Online Face Recognition System through the Internet

Hwangjun Song*, Sun Jae Chung*, Kyoungwon Min† and Hyeok-Koo Jung†
* School of Electronic and Electrical Engineering,
Hongik University, Seoul, Korea 121-791.
† Korea Electronics Technology Institute,
KyungGi-Do, Korea 451-865.
Email: hwangjun@wow.hongik.ac.kr

ABSTRACT

This paper presents an online face recognition system through the Internet. Generally speaking, the amount of transmitted data is related to the time delay over the Internet, and thus the compressed image is transmitted to the remote server to reduce the time delay in this work. First we investigate the relation among the face recognition rate, the compression ratio and image size, and then present the effective multi-frame-based online face recognition system based on the observation. Finally, experimental results tested on the real Internet environment are provided to show the superior performance of the proposed system.

1. INTRODUCTION

The demand of automatic face recognition system has been increasing rapidly for various applications such as security and identification, and it is an active research area in bio-informatics. In general, the face recognition system needs a larger database and high computational complexity. Thus, an online face recognition system under consideration in this work consists of a server and many network-connected clients (i.e. cameras) in this work. It is an efficient architecture of automatic face recognition system. In this scenario, each terminal extracts the features and transmits them to the remote server for the recognition. Generally, the most popular terminal is camera, which captures the image and transmits it through the network. In this case, data compression is required to reduce the amount of data to be transmitted through the Internet. But, compression can degrade the quality of image, which may deteriorate the performance of the face recognition system.

In this paper, we investigate the relation among quality of the compressed image, image size and face recognition rate. Based on the observation, we present an efficient online multiple-frame-based face recognition system and test the performance in the real Internet environment. This paper is organized as follows. Brief review and the proposed online face recognition system are given in section 2, and experimental results are presented in section 3, and finally concluding remarks are described in section 4.

2. THE PROPOSED ONLINE FACE RECOGNITION SYSTEM

Generally speaking, face recognition algorithms can be classified into four approaches, i.e. template matching approach, statistical classification approach, syntactic approach, and neural network approach. So far, elastic matching algorithm of template matching approach and LDA (linear discriminate analysis), PCA (principal component analysis) [1, 2] and KPCA (Kernel-PCA) [3, 4, 5] of statistical classification approach have been widely employed. Since template matching approach generally requires relatively higher computational complexity, statistical approach is widely employed. In PCA and KPCA, eigen-faces are constructed by Karhunen-Loeve transform based on the images stored in database before the matching process. All of them use only a image when face recognition is performed. In this work, KPCA is employed as a component in the proposed algorithm. [6]

The online face recognition system architecture under consideration is shown in Figure 1. It consists of the remote server, database and client, and they are connected through the Internet. In this scenario, client captures several images, detect the fact area in the images, resize and compress the images, and transmit through the Internet. The recognition process is done at server, and then sent back the recognition result to client. One unique feature of the proposed algorithm considers the multiple frames to improve the recognition rate and uses image compression to reduce the time delay over the Internet.

In this work, ORL-DB (40 Classes with 10 images), the widely employed for performance comparison, and our Hong-Ik DB (300 Classes with 14 images) are used in this

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work, and five images for a class are used for training. Pentium-4 1.4GHz 256M-DDRRAM is used as a server.

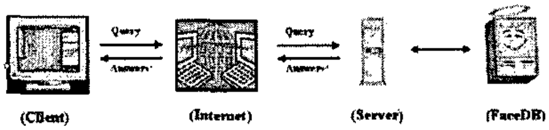


Figure 1. The structure of the proposed online face recognition system

2.1 Face Detection at the Client

Face detection is performed at the remote client to reduce the computational complexity of the remote server, and then the detected face part is compressed by Intel JPEG library To detect the face part, down-sampling is performed to reduce computational complexity and noise. And candidate regions are rapidly extracted after low-pass filtering the image in order to decrease high-frequency component (filtering/resampling). Now compensation technique is needed since the appearance of the skin-tone color depends on the lightning condition (light compensation). To extraction of face region, the corrected red, green, and blue color components are then nonlinearly transformed into the YCbCr color space (color space transformation). The skin-tone pixels which are detected using an elliptical skin model in the transformed space are grouped into face candidates (skin color detection). If face candidates have facial features such as eyes, extract face regions [7, 8]. This detection algorithm is employed as our proposed system. It is summarized in Figure 2.

