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Security Applications of Optical Face Recognition System: Access Control in E-Learning

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The educational system has gradually shifted from a face-to-face to an e-learning system, which has become prevalent in advanced countries with the advance of information technology, and connection of global networks. Accordingly, a growing demand is emerging for more reliable individual certification with technical precision in order to measure and record learning achievements and credentials of participants. The present system has a limit in terms of registration capacity, therefore, its accuracy has often been questioned. Against this background, an individual certification system is proposed particularly for access control in e-learning. Under our proposed system, a compact optical correlator for facial recognition is employed. This correlator was previously tested for of biometrics authentication accuracy and proved highly reliable, having recorded remarkably low error rates (below 1%). The recorded error rate is sufficiently robust that the system itself can be regarded as a valid and practical viable attestation system.

Key words: Compact optical correlator, access control for e-learning, multi-level zone plate array, facial recognition

1. Introduction

Information technology has been dramatically changing society and our lifestyles. Since the 1990s a rapid spread of computers, the Internet and mobile phones has brought us to the "ubiquitous" society we have today. In parallel with this, the educational system has gradually shifted from a face-to-face to an e-learning. According to a survey carried out by Japan's Ministry of Education, Culture, Sports, Science and Technology (March, 1999), the number of credits gained by a student without going to university has greatly increased from a minimum of 30 units to 60. In March 2001, legislation was enacted making remotely provided degrees and classes through the Internet and multimedia official.[1]

Along with this change the security issue is high on the agenda. Access control is vital in order to prevent disguise or forfeiture in attendance and actual learning under this novel situation. In the current system, username and password are most commonly used as personal authentication. Nonetheless this system is quite vulnerable to false identification in the form of deception or simple remembering of those numbers or words.

As an alternative, attention has been paid to biometric applications given its high reliability in systemic terms and its use of distinctive individual physical features.[2] Those characteristics can reduce the aforementioned risks. Moreover, this system has other advantages such as relative facility of image acquisition and data accumulation detectable by the human eye. All this saves unnecessary special devices, making it an attractive and suitable as an attestation system.

The authors' group has sought to apply a self-fabricated optical parallel correlator to meet the demand in the network environment. Through a series of experiments, we have enhanced the optical parallel face recognition system.[3] Moreover, the system is designed to suit the hypothetical practice of centralized control at a university, minimizing the process time through improved performance of the optical parallel correlator.

At Japan Women's University, the project "Research and development of an educational content and delivery system among more than two universities for the next-generation Internet environment" has been undertaken as a five-year plan, first requested by the Telecommunications Advancement Organization of Japan (TAO) in fiscal year 2001. This project has three principal themes, of which access control constitutes one. Our proposed face recognition system is considered to be the key in this security area.[4]

In this paper, we present application of the face recognition system to access control for e-learning. In the next section, the concept of the optical parallel correlation system for facial recognition and its application to access control are described. Section 3 provides the experimental procedure and results. Here, the optical correlator is applied to a more practical e-learning environment using two empirical cases. One tests the performance in inter-university wireless LAN and the other is concerned with mobile Internet with a low resolution camera and compressed images This is followed by the concluding section 4.

2. Design and Fabrication of a Personal Authentication System for Access Control.

2.1 Outline of our proposed system

The e-learning concept proposed in this paper is displayed in Fig. 1. "An inter-University cooperative type transmission system" for the next generation network environment is The distance between our University and Waseda University is 800 m and an optical wireless local area network and 2.4 GHz wireless local area network have been set up on both sites. This paper reports experimental carried with this setup to examine the proposed concept, integrating our original face recognition system into the student management system for e-learning.[4]

Utilization of the attestation system in e-learning is restricted to the following cases:

(a) Taking facial pictures by a computer-attached camera for identification, as students access learning resources from the computers in the classroom at either of the two universities.

