User Authorization Method based on Face Recognition for Auto Network Access in Home Network System

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Abstract

Security is very important under home network environment that provides trustworthy services after personal information authentication. Especially, reliable user authentication technology is needed to provide various tailored smart services for individual users at a home network system. This paper suggests a user authentication technique using long-distance face recognition to provide a safe home network service. For the long distance face recognition test, face images by actual distance from 1m-5m away were obtained directly. Both actual and virtual face images taken by distance were applied to resolve the issue rising from distance change while histogram equalization and MCT were used as a preprocessing to address the illumination change. The test result showed that an LDA-based face recognition algorithm that used histogram equalization as a preprocessing and face images by actual distance for training was found to show the best performance, so it is expected to be applicable for user authorization of home network system.

Keywords: Face Recognition, Auto Network Access, Home Network System

1 Introduction

The smart home network is a human-centered service system where cutting-edge information technologies are connected to many home appliances [15]. Besides, it gives convenience to user authentication with easy management on user information and recommends tailored smart contents for each individual by using authenticated personal information [7]. However, unlike the network environment of private businesses and public agencies, the home network has a vulnerable security system because of use of various wired and wireless network technologies. mixture of middleware and protocol, limited system resources and lack of user awareness on security. Therefore, information security technology that protects user information is essential to distribute the home network technology. One of the information security technologies for the home network is a user authentication technology that works when they log on to the home network [8].

User authentication that can be used under the home network service environment can be largely divided into ID/Password type, public key authentication type and biometrics-based type. The ID/Password type is a typical user authentication method, under which users keep their personal information at the system and use them only with memory. However, a certain level of complexity and periodic changes are required to maintain security. Public key type uses public key pass code technique and allows authentication based on personal key and public key. However, the level of security is dependent on where the personal and public keys are saved. Meanwhile, the biometrics-based type authenticates the users by applying biometrics such as their face or finger prints. Though it is exposed to disadvantage of requiring a high level of user cooperation depending on additional hardware equipment and biometrics, it is

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trustworthy and helps maintain a high security level. Besides, as it uses personal bio-information such as finger prints, iris or face, duplication or theft is difficult and information leak is less likely to happen than other techniques.

As face recognition, in particular, can be executed without contact or cooperation and from a far distance, researches on long distance recognition using faces are undergoing [12][1]. The face recognition technology detects the face that exists among the images input from the camera and verifies the identity. The conventional face recognition methods mainly consist of Elastic Bunch Graph Matching(EBGM) [17] that is based on geometric property, Principal Component Analysis(PCA) [16] or Linear Discriminant Analysis(LDA) [2] where statistic value of all faces is specifically recognized. Unlike the conventional face recognition method that is performed in a fixed distance under cooperative position, it is difficult to ask for cooperative position in the actual home network service environment such as smart robots, surveillances cameras as the distance between the camera and human is variable.

Generally, the face recognition method is highly dependent on the quality of images obtained from the image sensor, so face recognition performance excels in short distance versus long distance. Recently, there are researches on the long distance face recognition technology that uses a high performance zoom camera that produces high quality images even from a far distance [3][14]. However, face recognition that uses an expensive camera is costly for installation and maintenance and its general application is difficult.

In this paper, the research conducted the test by using the method to comprise various training images, preprocessing and face recognition method to develop a long distance face recognition algorithm applicable to user authorization of home network system. Under the actual home network service environment using cameras, the recognition rate declines when the face image was obtained from afar since the distance between the camera and user is not fixed. Therefore, the paper tried to overcome the issue arising from distance change through the method that uses face images by distance for training and the method that standardizes the size of face images. Face images by distance can be obtained from actual distance by the user moving in person and from the virtual distance by fixing a zoom camera in one position. Besides, as the surrounding lights change when the user face is obtained in an actual environment, the paper used histogram equalization and Modified Census Transform(MCT) as a preprocessing to overcome the issue from light change. For the long distance face recognition test, face images by actual distance from 1m-5m away were obtained directly. PCA and LDA were applied to face recognition and Euclidean distance was used as similarity measurement. Likewise, the research suggests long distance face recognition algorithm that is suitable for user authorization system through various tests.

The paper consists of Section 2 that introduces the conventional face recognition algorithm, Section 3 that explains how to analyze face recognition rate by distance and how to obtain face images by distance, Section 4 that analyzes the face recognition rate in various test environments and Section 5 to reach a conclusion finally.