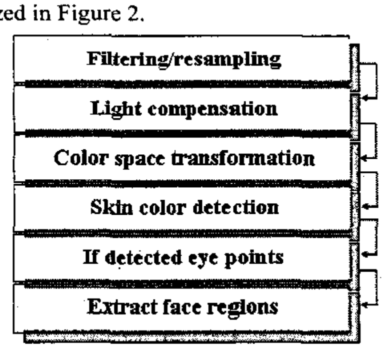


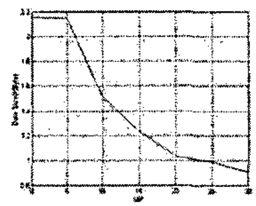
Figure 2.Face Detection algorithm flow-chart

2.2 Relation between KPCA Face Recognition Rate and Quality of Compressed Image

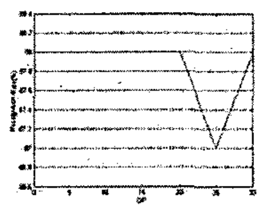
As mentioned earlier, the images are compressed to reduce the transmission delay. Now, we investigate the relation between the KPCA face recognition rate and the quality of compressed images. As shown in Figure 3, the subjective quality of compressed image is degraded and the amount of compressed image data decreases as the quantization parameter becomes larger (see (a) of Figure 4.). However, the face recognition rate is almost independent of the quantization parameter as shown in (b) of Figure 4. Based on this fact, we can significantly reduce the amount of transmitted data without the loss of face recognition rate at the server.

(a) (b) (c) (d) (e) (f)

Figure 3. Visual comparison of compressed image with respect to quantization parameters:
(a) Original image (b) QP=5 (c) QP=10 (d) QP=20 (e) QP=25 (f) QP=30



(a)



(b)

Figure 4. KPCA face recognition rate and ouput data size with respect to quantization parameter: (a) KPCA face recognition rate and (b) output data size. (Test DB is ORL-DB.).

2.3 Relation between KPCA Face Recognition Rate and Image Size

Now, we investigate the relation between the image size and KPCA face recognition rate. The reduced size image is obtained by wavelet-based low pass filtering, i.e. low-low band image is used. Actually, the reduced image size can decrease the computational complexity required for face recognition process at the server. We define the image size and its donation as shown in Table 1 and Figure 5. That is, the image size (S) is denoted by $S_{origin}/4^{(R)}$. And R=0 means that the image is the original image.

	R=0	R=1	R=2	R=3	R=4
Image Size(S)	96x112	48x56	24x27	12x14	6x12

Table 1. Definition of image size.

(a) (b) (c) (d) (e)

Figure 5. Face Image of Reduction :
(a)R=0(Origin image), (b)R=1, (c)=2, (d)R=3, (e)R=4

The relation between the image size and KPCA face recognition rate is summarized in Figure 6. As shown in (a) and (b) of the figure, the required database training time and the time required for the face recognition process are exponentially decreased as the image size becomes smaller (The following time includes the JPEG decoding time.). However, the face recognition rate decreases slightly according to the image size as shown in (c) of Figure 6.