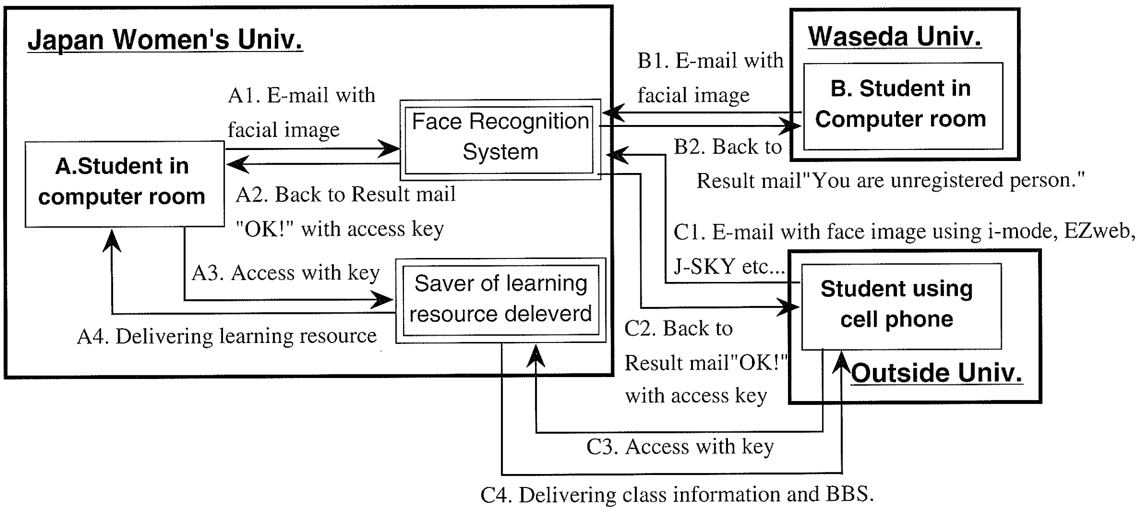

Fig. 1. Concept of e-learning access system.

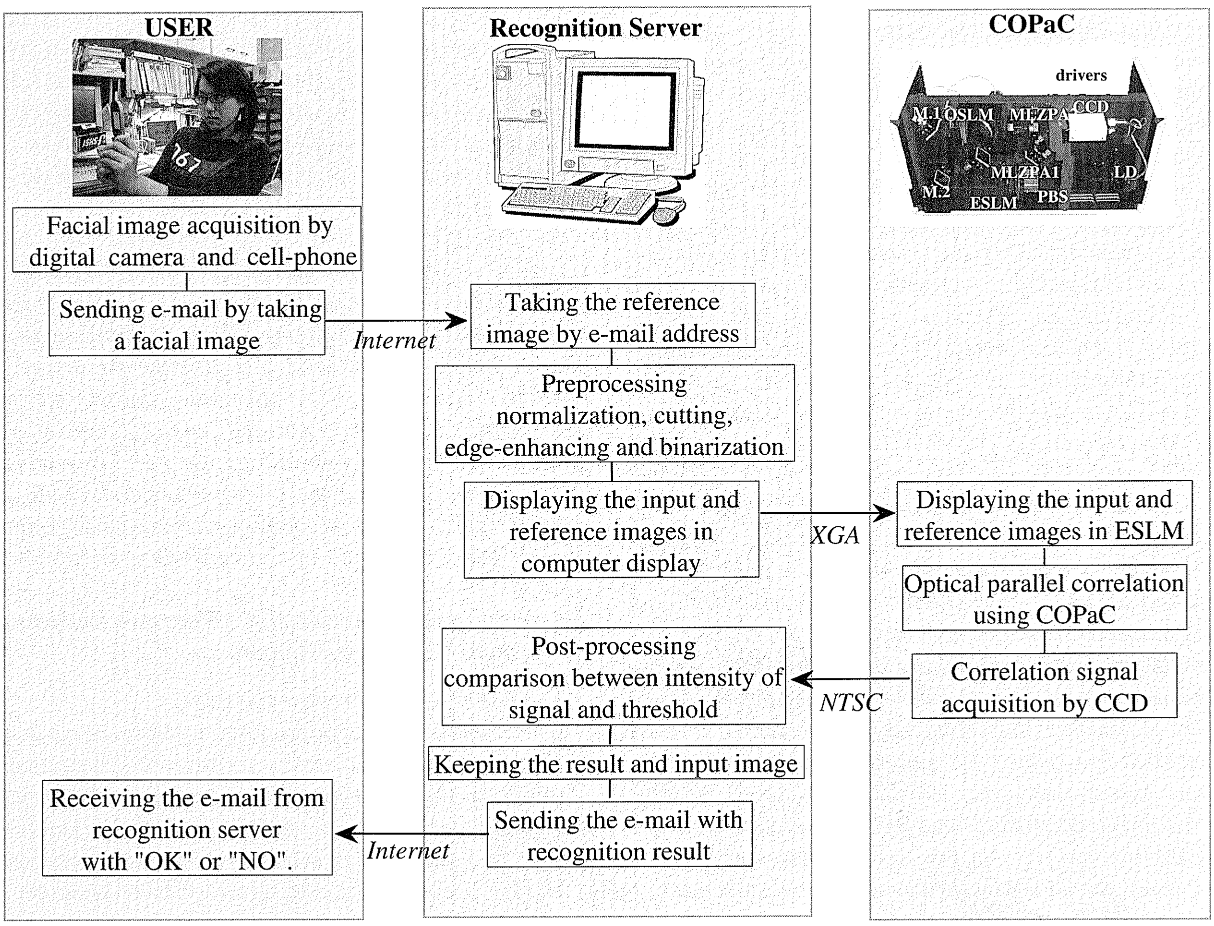

Fig. 2. Algorithm for facial identification using mobile network for e-learning.