2 Face Representation and Feature Extraction Methods

The face recognition rate change so much depending on external factors such as the variability of the face itself, illumination, background, angle and distance of a camera. The conventional research often removed the surrounding lights [13] or used the face's skin color data [11] to heighten recognition performance. Besides, improved algorithms have been suggested through improvement of face recognition algorithm [9][10]. The paper used histogram equalization and MCT as a preprocessing to reduce the illumination effect among others that influence the face recognition performance. It also used the method to configure the face images by distance for training to reduce the effect from distance change. PCA and

LDA were applied to face recognition to extract overall features of the face and reduce dimension.

2.1 Histogram Equalization

Histogram allows identifying the distribution of intensity value that is important information of images [6]. Histogram sees the intensity value from 0 to 25 as index and accumulates the frequency at the corresponding index table depending on the intensity value of each pixel that makes images. Histogram equalization equalizes the distribution of the image's intensity value. When the distribution is not equal and biased to a side, it goes through redistribution process to create histogram that has even distribution. Histogram equalization has the following equation in general. Here, h_s is the accumulate sum of histogram, n is the number of pixels of an image and I_n is the number of index of intensity value. Using histogram equalization makes dark colors bright and bright colors dark, maintaining appropriate intensity value for whole images, thus reducing the effect from light.

$$HQ = \frac{h_s}{n} * I_n \tag{1}$$

2.2 MCT

The MCT extracts structural features of an image. Therefore, it can extract data from an image while minimizing the effect from brightness change of an image or light [5]. MCT typically uses a 3*3 window and it can be assumed that there is little change in light with this size, and structural features of an image that is irrelevant with the light change can be extracted. MCT can be defined with the equation below.

$$\Gamma(X) = \underset{Y \in N'}{\otimes} \zeta(\bar{I}(X), I(Y)) \tag{2}$$

Where X is the location of pixels of an image and, when 3*3 window with X having the center is referred to as $W(X)$, N' is the set of pixels of $W(X)$ and Y is nine pixels each within this window. $\bar{I}(X)$ is the mean value of the pixels within the window and I(Y) is the brightness value of the pixels within the window. $\zeta()$ is a comparative function. If it is $\bar{I}(X) < I(Y)$, $\zeta(\bar{I}(X), I(Y))$ becomes one (1) while others become zero (0). $\otimes$ is concatenation operator and links nine binary formats of $\zeta()$ function. The binary formats linked are transformed into decimal number before becoming the pixel value of MCT image. Consequently, MCT minimizes the illumination effect while extracting only structural data.

2.3 PCA

PCA is a two-dimensional statistic method that uses the statistical feature of up to distribution and frequently used to effectively reduce the dimension of high-dimensional input data. Having the entire image data, PCA reduces their dimension by projecting them linearly to several axis directions that has large distribution. The method has the effect of maintaining data on input data distribution, load reduction of calculation, noise removal and data compression even if the dimension of the input vector reduces. For example, when it is assumed that the size of a face image $N * M$ and the number of face images in the training set is M, it can be described with one-dimensional vector that has the component of N^2 each. To calculate eigenface, average face of the training set is calculated. After the average face is calculated, the vector is calculated by subtracting the average face from the original image and the computed vector is used to produce covariance matrix, with which M eigenvector(s) and eigenvalue that best show data distribution are calculated. This process is repeated when a new image is entered to calculate weight and face recognition is performed by comparing the weight of images in the database and that of a new image. Even though face recognition using PCA is sensitive to illumination or environment change, various methods that changed the concept of PCA are widely applied.

2.4 LDA

PCA has several limitations due to its nature and the biggest among others is that it is poor at separating objects though it is good at summing up data. Discrimination among objects is important as face recognition is aimed to distinguish objects. Therefore, we need to know whether the face image change occurs due to object change or illumination or facial expression. LDA separates groups of different components and discriminates between the change of face components and change resulting from other factors. LDA is linear transformation that makes the greatest ratio of between-class scatter matrix and within-class scatter matrix and reduces the dimension of a specific vector for data. Between-class scatter matrix S_B and within-class scatter matrix S_W can be shown as follows:

$$S_B = \sum_{i=1}^{c} (\mu_i - \mu)(\mu_i - \mu)^T \tag{3}$$

$$S_W = \sum_{i=1}^{c} \sum_{j=1}^{K_j} (I_j^i - \mu_i)(I_j^i - \mu_i)^T \tag{4}$$

