MVA2000 IAPR Workshop on Machine Vision Applications, Nov. 28–30, 2000, The University of Tokyo, Japan

3—28

A Face Recognition Terminal with Effective Illumination for Access Control Systems

Toshio Sato, Hiroshi Sukegawa, Kentaro Yokoi and Akio Okazaki *
Information and Industrial Systems & Services Company
Toshiba Corporation

Abstract

In this paper, a high-performance face recognition terminal for access control systems is described. The terminal is specially designed to acquire stable face patterns for reliable recognition. To determine design of an image input device, we evaluate similarity values and their changes for three types of lighting apparatuses. Our basic experiment indicates that a combination of the upper-right lamp and the lower lamp accomplishes the best performance. Though an experiment using 100 individuals, we explain that the face recognition terminal achieves a competitive performance compared with other biometrics devices and offers better user-interfaces such as contact-less verification and remote monitoring.

1 Introduction

Biometrics is becoming important to assuring access control systems. Fingerprint verification is one of the major techniques, however, there are some problems for user interfaces. There is a disadvantage of being intrusive [1]; users must touch a sensor device to use fingerprint verification. Further, a fingerprint pattern is difficult to be confirmed by the human vision. To solve these problems, face recognition techniques have been applied to access control systems [2].

Many techniques of face recognition are reported to achieve high performance biometrics [2] [3] [4] [5] [6]. Face-It developed by Visionics Corporation [7], which uses algorithm of Rockefeller University, describes its performance as 0.68% of the equal error rate (EER) [1] that is competitive with fingerprint verification devices.

As it is known that face recognition has a problem to be affected by variation of illumination [8], researchers propose algorithm to eliminate the influence. However, when variation of illumination makes a pattern of a person equal to one of others, it is difficult to discriminate them using any algorithm.

In this paper, we investigate effective lighting to capture facial patterns. Based on the investigation, we design a face recognition terminal with lighting apparatuses for access control systems and evaluate its performance.

The rest of the paper is organized as follows. In Section 2, a basic experiment is described to determine arrangement of lighting apparatuses. We explain the face recognition terminal in Section 3 and its performance in Section 4. In Section 5, we discuss the merits of face recognition and the terminal for access control systems.

2 Influences of illumination

To design a lighting apparatus for face recognition, we evaluate three arrangements of lighting; without lighting, with the upper and the lower lights, and with the right-upper and the lower lights. A lighting apparatus consists of a fluorescent lamp and a diffuser. We change the condition of external illumination switching a ceiling light, and evaluate similarity values for each arrangement using four individuals. The method to calculate similarity values is described in Section 3 and the similarity value of 1000 indicates perfect matching. The dictionary data is captured with the ceiling light.

Table 1 shows average, maximum and minimum similarity values for four individuals with the same individual's dictionary. Without any lighting apparatus, the average similarity value becomes less than 900 under different illumination condition from enrollment (i.e. without the ceiling light).

Using lighting apparatuses, difference of the average similarity against the change of illumination becomes smaller and the maximum similarity value is higher. Compared two arrangements of lighting, a combination of the upper-right and the lower lamps performs better than the upper and the lower lamps.

*Address: 70, Yanagi-cho, Saiwai-ku, Kawasaki, 212-8501 Japan. E-mail: {toshio4.sato, hiroshi1.sukegawa, kentaro.yokoi, akio.okazaki}@toshiba.co.jp

[1]EER is a cross point where the false acceptance rate (FAR) and the false rejection rate (FRR) have a same value.

Table 1: Changes of similarity by illumination. The dictionary data is captured with external lighting

Lighting apparatus	Illumination condition	Average	Min.	Max.
w/o lighting	equivalent to enrollment	937.75	865	972
	different with enrollment	896.00	874	919
upper and lower	equivalent to enrollment	971.75	958	978
	different with enrollment	955.50	933	974
upper-right and lower	equivalent to enrollment	975.00	962	983
	different with enrollment	973.00	961	978

Figure 1: Effects of lamps. Without lamps (left) and using an upper-right lamp and a lower lamp(right).

Figure 1 shows an image captured using the upper-right and the lower lamps. The upper-right lamp makes the right side of a face image with shading and the left side of an image without shading. The right side represents plane face features and the left side represents three-dimensional features of a face. Although, a face pattern is symmetry and includes redundant data, this lighting apparatus makes input images unsymmetrical and significant.

3 Face recognition terminal

3.1 Hardware platform

According to the results obtained in Section 2, we have designed a face recognition terminal. The terminal consists of a video camera, lighting apparatuses, a wireless card reader, a PC, a display device, and a door-control device. The lighting apparatus which consists of a fluorescent lamp and a diffuser, is placed at the upper-right position and at the lower position as shown in Figure 2. Tall walls are also established around the terminal to eliminate external illumination such as ceiling lights. The display device shows the input image to make users stand at the same position.

