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The LDA-based Face Recognition at a Distance using Multiple Distance Image

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***Abstract*— These days surveillance system has been developed into intelligent system that can judge and handle using human recognition technology that can recognize the people. In this paper, LDA-based face recognition algorithm for the intelligent surveillance system is proposed. While the existing face recognition algorithm uses the short distance images for training images but the proposed algorithm uses face images by distance extracted from 1m to 5m for training images. In the proposed LDA-based long distance face recognition algorithm, bilinear interpolation uses for the normalization and Euclidean Distance measure method is used for similarity measure. As a result of experiment, it is confirmed that the proposed algorithm showed improved face recognition performance 6.1% in short distance and 31% in long distance.**

Keywords-component; intelligent surveillance system, image interpolation, long distance face recognition, linear discriminant analysis(LDA)

I. INTROTRGDUCTION

Recently, the video surveillance system has been developed to be intelligent, which includes finding criminals automatically or detecting fires by applying the techniques such as image analysis, computer vision or pattern recognition [1]. To satisfy the intelligent surveillance system, the long distance human identification technique applicable to the surveillance camera environment is needed [2]. Face recognition has relatively low recognition rate compared to fingerprint and iris recognition but since it is able to recognize in non-contact and non-cooperative environments and even in long distance, the studies on long distance human identification using the face are still ongoing[3,4]. In face recognition, there are methods to recognize the face by geometric features, which are the size and location of the face components, such as eye, nose and mouth and to recognize using the statistical values of entire face including Principal Component Analysis(PCA) and Linear Discriminant Analysis(LDA)[5, 6].

The majority of surveillance cameras have reduced quality of images as the distance between the people and the camera increases. When the existing face recognition algorithm applies to the surveillance camera system as it is, the recognition rate is reduced as the distance between the people and the camera increases. To apply face recognition to the surveillance camera system, the quality of images which decreases as the distance increases should be considered. Recently, the technology that recognizes the long distance face using expensive camera which can obtain the high quality image from long distance is being studied [7,8]. However, in case of face recognition, using expensive camera, it costs a lot to install and manage, making it difficult to use universally. Therefore, it is necessary to develop the long distance face recognition algorithm which can operate in the existing installed surveillance camera environment.

In case of long distance face recognition using LDA, the size of recognition images should be normalized fitting to the data size of training images. In general, since images taken from long distance are smaller than images taken from short distance, interpolation should be used to normalize the image size. Interpolation is a technique to enlarge or shrink the image at the input resolution based on the image entering, and it includes nearest neighbor, bilinear and bicubic convolution interpolations [9].

In this paper, LDA-based long distance face recognition algorithm applicable to the environment of surveillance camera is proposed. While single distance face images are used as training images for existing face recognition, the proposed method uses face images by distance of 1m to 5m for the user training images. The size of face images extracted by distance are different in face images by distance of 1m to 5m, and thus the face images are normalized into the same size by using bilinear interpolation. In addition, as for similarity measure method, Euclidean Distance measure has been used. As a result of experiment, the face recognition rate of existing algorithm was 85.8% in short distance and 44.0% in long distance, but the proposed face recognition algorithm showed 6.1% and 31.0% improved performance for 91.9% from short distance and 75.0% from long distance, respectively.

The composition of this paper is as follows. In section II, face recognition and interpolation which will be used in normalization of face image size are introduced. In chapter III, the proposed long distance face recognition algorithm and experiment results are explained and chapter IV concludes the paper.

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II. BACKGROUND

A. Face Recognition

Face recognition technology is variously studied ranging from still image-based face recognition from controlled environment to video image-based face recognition from crowded environment. In this paper, LDA which use feature extraction method using basis vector are used. To express two dimensional face images, face shape and texture information are vectorized. For face shape information, physiographic features like distance and ratio of face elements such as eye, nose and mouth are used. Texture information is expressed as brightness information itself in the face area. By arraying the brightness value of two dimensional face images in order, features are extracted by expressing first-dimensional vector. The feature extraction process in face recognition is to find the base vector for linear transition. PCA technique is to find the eigenvector for covariance matrix as basis vector and LDA is to find the basis vector which reduces the scatter within the class and increases the distance between averages of each class. LDA use face images as a feature vector for face recognition by reflecting the face images to basis vector.

Table 1 shows the training process of LDA technique briefly. Table 2 shows the recognition process of LDA technique briefly. In here, the most similar feature vector images are used as recognition result images by measuring the similarity of feature vectors between recognition images obtained and training images.

