 2002.

[4] K. Terada, H. Tani and S. Oe: “An experiment of eyes from facial image by using genetic algorithms”, *The Transaction of Electrical Engineers in Japan*, Vol. 123, No. 5, pp.938-945, May 2003 (in Japanese).