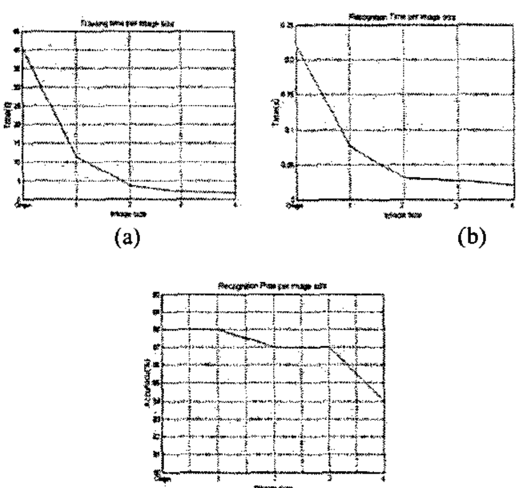


Figure 6. Recognition rate and processing time with respect to Image size and QP (Test DB is ORL-DB.): Training processing time, (b) Recognition processing time, and (c) Recognition rate.

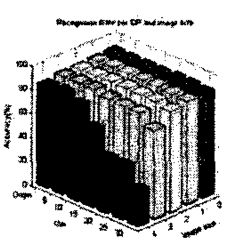


Figure 7. Recognition rate with respect to image sizes and quantization parameters.

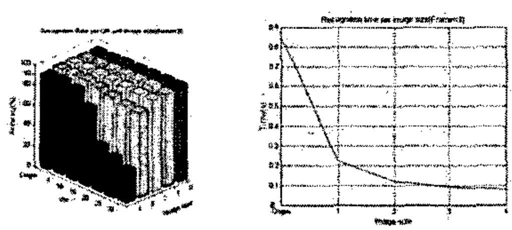
The recognition rate in terms of image sizes and quantization parameters is summarized in Figure 7. As shown in the figure, the recognition rate is almost same in some region and decrease rapidly outside the region. Based on this fact, we can determine the optimal image size and quantization parameter with respect to the recognition rate and the amount of data.

2.4 Face Recognition Rate and Computational Complexity When Multiple Images are Available

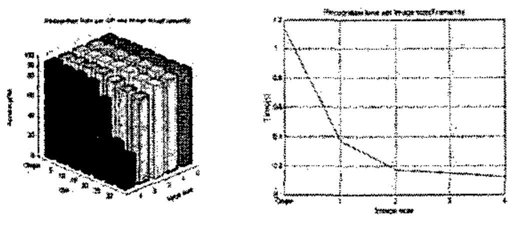
So far, we investigated the face recognition rate in terms of image size and quantization parameter, and found that the face recognition rate stays almost constant in some region. Now, we propose a face recognition algorithm using multiple frames to improve the recognition rate while existing algorithms use only a frame. That is, the recognition rate can be significantly improved by the majority-making-decision rule when multiple frames are available, i.e. if more than the half of received images correspond to an image of the database at the server, then we decide that the image is a correct one. Then, the theoretical face recognition rate is calculated as follows.

$$P_{recog} = \sum_{k=\lceil n/2 \rceil}^{n} \binom{n}{k} p_{kpca}^{k} (1 - p_{kpca})^{n-k}$$

where n is the number of the received images, p_{kpca} is the average face recognition probability of a image by KPCA, $\binom{n}{k}$ is the number of possible combinations when k elements are selected from n elements, and $\lceil x \rceil$ is the smallest integer number that is greater than x . For example, if p_{kpca} is 0.94, 3 images are transmitted and majority-making-decision-rule is employed, then P_{recog} is about 0.99. In the following, we tested two cases: 3-image case and 5-image case. The experimental data is summarized in Figure 8. The proposed algorithm is compared with the KPCA. The recognition rate and the required computing time are used as performance measures. They mean that the recognition rate is significantly increased with a lower computational complexity and time delay.



(a) (b)



(c) (d)

Figure 8. Recognition rate and processing time with respect to Image size and QP: (a) recognition rate when the number of frames is 3, (b) processing time when the number of frames is 3, (c) recognition rate when the number of frames is 5, and (d) processing time when the number of frames is 5.