TABLE I. TRAINING PROCESS OF LDA TECHNIQUE

1. Definition of P number of training image vector

$$X = [x^1 \mid x^2 \mid \ldots x^P]$$

2. Definition of within-class scatter matrix of i-th

$$S_i = \sum_{x \in X_i} (x - mean_i)(x - mean)^T, \quad mean = \frac{1}{P_i} \sum_{x \in X_i}^{p} x$$

3. Definition of within-class scatter of matrix S_w

$$S_W = \sum_{i=1}^{C} S_i$$

4. Definition of between-class scatter of matrix S_b

$$S_B = \sum_{i=1}^{C} n_i (mean_i - mean)(mean_i - mean)^T, \quad mean = \frac{1}{P} \sum_{i=1}^{p} x^i$$

5. Definition of matrix that maximizes the ratio of S_w and S_b

$$W_{opt} = \arg\max \frac{\left| W^T S_B W \right|}{\left| W^T S_W W \right|} = \left[w_1, w_2, \cdots w_m \right]$$

$$S_B w_i = \lambda_i S_W w_i, \; i = 1, 2, \cdots m$$

TABLE II. RECOGNITION PROCESS OF LDA TECHNIQUE

1. Definition of P number of recognition image vector

$$Y = [y^1 \mid y^2 \mid \ldots y^P]$$

2. Difference of each image vector and average image vector

$$\overline{y^i} = y^i - mean, mean = \frac{1}{P} \sum_{i=1}^{p} y^i$$

3. Definition of feature vector for recognition image using W_{opt}

$$\widetilde{y^i} = W_{opt} \overline{y^i}$$

B. Interpolation

For long distance face recognition, since the size of face images extracted according to the distance between camera and the subject is different, the size of face images to be verified should be normalized to fit to the size of training images. Interpolation is used to adjust the image size. The nearest neighbor interpolation is the simplest method among interpolations and it refers to the pixel of nearest original images from the location that the output pixel is to be produced. Bilinear interpolation is a technique to produce the pixel to be interpolated using adjacent four pixels. The interpolated pixel is determined by the sum of four pixels multiplied by weighted value. At this time, weighted values are determined linearly and are inversely proportional to the distance from each of the adjacent pixels. Fig. 1 shows the bilinear interpolation using one-dimensional linear interpolation. To find the interpolated pixel I, the bilinear interpolation is performed using the values of adjacent four pixels (A, B, C and D). The bilinear interpolation provides better image than nearest neighbor interpolation but it increases in computational complexity and edges parts are not smooth.

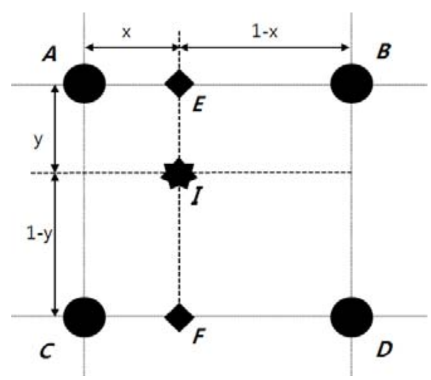


Figure1. Bilinear interpolation.

Interpolation using higher-order polynomial equation defines the function of weighted value and is a method to calculate the pixel values by adding all values of neighboring pixel values of original images multiplied by weighted values. The representative method using higher-order polynomial equation includes cubic convolution

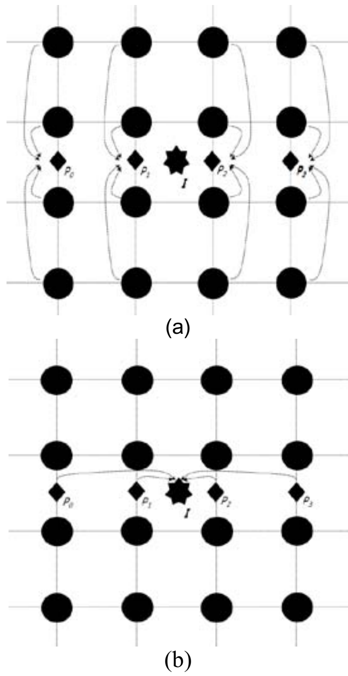


Figure2. Bicubic convolution interpolation. (a) Vertical interpolation. (b) Horizontal interpolation