Where C is the number of objects, μ_i is the mean image for each object and μ is the mean image of all images.K_j is the number of the image of object in i sequence. Therefore, W where S_B becomes the maximum and S_W becomes the minimum can be described as below. If eigenvector and eigenvalue calculated from Equation 1 and 2 are applied to Equation 3, optimal eigenvector can be calculated that shows the level of group's discrimination. This process is repeated when a new image is entered to calculate weight and face recognition is performed by comparing the weight of images in the database and that of a new image. LDA is widely used for research related with face recognition as it clearly discriminates the features of each group.

$$W = argmax_w \left| \frac{W^T S_B W}{W^T S_W W} \right| \tag{5}$$

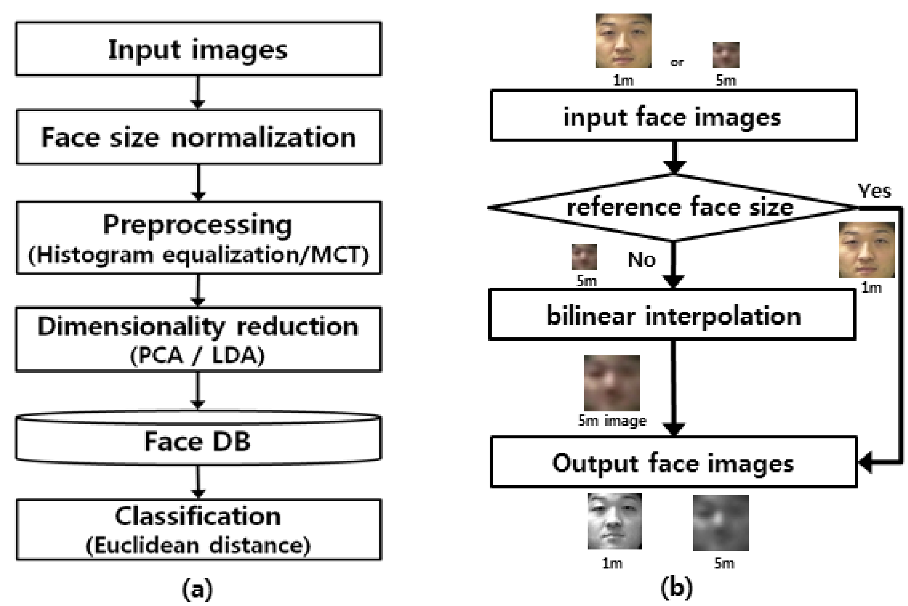

Figure 1: The block diagram of the face recognition and face size normalization process for long distance face recognition (a) Face recognition (b) face size normalization

3 Multiple Training Image and Face Recognition Algorithm

3.1 Face Recognition Algorithm

Figure 1 shows the face recognition test process and face image size normalization process. Figure 1(a) is the face recognition test process where face images extracted by distance from 1m-5m away are used. The input face image is standardized through interpolation and histogram equalization or MCT is applied as a preprocessing that is robust to illumination change. Face recognition uses PCA or LDA to extract overall features of face and reduce dimension. The extracted feature data are saved at DB and used for face recognition by Euclidean distance similarity measurement. As face recognition method based on outlook like PCA or LDA has the problem of small sample for within-class scatter matrix, face recognition cannot be applied when the size of a training image sample is bigger or smaller than that of test image sample. In other words, face images extracted from various distances can have different face image sample dimensions depending on the distance. To resolve the issue, the paper uses the face size normalization as shown at Figure 1(b). The process of face image standardization per distance is as below. When face images per by distance of various sizes are input, the input images are scaled to fit the reference face size of face images used for training. If the reference size used for training has 1m as its standard, the size of reference face image is 70*70. When the size of input face image is 70*70, equalization comes next and when it is smaller or bigger than 70*70, it is scaled to 70*70 through bilinear interpolation. All face images entered through the process are standardized to 70*70 that is the current reference face size.