Based on the observation, we select the optimal parameters and implemented online face recognition system with the parameters: image size is set to R=3, QP is 10, and the number of images is 5.

3. IMPLEMENTATION OF ONLINE FACE RECOGNITION SYSTEM

The architecture of the implemented system is shown in Figure 9. During the experiment, our Hongik-DB2001 (300 Classes with 14 images) is employed.

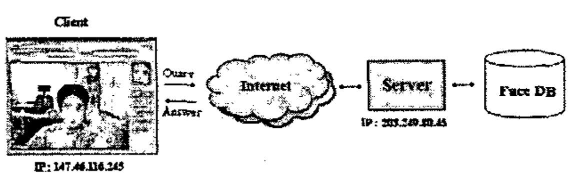
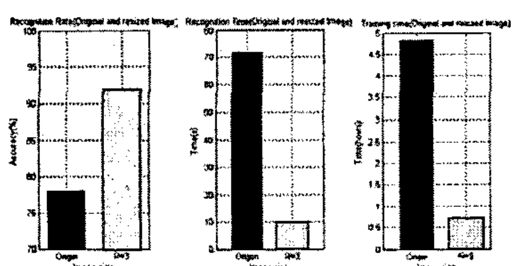


Figure9. The architecture of proposed system



(a) (b) (c)

Figure 10. Performance comparison between KPCA and the proposed algorithm: (a) Recognition rate, (b) Recognition time, and (c) Training time in terms of original image and the selected parameters.

When the experiment is preformed in real Internet environment as shown in Figure 9, the results are summarized in Figure 10. The (a) of Figure 10 shows recognition rate, (b) represents the required time for the recognition at the server, and (c) is the training time. Since the amount of data is reduced, the transmission time delay over the Internet is also decreased (But it is time varying according to network condition.). The recognition rate is improved by more than 14 % and the required recognition time is decreased by about 86 %. Furthermore, the training time is also significantly reduced since the image size becomes smaller.

4. CONCLUSION

We have presented an online face recognition system through the Internet. One unique feature of the proposed system is based on multiple frames while existing face algorithms use only an original image. Resizing and compression have been employed to reduce the transmission delay and the processing delay at the server. Based on the various observations, an effective face recognition system has been implemented and showed the superior performance. Although KPCA is used in this paper, the basic idea proposed in this paper can be extended to any face recognition algorithm.

5. REFERENCES

1. Zhujie, Y.L.Yu, "Face Recognition with Eigenfaces," IEEE International Conference on Industrial Technology, pp. 434 -438, Dec. 1994.
2. M.A. Turk , A.P. Pentland, "Eigenfaces for recognition," Journal of cognitive neuroscience, Vo.3, No.1,1991.
3. Y. Zhang, C. Liu, "Face recognition using kernel principal component analysis and genetic algorithms," IEEE Workshop on Neural Networks for Signal Processing, 4-6 Sept. 2002.
4. K.I. Kim, S.H. Park, H.J. Kim, "Kernel Principal Component Analysis for Texture Classification," IEEE Signal Processing Letters, Vol. 8 No. 2, pp. 39 -41, Feb. 2001.
5. M.H. Yang, N. Ahuja, and D. Kriegman, "Face recognition using kernel eigenfaces," IEEE International Conference on Image Processing, Vol. 1, pp. 10-13, Sept. 2000.
6. J. Zhang, Y. Yan, M Lades;"Face Recognition: Eigenface, Elastic Matching, and Neural Nets," Proceeding of the IEEE,85(9),1998,1422~1435
7. R.L. Hsu, M. Abdel-Mottaleb, A.K. Jain.; "Face detection in color images," International Conference on Image Processing, 2001.
8. K. Sobottka, I. Pitas, "Segmentation and tracking of faces in color images," the Second International Conference on Automatic Face and Gesture Recognition, pp. 236 -241 Oct. 1996.