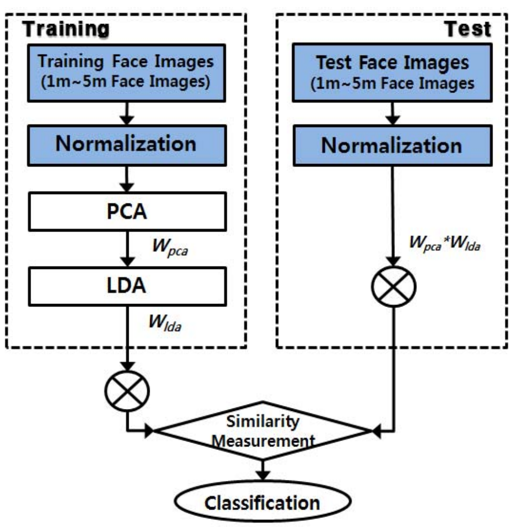
interpolation. Fig. 2 shows the process of performing the two-dimensional cubic convolution interpolation using one-dimensional cubic convolution interpolation. Bicubic convolution interpolation produces new interpolated pixels using 16 pixels of original images. Through four times of cubic convolution interpolation in vertical direction as shown in Fig. 2(a), four interpolated pixels (P_0, P_1, P_2 and P_3) are produced. Using newly produced four interpolated pixels, when the cubic convolution interpolation is performed once horizontally, the final interpolated pixel I is produced as shown in Fig. 2(b). Bicubic convolution interpolation refers to more pixels than bilinear interpolation so its image quality is good but it requires more computational complexity.

III. Proposed Long Distance Face Recognition Algorithm and Experiment Results

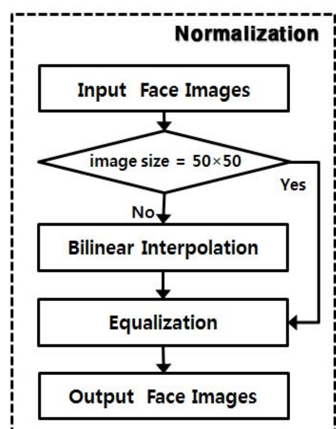
Fig. 3 is the flowchart of proposed LDA-based long distance face recognition and Fig. 3(a) shows the overall flow and Fig. 3(b) presents the normalization process of face images being entered. The overall flow of face recognition algorithm is same as existing face recognition. However, it has a difference in that proposed algorithm uses face images by distance of 1m to 5m as training images and adds the normalization process for face images by distance.

The training process using face images by distance is as follows. If face images of 1m to 5m distance are entered, the average face vector of normalized face image is calculated through normalization process. After calculating the difference of average face vectors in each face image, find the covariance matrix. After finding the eigenvector and eigenvalue from determined covariance matrix, finally W_{pca} is generated. W_{pca} generated through PCA is optimized by LDA again. Find W_{lda} which is the data which the ratio of between-class scatter and within-class scatter in LDA is maximum. The test process using face images by 1m to 5m distance is as follows. When the face image of 1m to 5m distance is entered, it is normalized through normalization process. From normalized face images, feature vectors are extracted through difference of average face image vector and W_{lda} projection. Finally, by comparing the feature vectors in test area and training areas, the face image that has the most similar value is classified.

The normalization of face image by distance is as follows.



(a) The overall flow of proposed system

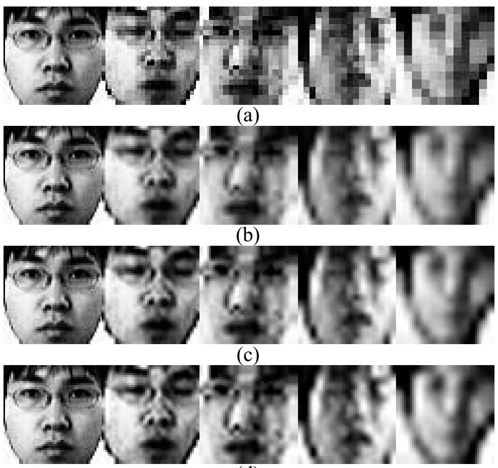


(b) The normalization process of face images

Figure3. Long distance face recognition flowchart using LDA

(a) 1 m (b) 2 m (c) 3 m (d) 4 m (e) 5 m

Figure4. Examples of extracted face image by distance.