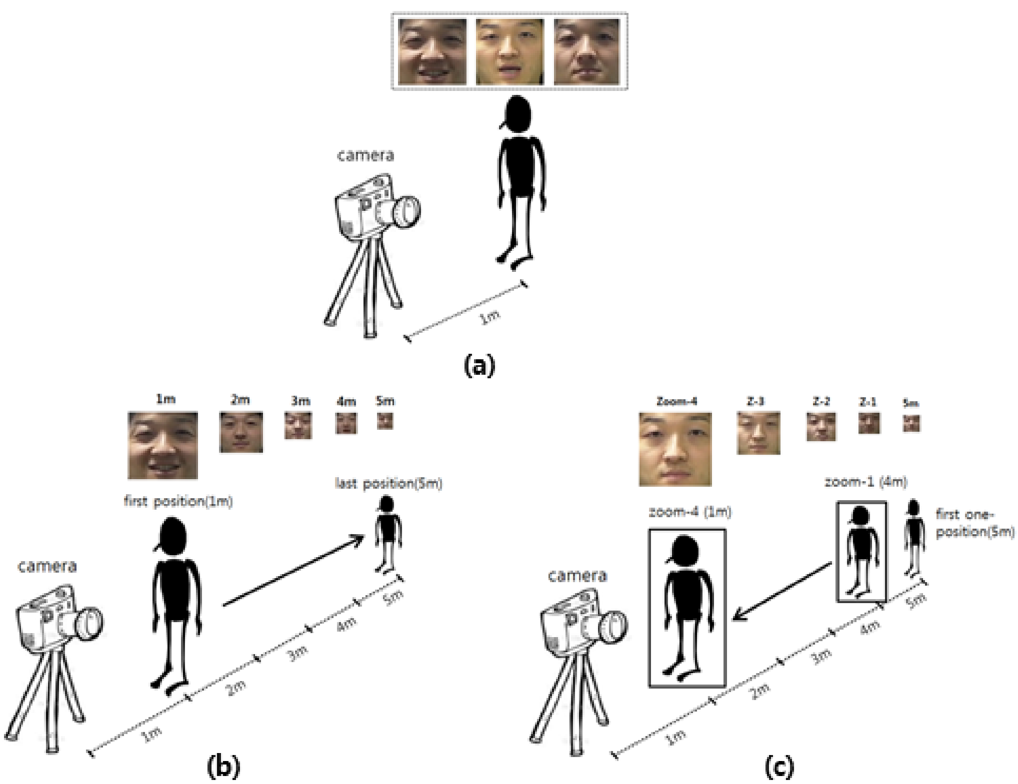

Figure 2: How to obtain face images for training (a) How to obtain face images of single distance (b) How to obtain face images by actual distance (c) How to obtain virtual face images by distance using a zoom

3.2 How to Acquire Face Images by Distance for Training Images

In case of the conventional short distance face recognition, the face images used for training and those for test are obtained in similar size regardless of distance change. However, in case of long distance face recognition, the distance between the camera and person is not fixed, thus creating inconsistent image size. That is, as face images shot from 1m away and 5m are different, recognition rate can change depending on which face images are used for training. The paper uses the face images per distance for training to improve the recognition rate that decreases due to distance. Figure 2 shows how to acquire face images used for training. Figure 2(a) is the method to obtain multiple face images from the conventional single distance. As the user is in a fixed position, additional cooperation is unnecessary and face images can be obtained quickly. Figure 2(b) is the method to obtain face images by actual distance where the user moves 1m-5m in person to get face images with a fixed camera. The method has both advantage of obtaining face images per actual distance and disadvantage of requiring additional cooperation from the user and much time over the conventional single distance method. Figure 2(c) uses a zoom camera to obtain virtual face images by distance. The user positioning 5m away can get the face images of each distance with the zoom camera. Here, face images that are similar to those by actual distance can be obtained and additional user cooperation is not needed.

4 Performance Analysis of Long Distance Face Recognition Depending on Training Image Composition

As the paper used face images by distance and a zoom camera for the face recognition test, it faced difficulty using the conventional face DB. For experiment, we set up a new DB with face images. With test DB assumed as the household home network service environment such as smart robots, surveillances cameras, 150 face images per person (1m-5m: 30 each) are obtained from ten people each. The size of original images used for test is 640*480 and they were shot with the same magnification where zoom is not applied. The paper defines the images from 1m-2m as short distance and 3m-5m as long distance based on the test images. Face recognition classifies the most similar first face image among those saved in the database as the result of test image as 1:N research method instead of 1:1 test. Besides, since the test extracts the face area directly under the assumption that all face images are extracted from the input images regardless of distance, the extraction result is more elaborate than automatic face extraction. The extracted face images are used as they are produced without considering distortion or rotation. Table 1 shows the test condition to analyze face recognition rate change by distance depending on training image composition.