(b) Taking facial images by a cellular phone attached camera for identification, as students access the progress of lectures and BBS using the web function of the cellular phone.

Although it is necessary to construct an ad hoc system adjusted to the purposes of respective parties', given the current embryonic stage, the detailed algorithm is primarily concerned with the identification between the authentication servers and user purpose, which is common to both cases. In addition, a verification experiment on robustness was carried out by checking the effects of using wireless local area network and the cellular phone. Figure 2 shows the algorithm for facial identification using a mobile network for e-learning.

As image input devices, digital cameras and portable-attached cameras were selected for their greater utility (i.e. wider circulation and reasonable cost). As image delivery devices, wireless local area network and cellular phones were proposed. Images taken by these cameras were forwarded to the authentication server by e-mail. A person who is logging-in is to be identified by the image in the server's database through the individual's. E-mail addresses are also used as a key to individual identification, as participants were asked to register these when first registering the database with their facial images.

The instant a person enters; the matching process begins in a search for his/her reference image stored in the database. Simultaneously, the input image is pre-processed by edge-extraction and binarization (20%). This pre-processed image is forwarded to a compact optical parallel correlator (COPaC), where a parallel joint transform correlator (PJTC) system is installed and calculates correlation signals in the light intensity. Using this intensity level, it identifies the person based on the threshold value set beforehand. The result returns to the user via E-mail, and access is permitted if the data match. Likewise, it is possible to append and assign questions, task and lecture information.

The difference from conventional attestation systems needs to be addressed. Old systems have not assumed the network environment where facial images are taken by low resolution camera. In this experiment, 640×480 pixels was the minimum size possible, even with a cellular phone attachment camera. However, it automatically becomes 160×120 pixels at the time of forwarding by E-mail due to its compression scheme. Therefore, a low resolution image with little information has yet to be detectable in order to put the system into practice. Furthermore, in wireless local area network, it is necessary to compress images to a maximum of 100 KB. In this case, resolution level was 72 pixels/inch, but the same pixel volume is subject to change depending on the image size. Using wireless local area network, the image size needs to be adjusted according to the average speed of 4 Mbps. To tackle this underlying problem in the network-type face recognition system, the system was further examined for its durability.[5] Therefore, low resolution image with little information is still needed to put the system into practice.

2.2 *Compact optical parallel correlator (COPaC II) and its evaluation*

This chapter features the COPaC II,[6] which is the core of the recognition system. As shown in Fig. 1, this optical recognition correlation has advantages in its compactness, bring $20 \times 24 \times 43\,\mathrm{cm}^3$ in size and 6 kg in weight. Our application of the PJTC principle to the face recognition system is unprecedented in this field, and therefore merits attention and further evaluation.

In our PJTC system, the multi level zone plate arrays (MLZPAs)[7,8] play essential roles: (a) they generate multiple images, and (b) they act as the Fourier-transformers. One of diffractive optical elements, the MLZPA satisfies such requirements as an small aberration, high efficiency, compactness as array structure and flexibility in designing a system of massive parallelism. The system features the MLZPAs and two space light modulators, making the best of the parallelism and high speed of light. The present processing speed is 6.6 face/sec and depending on the function of spatial light modulators (SLMs).