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

Figure5. Examples of face image by normalized distance (left: 1 m ~ right: 5 m) through interpolation. (a) Nearest Neighbor interpolation. (b) Bilinear interpolation. (c) Bicubic convolution interpolation. (d) Lanczos3 interpolation.

Once the face images for training are entered, the size of input face images is judged. If the size of image is 50x50, the next step which is equalization will be conducted, but if the size is smaller than 50x50, the equalization will be conducted after enlarging the size to 50x50 through interpolation. All face images entered through this process will be normalized into 50x50 image size.

Fig 4 is the original face image extracted from person 1 according to the distance change of 1m~5m. The sizes of extracted face images are 50×50, 30×30, 20×20, 16×16 and 12×12 from 1m to 5m, respectively. The face images extracted by distance are normalized by four kinds of interpolation as shown in Fig. 5.

Face recognition experiment uses ETRI face DB. As shown in Table 3, ETRI face DB obtained 500 face images (1m~5m: 100 images for each) per person from 10 people considering various lighting environment and distance change [10]. Acquired face images were obtained through 1m to 5m distance change. In this paper, face images extracted from 1m to 2m based on the experimental images considers as short distance and face images extracted from 3m to 5m considers as long distance. Face recognition, which is 1:N search method rather than 1:1 authentication, uses the method to classify with results for verified images of first face images which are the most similar one among face images stored in database. In addition, the experiment was carried out under the consumption that every face is extracted from input images regardless of distance, and a twisting or rotation of face was not considered.

The existing face recognition algorithm has only used the single distance face images for training images, but the proposed algorithm recognized the face using the face images by distance for training images. Through experiment, the excellence of LDA-based long distance face recognition using the face images by distance as training was proved. Also, when the face images by distance were used as training, the similarity measurement method and face image normalization method that are appropriate long distance face recognition are proposed. Table 4 is the experimental condition to prove the excellence when face images by distance were used as training. In CASE 1, only images taken at 1m were made up for training images and the total number of training images per person was 20 images. In CASE 2, images taken at 1m to 5m were used for training images and the number of training images per person was total of 20 images by 4 images for each distance.

TABLE III. ETRI FACE DATABASE

- Total persons : 10
- Environment of obtained face images
  - various lighting change
  - 1m~5m distance change
  - face position change
- Face image size
  - 1m : 50×50 2m : 30×30 3m : 20×20 4m : 16×16 5m : 12×12
- The number of total obtained face images : 5000 images
- Obtained face images per a person : 500 images

TABLE IV. FACE RECOGNITION EXPERIMENT ACCORDING TRAINING IMAGES

CASE	Training condition
1	Training image per person -1m : 20 images Test image per person -1m~5m : 80 images each
2	Training image per person -1m~5m : 4 images each Test image per person -1m~5m : 80 images each

A. Face Recognition Rate Changes according to Interpolation

This experiment was carried out using Table 4 in order to find appropriate interpolation for proposed algorithm. LDA was used for face recognition method and Euclidean Distance was used for similarity measure. For normalization of face image size by distance of 1m to 5m, the nearest neighbor, bilinear, bicubic convolution and Lanczos3 interpolations were used [11]. Fig. 6 shows the results of face recognition rate using normalized face images by distance through interpolation. For experimental condition as shown in CASE 1 in Table 4, for training images per one person, 20 images of 1m face image were used and 80 images of face image by distance of 1m to 5m were used for verification images. As a result, when Lanczos3 interpolation was used, in short distance the face recognition was 85.6% which had the best performance. In long distance, when bicubic convolution and Lanczos3 were used, it showed similar performance for 44% and 44.1%, respectively. Fig. 7 shows the results of face recognition rate using normalized face images by distance through interpolation. For experiment condition, as shown in CASE 2 in Table 4, total of 20 face images for 1m to 5m distance by each 4 images were used for training images. As for test images, each of 80 face images by 1m to 5m distance was used. As a result, when Lanczos3 interpolation was used the face recognition was 92.9% which showed the best face recognition performance. In long distance, the face recognition performance was excellent for 75.0% when bilinear interpolation was used.

As a result, when the short distance face image is used as training, it is better to use Lanczos3 for image normalization method in LDA-based face recognition. And when using the face images by 1m to 5m distance as training, the face recognition performance was the best using the bilinear interpolation.