Table 1: Face recognition experiment Depending on Training image composition

Case	Training condition		
1	Training image per person	: 1m	: 3 images
	Test images per person	: 1m - 5m	: 30 images each
2	Training image per person	: 1m - 5m	: 1 image each
	Test images per person	: 1m - 5m	: 30 images each
3*	Training image per person	: 1m - 5m	: 1 image each
	Test images per person	: 1m - 5m	: 30 images each

*Training image is the virtual face image by distance obtained with a zoom

4.1 Using Single Distance Face Images for Training

Because face recognition based on outlook can experience recognition rate change depending on the face image data used for training or the number of data, selecting training images is very important. Especially, lack of data from distance between the camera and objects in the long distance face recognition causes low recognition rate. Because of this, the conventional face recognition method that used single distance face images for training is used to analyze the recognition rate by distance. The test was done under the condition of Case 1 at Table 1. Case 1 used the face image from 1m for training and the number for training per person was 5. The total number of training images was 50 for ten individuals. The number of test images was 30 each per person by distance. The total number of test images per person was 150 and it becomes 1500 for ten individuals. Face size normalization used bilinear interpolation [6] while histogram equalization (H_E) and MCT were used as a image preprocessing. Face recognition used PCA and LDA and similarity measurement used Euclidean distance [4]. Figure 3 is the example of face images obtained from single distance used for training. Figure 3(a) is the original, Figure 3(b) is normalization with histogram equalization and Figure 3(c) is preprocessed with normalization with MCT.

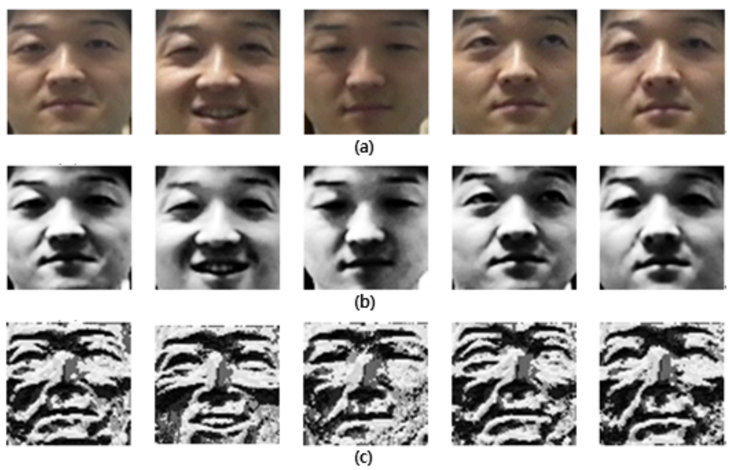

Figure 3: 1m face image used for training (a) Original image (b) Normalization + Histogram equalization (c) Normalization + MCT

Figure 4 presents the face recognition rate change when single distance face images were used for training. As a result of the test, H_E+PCA showed the best rate at 92.0% in short distance while H_E+LDA marked the best at 73.3% in long distance. When mean recognition rate was compared from 1m-5m, H_E+LDA recorded the best performance at 80.7%. The method that used single distance face images for training demonstrated excellent result from 1m in general though the rate plummeted when the distance becomes farther away.

4.2 Using Face Images by Actual Distance for Training

Outlook-based recognition rate can be improved with increasing the number of face image data used for training or using a variety of data. The paper uses face images per distance to address data loss caused by distance. When the face images shot from 1m-5m were used for training, the test was done under the condition of Case 2 at Table 1 to analyze the face recognition rate change by distance. Case 2 used face images extracted from 1m-5m for training and the number of images for training per person was 1 by distance and 5 in total. The total number of training images was 50 for ten individuals. The number of test images was 30 each per person by distance. The total number of test images per person was 150 and it becomes 1500 for ten individuals. Other test environment is the same with the face recognition