The COPaCII was evaluated by an authorization method designed for this type of general attestation accuracy. A collation experiment conducted on 300 facial images dealt with each one individually. Then, two different kinds of mismatched rates: False Non-Match Rate (FNMR) and False Match Rate (FMR) were calculated and tested. The sample number 300 was determined based on the definition of one of the accuracy evaluation authorities, the National Biometric Test Center (NBTC). The error margin P in the sample number N was given by the following equation, with a reliability of 95% and an error margin $P = 0.01$.

$$N = 3/P \tag{1}$$

The results are shown in Fig. 3. FNMR 0% and FMR 0.3% were obtained at the threshold value of 62 where the lowest error rate of both values was recorded. Moreover, the effects of temperature modulation and mechanical vibration have to be noted. As the main causal factor, heat radiation from the drive circuits such as light sources and CCD cameras was examined. 1:1 collation for experiments of 300 pairs as carried out every there alternate hour for 12 h, and peak error rates were FNMR and FMR: less than 1%.[3]

At the biometric security level that the IPA (Information Technology Promotion Agency, Japan) sets as a desired target, a system with FMR below 1% can be applied to a PC login control.[9,10] This durability test thus demonstrated that the system is sufficiently steady and capable of performing well for access control in educational institutions. Moreover, it is widely believed that the waiting time for connected access in the Internet use is just seven seconds.[11] Given the corresponding time with the database, the attestation speed requires approximately 1 sec in e-learning. Since the processing speed in COPaCII is 6.6 faces/sec, the one-by-one one-by-one modeling of checkpoint control system would provide a sufficiently viable processing speed.

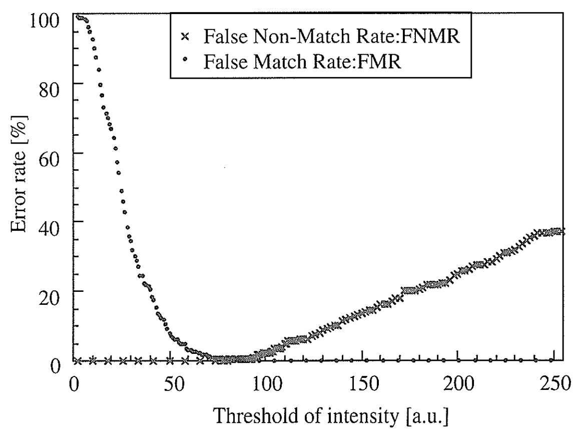

Fig. 3. Evaluation of face recognition system.

3. Application of COPaCII to the E-learning Access Control

Through previous experiments, it has been established that COPaCII is applicable as a stand-alone system. Despite all these merits, further consideration is necessary before it is applied to a network-type mobile environment where photo-shooting conditions are arbitrary and irregular. To meet this target, a higher degree of robustness as an accurate and efficient face recognition system has to be secured. Three particular targets are identified to achieve this goal.

(1) Recognition of images taken by low resolution camera
(2) Recognition of compressed images
(3) Recognition of images taken outdoors

These issue are tackled in the following sections.

3.1 Recognition of images taken by low resolution camera

Figure 4 exhibits recognition of facial images taken by low resolution camera. Setting up 3 different resolution levels (640 × 480, 320 × 240, 160 × 12), correlation experiments were performed using 10 input images against 100 images in the database. The figure shows the experimental results including preprocessed images through normalization, edged-enhancement and binarization of 20%. Figure 5 shows are the correlation values and here the threshold value is set at 0.45. The x-axis shows the image resolution and the y-axis the comparison value [expression (2)]. From these results, the minimum ratio, which is 100% recognition, was accomplished with the exception of 90% with 160 × 120 pixels. These results demonstrate that the low resolution camera attached to a cell phone can function as a face recognition system.

$$C_i = \frac{\left(\sum_{j=1}^{N} P_{ij}/P_{i\max}\right) - 1}{N-1} \tag{2}$$

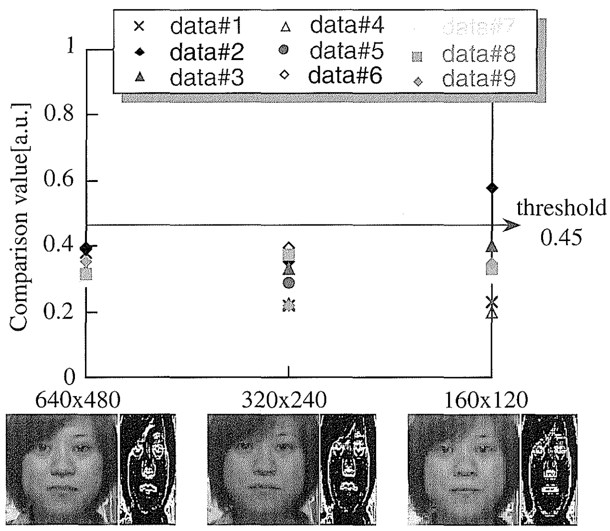

Fig. 4. Effect of camera resolution.