B. Face Recognition Rate Change according to the Configuration of Training Images

Through this experiment, the effect on the face recognition rate of the configuration of the training image and the excellence of LDA-based face recognition when the face images by distance were used as training images are proved. Fig. 8 shows the results of the configuration of training image affected on face recognition in LCA-based face recognition. In CASE 1, Lanczos3 interpolation was used and in CASE 2, bilinear interpolation was used for normalization of face image size. L2 was used for the similarity measure. As a result, when using single distance for training images, the performance was 85.8% in short distance and 44.0% in long distance. When using face images by distance of 1m to 5m, the short distance had better performance for 91.9% than when using single distance for training images which was 75.0%. Consequentially, when the same number of training images was used, the face recognition rate was improved if the multi-distance face images were used rather than single distance face images.

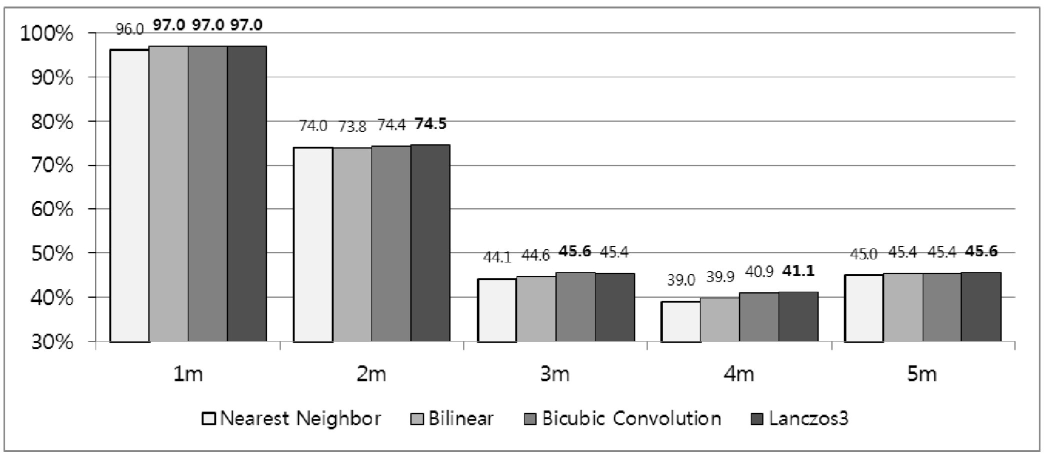


Figure6. Face recognition rate of CASE 1 according to interpolation

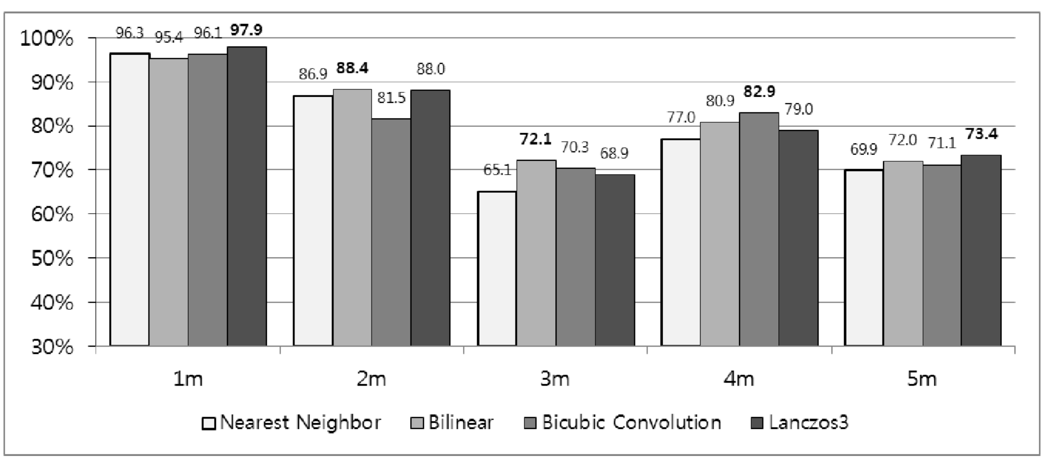


Figure7. Face recognition rate of CASE 2 according to interpolation

C. Face Recognition Rate Change according to Similarity Measure

Through this experiment, when the face images by 1m to 5m distance were used, the similarity measure that is appropriate to long distance face recognition is proposed. The configuration of training images were like CASE 2 and LDA was used for the face recognizer. The bilinear interpolation was used as image normalization method. For