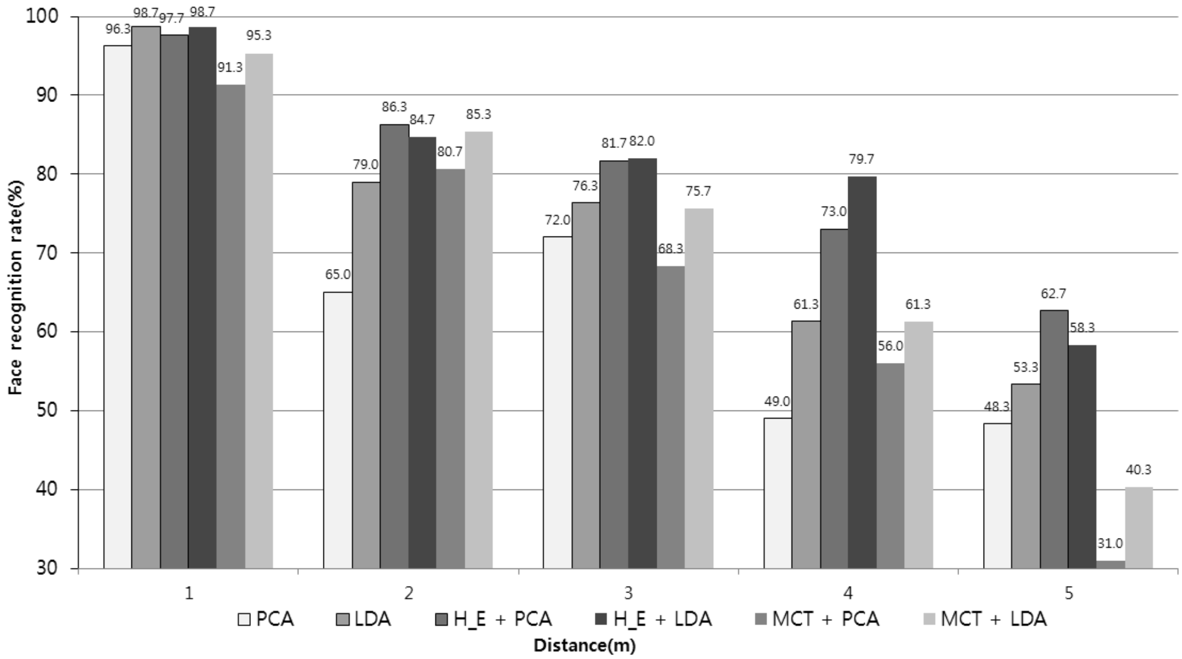

Figure 4: Face recognition rate change based on single distance face images

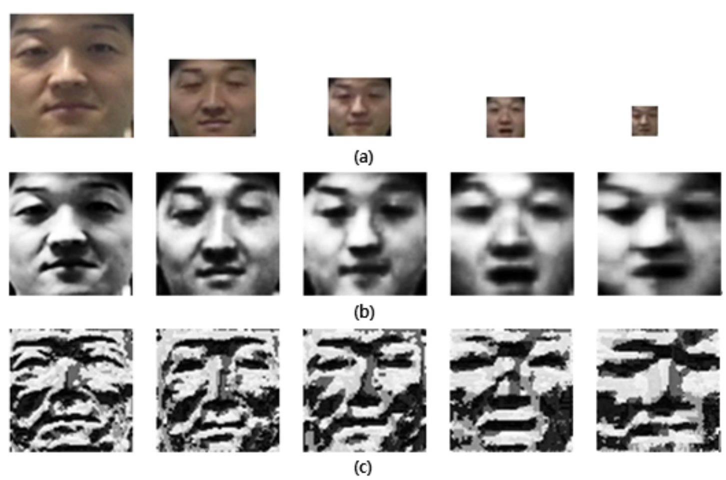

Figure 5: Face images from 1m-5m used for training (a) Original image (b) Normalization + Histogram equalization (c) Normalization + MCT

based on single distance face images. Figure 5 is the example of face images obtained by actual distance from 1m-5m. Figure Figure 5(a) is the original, Figure Figure 5(b) is normalization with histogram equalization and Figure Figure 5(c) is preprocessed with normalization with MCT.

Figure 6 illustrates the face recognition rate change when face images by actual distance were used for training. As a result of the test, H_E+LDA showed the best rate at 97.2% in short distance and 95.1% in long distance. When mean recognition rate was compared from 1m-5m, H_E+LDA also recorded the best performance at 95.9%. The method that used face images by actual distance for training demonstrated lower rate than the method using single distance face images for training from 1m away. However, mean recognition rate of 1m-5m was found excellent.