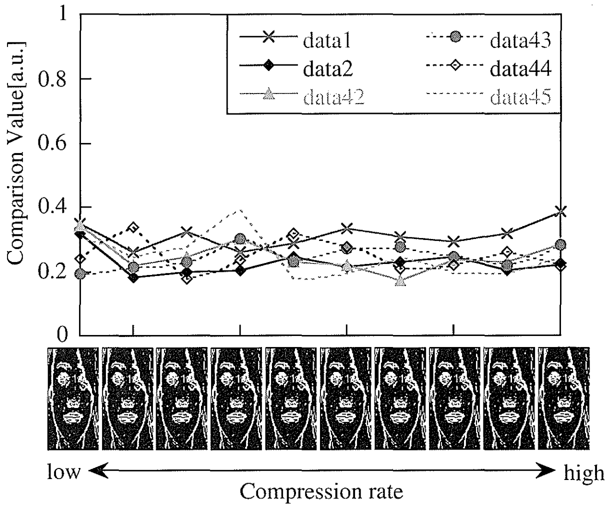

Fig. 5. Effects of image compression rates.

3.2 Effects of compression on image recognition in mobile network

Under the mobile network environment, a large volume of data files must be compressed to proceed through the narrow band provided. The influence of compression rate in mobile telecommunications must be considered.

Photos (640 × 480 pixels) taken by digital camera (*e.g.* Olympus CAMEDIA C-900, 1,310,000 pixels) were compressed in 10 stages down to images of 320 × 240 pixels, with the aid of JPEG and using the Adobe Photoshop. Figure 4 displays the data compression ratio and the relationship of the PSNR (Peak Signal-to-Noise Reconstructed).[12] PSNR denotes the reference level, which is used as the quality of image compression. Thus, the higher the compression ratio becomes, the lower the quality of the image. Input images are all compressed JPEG images of 10 registered persons. The database contains 100 non-compressed images.

Experimental results are shown here. The x-axis is the PSNR, while the y-axis is the comparative value. It is proved that the data size has a negligible effect on face recognition rate despite a high compression rate of 1/20.

3.3 Effects of exogenous conditions (background and illumination)

Influence of illumination (natural or other light) and background settings on the recognition rate deserves careful attention. In front of a complex background, the influence of natural light and backlight generally prevents a clear picture, blurring central parts of the face (i.e., the edges of eyes and nose with a mouth). Figure 6 depicts this case of a complex background where the picture was taken using natural light. As shown, there was no strong influence of recognition rate against this type of background. However, the edge of the picture emphasizes the part of the imagelit by light coming from the background and the back. Therefore, the feature element disappears with the relative decrease in of pixels of the edge parts.

The next stage is to examine the filter of edge extraction.

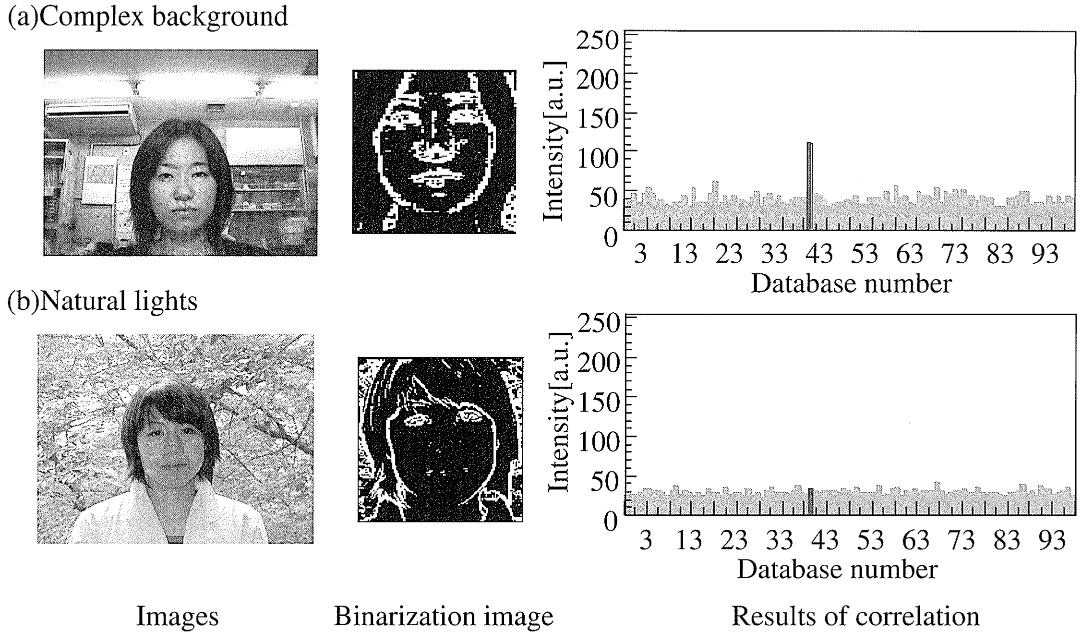

Fig. 6. Effect of complex background and illumination.