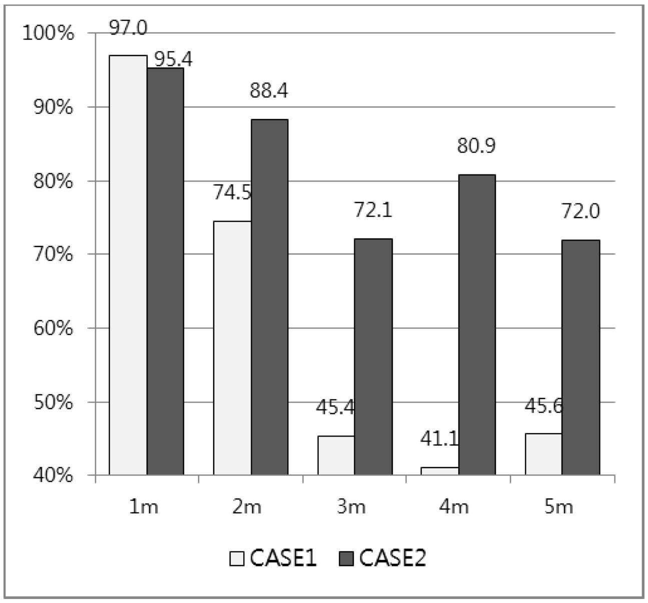


Figure8. Face recognition rate according to training images

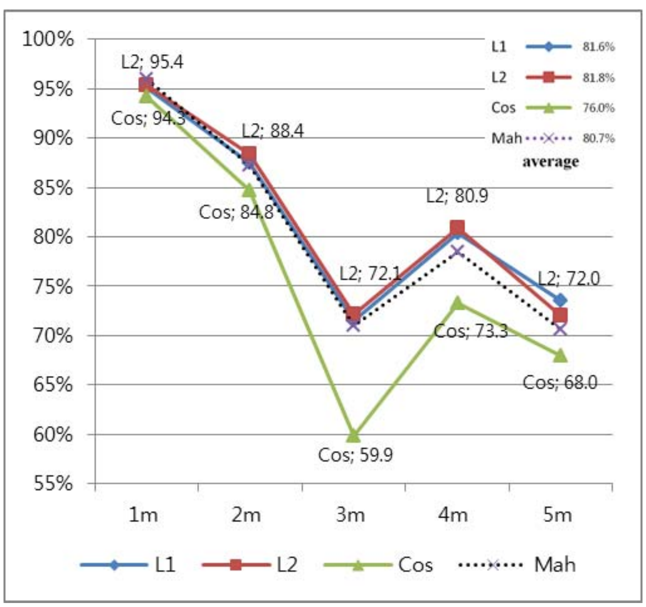


Figure9. Face recognition rate according to similarity measure

similarity measure, Manhattan Distance (L1), Euclidean Distance (L2), Cosine Similarity (Cos), and Mahalanobis Distance (Mah) distance scale method were used [12].

Fig. 9 shows the face recognition rate of LDA-based face recognition according to similarity measure. As a result, L2 was used for short distance and it showed the best performance for 91.9%. In long distance, L1 and L2 showed similar performance as 75.1% and 75%, respectively. The overall average face recognition rate of 1m to 5m were 81.6%, 81.8%, 76.0% and 80.7% respectively when using L1, L2, Cos and Mah and the recognition rate of L2 was the best. Consequently, in LDA-based long distance face recognition which multi-distance images were used as training, the face recognition performance was the best when the Euclidean Distance (L2) similarity measure was used.

IV. CONCLUSION

As various incidents are frequently occurred recently, the interest in long distance human identification technology is also increasing with the development of intelligent video surveillance camera. The face recognition which has used the existing single distance face images as training images has disadvantage of lowering the recognition rate as the distance between surveillance camera and the user increases. In this paper, LDA-based long distance face recognition algorithm appropriate to the environment of surveillance camera is proposed. The face images by distance were used in proposed face recognition algorithm and the low resolution images by distance were normalized using bilinear interpolation. For the similarity measure, Euclidean Distance measure method was used. As a result of experiment, the proposed face recognition algorithm had improved face recognition rate for 6.1% in short distance and for 31.0% in long distance compared to the LDA-based face recognition using existing short distance face images.

In the future, the study to produce the face images automatically using short distance images will be carried out and the face recognition rate will be improved by adjusting twisting or rotation of face.

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