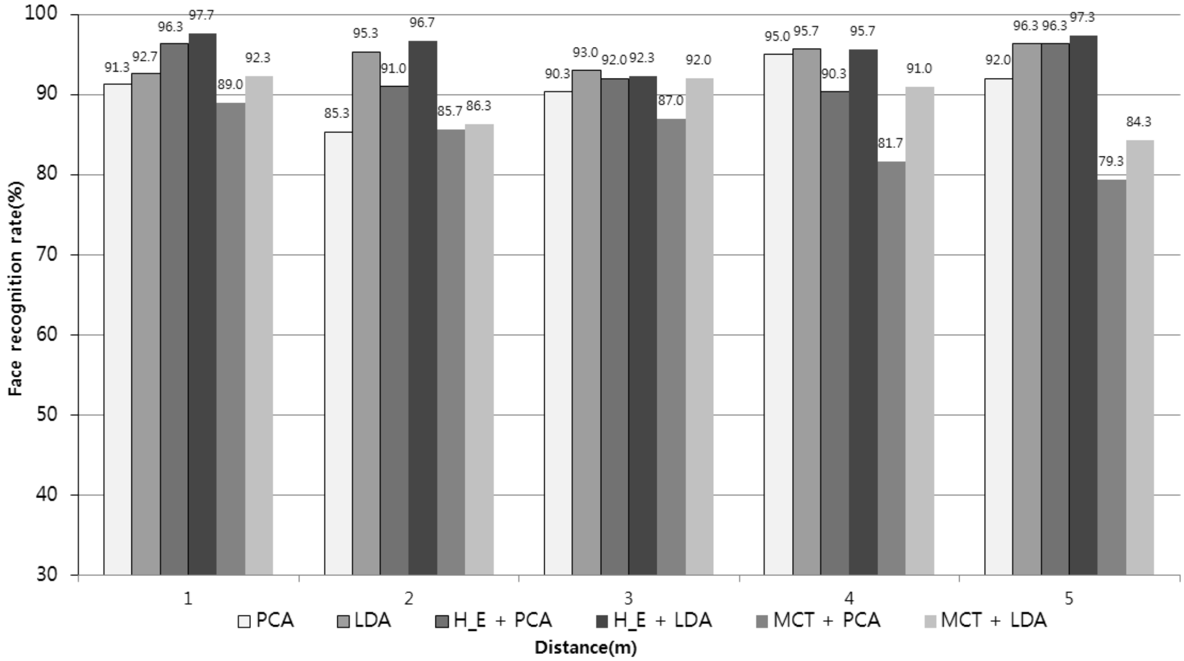

Figure 6: Face recognition rate change based on face images by actual distance

4.3 Using Virtual Face Images by Distance for Training Obtained with a Zoom Camera

Outlook-based face recognition produces a limited number of images used for training and requires user cooperation to secure many images. Face recognition performance improved when the face images by actual distance were used for training. However, high level of user cooperation is needed to obtain face images by distance used for user registration. The paper used a zoom camera to get face images by distance in an environment that needs low level of cooperation. Figure 7 is the face images by distance obtained with a zoom camera. Figure 7(a) is the original, Figure 7(b) is normalization with histogram equalization and Figure 7(c) is preprocessed with normalization with MCT. When the virtual face images by distance obtained from a zoom camera were used for training, the test was done under the condition of Case 3 at Table 1 to analyze the face recognition rate change by distance. Case 3 used the face images extracted from 1m-5m for training and the number of images for training per person was 1 by distance and 5 in total. The total number of training images was 50 for ten individuals. The number of test images was 30 each per person by distance. The total number of test images per person was 150 and it becomes 1500 for ten individuals. The images used for the test were produced from a fixed camera and the zoom camera was used only to get face images for training. Other test environment is the same with the face recognition based on single distance face images.

Figure 8 presents face recognition rate change when virtual face images by distance obtained with a zoom camera were used for training. As a result of the test, MCT+PCA showed the best rate at 87.5% in short distance and H_E+LDA posted the best result at 92.3% in long distance. When mean recognition rate was compared from 1m-5m, H_E+LDA recorded the best performance at 90.3%. The method that obtained virtual face images from 1m-5m using a zoom camera demonstrated lower rate than the method using face images by actual distance. However, it showed better performance than the conventional method that used single distance face images.

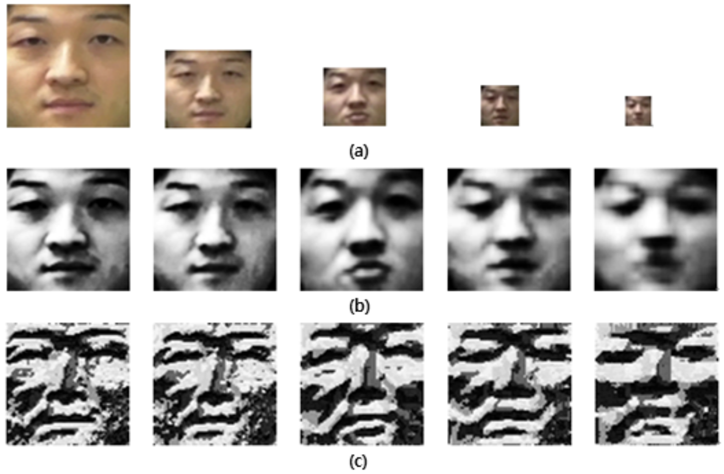

Figure 7: Face images from 1m-5m used for training (a) Original image (b) Normalization + Histogram equalization (c) Normalization + MCT