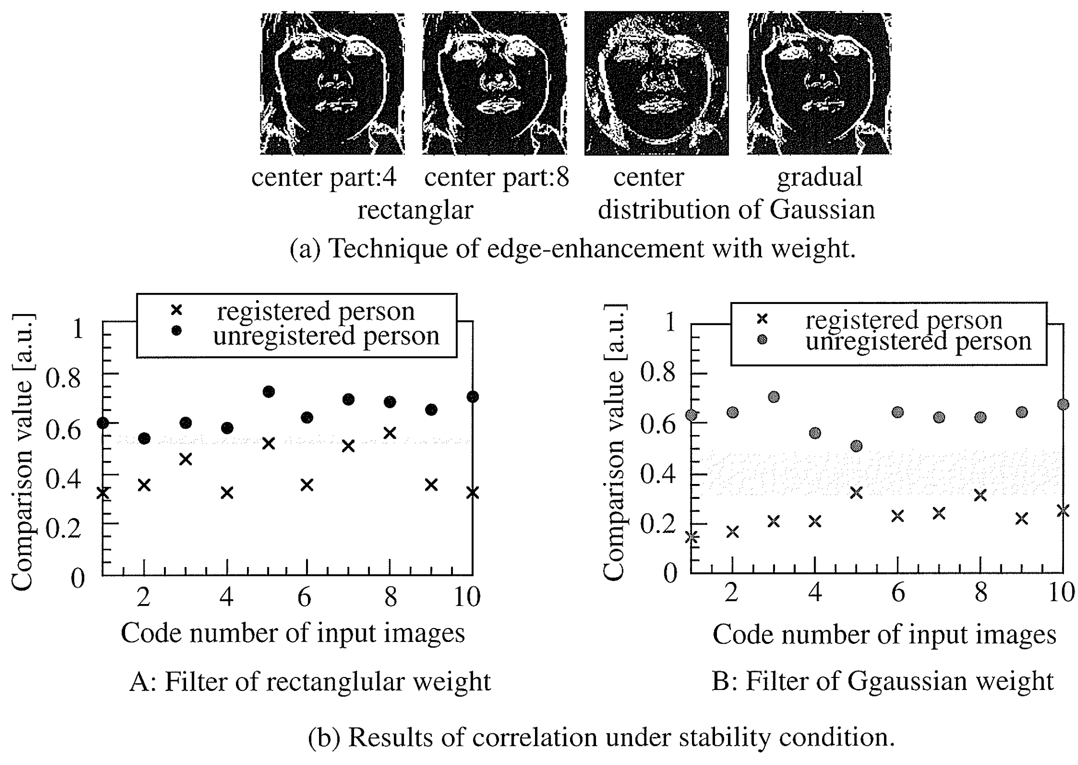

Fig. 7. Improvement of changing illumination.

A nonlinear Sobel filter with the preprocessed weight of 2 was used under a stable and interior illumination condition. To consteracta unstable background, the filter was adjusted to stress the central portions. This process was facilitated by creating a filter of which the weight alters in a to rectanglar or Gaussian shape. Through this enhancement, the feature element of the central part of the face could be extracted. Moreover, the proposed filter should provide an optimal technique not only under this peculiar environment but also under ordinary fixed conditions. Subsequent recognition experiments were thus carried out under a fixed photo-shooting condition (plain background and indirect illumination 300 lx from the first using ten samples. The filter with weight in a Gaussian shape is more effective, as the result in Fig. 7(b) shows. The expression of the filter applied here can be given as (3).