Wireless memory cards and a reader are associated with the terminal to perform contact-less verification. The terminal receives an ID of wireless memory card and prepare one of the dictionary data for each individual. According to the recognition results, the PC sends a command to the door-control device

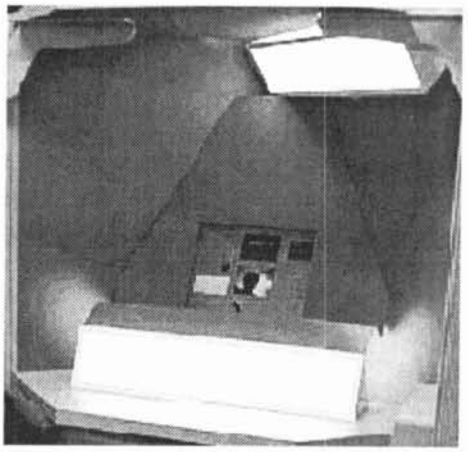

Figure 2: Face recognition terminal

3.2 Face recognition software

The face recognition process is totally implemented by software without using any special hardware. A face area is detected using the subspace method and facial feature points are detected to extract a facial pattern using a separability filter [9]. The separability filter consists of two regions defined by concentric circles and a mask. Although separability filter detects many feature points including pupils, nostrils, mouth edges, and eye blows, four feature points corresponding to pupils and nostrils are selected based on constrains.

The extracted facial pattern is pre-processed to compensate angles and normalized in size of 30 $\times$ 30 pixel. Then, normalization of the gray level and pre-processing to emphasize horizontal lines are applied. The pre-processed pattern includes 15 $\times$ 14 pixels. The extracted patterns are collected among ten sequential video frames to calculate the subspace of input images. The Mutual Subspace Method [6] is applied for calculating a similarity value between subspaces of input images and dictionary data. The subspace consists of the ten-dimensional vector data.

The dictionary data has been captured using the same terminal for each person. While capturing dictionary data, instruction signs are displayed to collect various angles of the face pattern. Using a PC (Pentium III, 500MHz), 5 frames/sec can be cap-

Table 2: Statistical properties of similarity distributions

Illumination condition	Dictionary	Average	Standard deviation
equivalent to enrollment	genuine	974.7	21.497
	impostor	698.3	88.77
with external lighting	genuine	969.0	21.633
	impostor	694.1	88.86

tured and processed for face recognition.

4 Performance of the terminal

We evaluate a performance of the face recognition terminal using 100 individuals. The dictionary data is produced using 100 frames and, in another test process, 50 frames are captured for recognition of each individual. Since the similarity value is calculated for ten frames, 40 similarity values can be obtains for 100 frames. If feature points cannot be detected in a frame, the frame is not used for calculation and the number of similarity values decreases. The maximum similarity value is selected for the output data of a entry.

Figure 3 shows FAR and FRR curves obtained by accumulating the distribution of similarity values for same individual's dictionary and others' dictionaries, respectively. We evaluate two kinds of input data; data captured under the same illumination condition of dictionaries and under the different condition with external lighting such as ceiling lights. The dictionary data is captured without external lighting.

In the same illumination condition of enrollment, a threshold value for the similarity is set 903 to perform 0.1% of FAR and the FRR value is 2.02% at the threshold. In the condition with external lighting, a threshold level for the similarity value is set as 903 to perform 0.1% of FAR and the FRR value is 0%. The EER values of two illumination conditions are 0.9% and 0.05%, respectively.

Although, the EER value of the same illumination as enrollment should be better, two samples of false rejection appear on the lower similarity as a skirt portion of the curve in Figure 3. Excepting this portion, the FRR curve of the same illumination condition is totally better than one of the condition with external lighting. Table 2 explains average and standard deviation values for the distribution of the similarity. The average of FRR distribution for the same condition of enrollment is higher and the standard deviation for the same condition is smaller than ones of the condition with changes of illumination.

The designed lighting apparatus works well to compensate influences of external lighting and achieve stable face recognition. Totally, the face recognition terminal has one of the best performance among face recognition systems and can be introduced into practical access control systems.