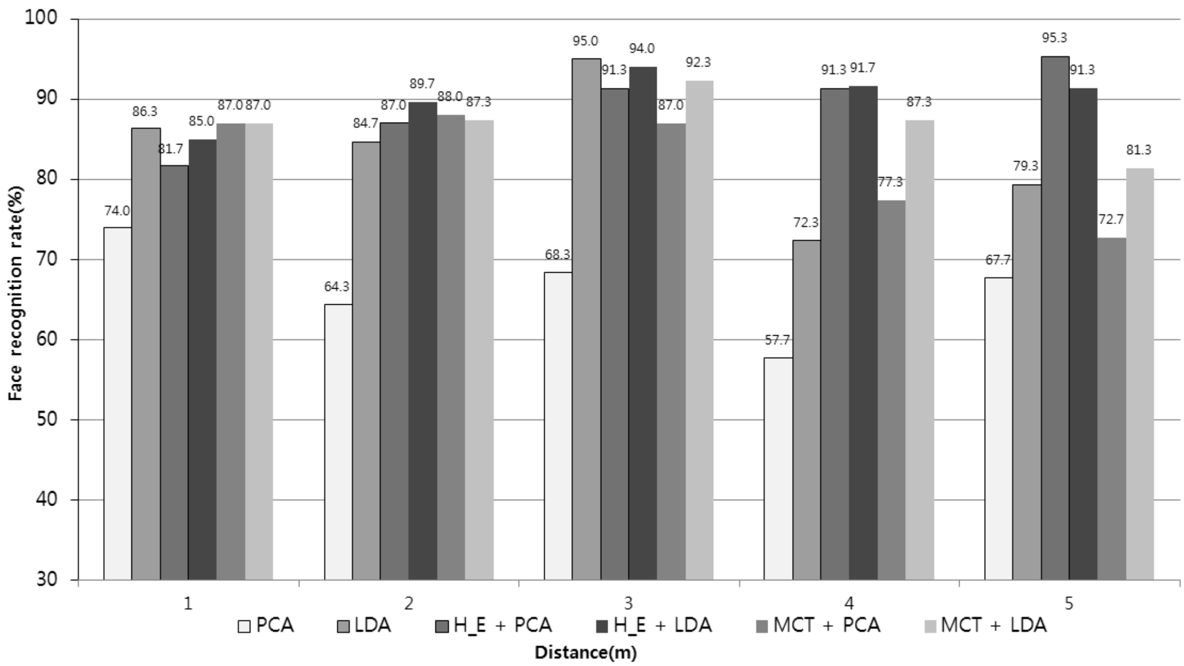

Figure 8: Face recognition rate change based on virtual face images by distance

5 Conclusion

The home networking service collects and analyze personal information to provide various tailored smart services for individual users and reliable user authentication is necessary to prevent information leak caused by such information collection and analysis. The study suggests biometrics-based user authentication that can be applicable to the home networking system. The paper performed the tests by using various training image composition methods, preprocessing and face recognition methods to analyze the long distance face recognition method applicable to home network environment. For long distance face recognition test, face images per actual distance were obtained directly from 1m-5m away. The paper used face images both by actual distance and virtual face images by distance using a zoom camera to resolve the issue arising from distance that affects face recognition rate. Besides, face image size normalization used bilinear interpolation while histogram equalization and MCT were applied as image preprocessing. PCA and LDA were used for face recognition while Euclidean distance was used for similarity measurement. The test result showed that using face images by actual distance for training and histogram equalization showed the best performance for long distance face recognition, so it is expected to be applicable for user authorization of home network system.

5.1 Future Work

To acquire reliable data in the future, algorithm that is suitable for long distance face recognition should be developed by securing various test DB with different number of researchers and illumination change. Additionally, the proposed algorithm will be developed into a structure that is able to use minimization and low power processing of the proposed algorithm suitable for an object communication service environment.

5.2 Acknowledgments

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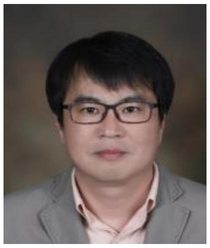

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