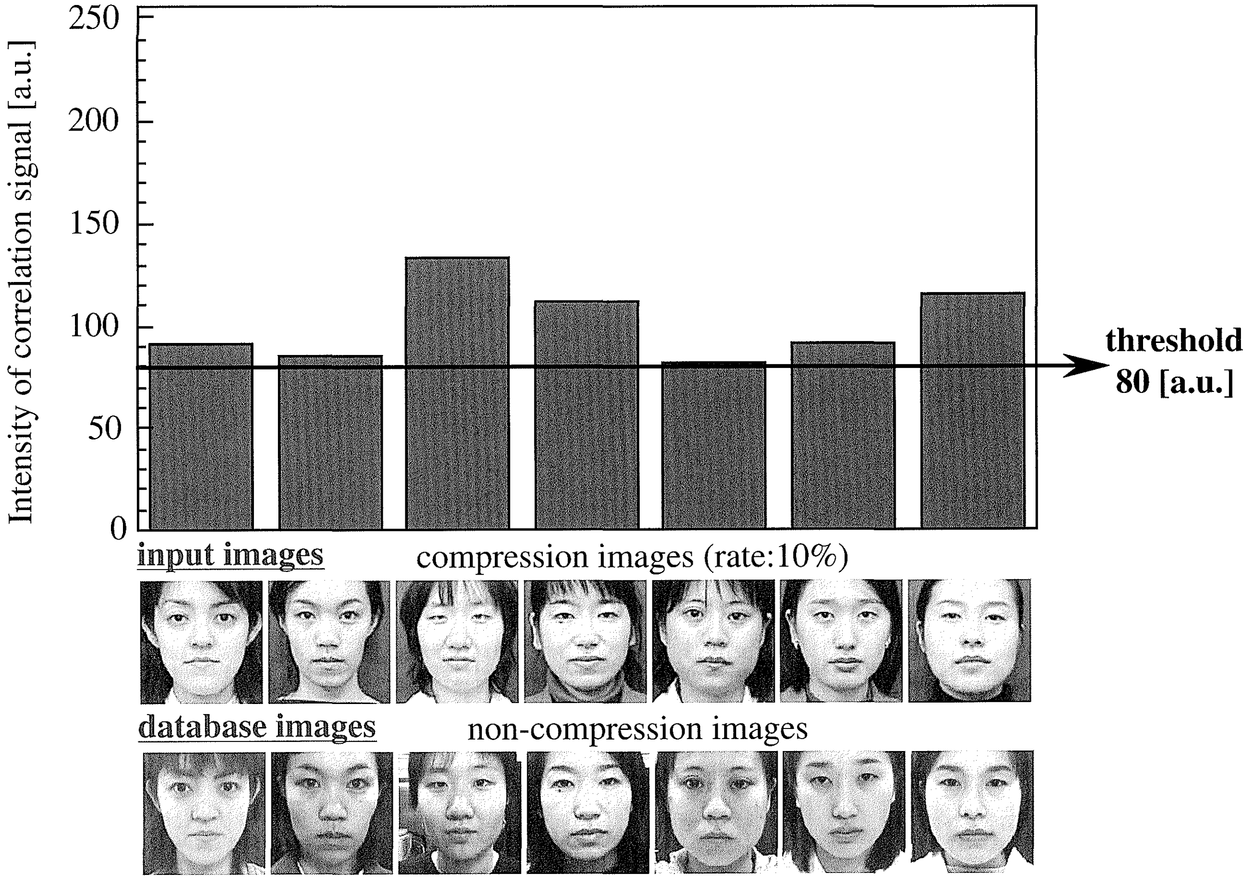

Fig. 8. Result of experiments using wireless LAN.

$$I'(x,y) = \left\{\sqrt{(A)^2 + (B)^2}\right\}4k$$
$$A = -I(x-1,y-1) - 2I(x-1,y) - I(x-1,y+1) + I(x+1,y-1) + 2I(x+1,y) + I(x+1,y+1)$$
$$B = -I(x-1,y-1) + I(x-1,y+1) - 2I(x,y-1) + 2I(x,y+1) - I(x+1,y-1) + I(x+1,y+1)$$
$$k = \exp\left\{-(\{(x-64)(x-64) + (y-64)(y-64)\}/(64)^2)\right\} \quad (3)$$

In this equation, $I(x,y)$ denotes the brightness of image I in coordinates (x,y). $I'(x,y)$ signifies the brightness of edge extraction image I' in coordinates (x,y).

3.4 *Experiments for system application to e-learning*

Using the above results, experiments of two-types on access management in e-learning ware implemented. Two types of experiments were attempted: one tested access from a remote classroom computer and the other access through the cellular phone from one's home.