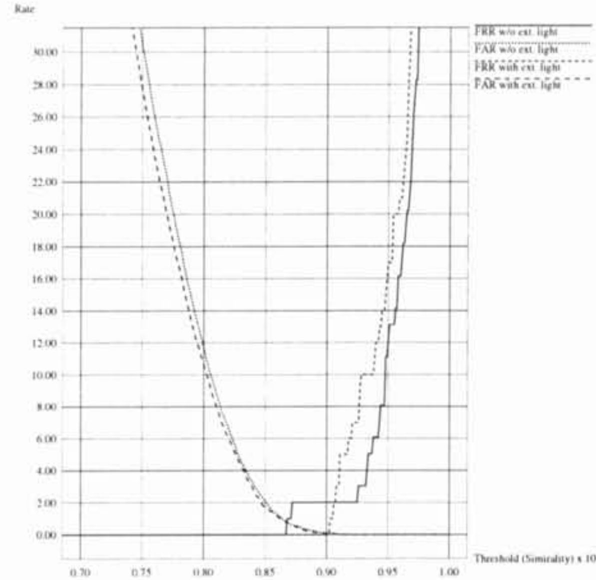

Figure 3: FAR and FRR curves for with and without external lighting.

5 Applications for the access control

5.1 Contact-less and Distributed verification

As considered that most computer system demands an ID and a password for access control, the combination use of ID and biometrics is acceptable for access control of the real world including door control. Since these procedures might frustrate users, a simple operation such as contact-less verification is demanded. As face recognition has an advantage to realize contact-less verification and a wireless card reader is applied to get the ID of an individual, the terminal achieves contact-less 1:1 verification.

As designed to achieve robust facial recognition against changes of illumination, the terminal has can be placed at various kinds of area. In other words, multiple terminals are available for the large security area using the common dictionary data. The

Figure 4: A screen-shot image of remote monitoring. Video monitoring (upper) and face recognition results (lower).

common dictionary data can be distributed to the terminals.

5.2 Remote monitoring

To assure the security control of the large scale area using multiple face recognition terminals, the terminal includes remote monitoring function that supervisors can confirm recognition results from remote PCs. Facial images and related surveillance videos are broadcasted and are viewable as shown in Figure 4.

The monitoring system can also control the doors through the network by the supervisor. Since any biometric method is not perfect, another mean to control users' access is needed. Consequently, remote monitoring has abilities to improve total usability and securities.

Face recognition has an advantage for the human interface. In general, a face is easy to be recognized by the human vision. For instance, people can identify an individual through a image captured by the face recognition terminal. However, using fingerprint images, particular skills are demanded to discriminate individuals by the human vision. Our lighting apparatus makes appropriate facial images not only for face recognition but also for remote monitoring.

6 Conclusions

We have developed a high-performance face recognition terminal with effective illumination. The terminal is designed to acquire stable face patterns against changes of illumination and achieve higher performance for access control systems. Remote monitoring function is also developed to confirm the results by supervisors. The result explains our approach achieves a competitive performance of face recognition compared with other biometrics and offers better user-interfaces such as contact-less verification and remote monitoring.

Acknowledgments

The authors would like to thank Hironori Dobashi, Toshio Hirasawa, and Osamu Kuratomi for providing valuable data and discussions.

References

[1] A. Pentland and T. Choudfury, "Face Recognition for Smart Environments", IEEE Computer, vol.33, no.2, pp.50-55, 2000.

[2] M. Doi, Q. Chen, A. Matani, O. Oshiro, K. Sato, and K. Chihara, "Lock Control System Based on Face Identification", Trans. IEICE, Vol. J80-D-II, No.8, pp.2203-2208, 1997 (In Japanese).

[3] L. Wiskott, J. Fellous, N. Kruger, and C. von der Malsburg, "Face Recognition by Elastic Bunch Graph Matching", IEEE Trans. on PAMI, Vol.19, No.7, pp.775-779, 1997.

[4] P.S. Penev and J. Atick, "Local Feature Analysis: A General Statistical Theory for Object Representation", Network: Computation in Neural Systems, pp.477-500, 1996.

[5] M. Turk and A. Pentland, "Eigenfaces for Recognition", J.Cog.Neurosience, pp103-108, 1991.

[6] O. Yamaguchi, K. Fukui, and K. Maeda, "Face Recognition using Temporal Image Sequence", Proceeding of the Third International Conference on Automatic Face and Gesture Recognition, pp.318-323, 1998.

[7] http://www.visionics.com/

[8] Y. Adini, Y. Moses, and S. Ullman, "Face Recognition: The Problem of Compensating for Changes in Illumination Direction", IEEE Trans. on PAMI, vol. 19, no.2, pp.721-732, 1997.

[9] K. Fukui and O. Yamaguchi, "Facial Feature Point Extraction Method Based on Combination of Shape Extraction and Pattern Matching", Systems and Computers in Japan, vol.29, no.6, pp.49-58, 1998.