3.4.1 *Face recognition experiment using wireless local area network*

The distance between two universities Japan Women's University and Waseda University is 800 m, and the optical wireless local area network and 2.4 GHz wireless local area network have been an installed. Identification system and certification server are installed individually on both university campuses. This experiment was carried out in fine weather and was based on the assumption that access was attempted during a remote class at Waseda in search for contents of Japan Women's University. Throughput was 1.7 mbps. Photographs were taken by a camera (resolution 1,310,000 pixels, 900 KB), compressed at Waseda, and the compressed images are transmitted to Japan Women's University through Wireless Local Area Network. A recognition experiment was performed with these transmitted images. Preprocessing of edge-enhancement and binarization was conducted, followed by calculation of correlation signals using COPaCII. One-to-one collation was adopted since this was an access control experiment under the e-learning condition. Figure 8 presents experimental results of the identification using the mobile network. Input images of 7 women are compressed by 10%; in contrast, images in the database are non-compressed images. X-axis of this graph delineates the number assigned to a person, while the y-axis shows the intensity level of correlation signal. Setting the threshold value at 80 (a.u.), under which a False Match Rate is 0%, 100% recognition rate was obtained.

It was demonstrated were that individual identification is possible in the case of high-compressed images by low resolution camera. Thus, our COPaCII system has proves durable in mobile network under an e-learning condition.

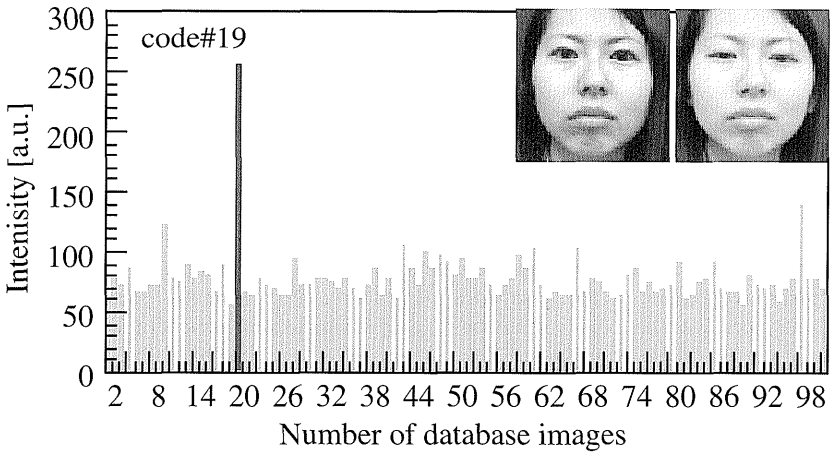

Fig. 9. Result of experiments using cell-phone.

3.4.2 Face recognition experiment using cell-phones from one's home

It has been suggested that a cellular phone with a camera could possibly used for access control. The present resolution level of these cameras ranges from 110,000 to 300,000 pixels, which is supposedly within the tolerance level, although there is some variation in the type of camera: some are CCDs, others CMOS censors. The J-SH51 (serial number, product by SHAPE) was selected, as a cellular-phone attached camera. It is assumed that the owner of this portable takes self-portraits. JPEG compression was automatically made and the email function of a cellular phone is used. An image was transmitted to a recognition server. In this experiment, we used ten persons for consecutively days.

Figure 9 shows the example of code#19. To demonstrate whether or not the system could clearly recognize others, the collation with 100 people was performed. The result confirms that a poorly-sensitivity photo is a picture by the cellular phone-attached camera, It is therefore shown that individual attestation in a mobile environment of both a portable camera and camera-attach pocket cellular-phone is possible.

4. Conclusion

With e-learning becoming a more dominant and popularly used method, an individual recognition system is essential for security together with the enhancement of the whole range of infrastructure and teaching contents. With this in mind, this paper sought to implement on our compact optical correlator system through experiments and evaluations. The system features biometrical identification schemes with reasonable prospects for further applications. Through one-to-one identification experiments using the images of 300 persons' taken in one day, FMR 0.3% and FNMR 0.0% validates the robustness of our COPaC system.

Among a series of challenges of the system between clients and the server are camera resolution, compression rate for transferring images and improving pre-processing filter. Experimental results proved the system's high practicability after it was applied to a mobile e-learning environment between Waseda University and Japan Women's University.

The processing speed in COPaCII of 6.6 faces/sec is also remarkable as the recognition speed in a one-to-open access control system. Under the presumed situation of a centralized control, the speed of about 200 ms is demanded, as deduced from the fact that science classes have 50 students.

We have fabricated an ultra-fast facial recognition system with Vander Lugt matched filtering, which is another well-known optical correlation distinct from PJTC. The system has achieved a 1000 faces/s throughput of 1-channel processing. It is hoped that in future a centralized control system in e-learning will be implemented yielding von better performance.

Acknowledgements

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