Efficient Face Recognition using Low-Dimensional PCA: Hierarchical Image & Parallel Processing

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ABSTRACT

This paper proposes a technique for principal component analysis (PCA) to raise the recognition rate of a front face in a low dimension by hierarchical image and parallel processing structure. The conventional PCA shows a recognition rate of less than 50% in a low dimension (dimensions 1 to 6) when used for facial recognition. In this paper, a face is formed as images of 3 fixed-size levels: the 1st being a region around the nose, the 2nd level a region including the eyes, nose, and mouth, and the 3rd level image is the whole face. PCA of the 3-level images is treated by parallel processing structure, and finally their similarities are combined for high recognition rate in a low dimension. The proposed method under went experimental feasibility study with ORL face database for evaluation of the face recognition function. The experimental demonstration has been done by PCA and the proposed method according to each level. The proposed method showed high recognition of over 50% from dimensions 1 to 6.

***Keywords**: Face recognition, PCA, Parallel processing.*

1. INTRODUCTION

Face recognition involves the analysis of still or moving images inputted in a photo or camera in order to find the most similar face from the existing database. This technology can be used safely without the possibility of being robbed, lost, or forgotten, compared with other security means, and is easily available by using already-established cameras, without the need for separately-made sense like the iris or a fingerprint. In addition, a great quantity of data can be obtained, as most identification cards have photo data, and applied as a monitoring method in public services as it is not a touch-type. Particularly as a tool in immigration and during terrorist alerts, the use of face recognition at airports for comparison of passengers' faces with the database of lawbreakers will assist in law enforcement.

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Face recognition has two methods: the recognition of geometric features of facial components like the size and position of eyes, nose and mouth[1], and the recognition of statistical values of the whole face in systems such as principle

makes directly the scatter matrix from 2D image matrices. 2D-PCA deals with the small size scatter matrix than traditional PCA-based methods and evaluates the scatter matrix accurately.

The most popular method among these, PCA, obtains eigenvalue and eigenvector by using the dispersion of the total training images, and arranges face images in a row according to the sizes of their eigenvalues, and characterizes them as the coordinates of the corresponding eigenvectors. During recognition, the feature vector of the test image is compared with that of the training image stored in the database. In this method, the size of the high-dimensional eigenvalue is rather small as most of the information is in a low dimension. Therefore, face recognition by PCA, eigenvalues of

ting simultaneously. The processors may work on different aspects of the same program at the same time. The benefit of using the parallel processing is to save time in solving large and complex problems[8].

As for the proposed images by levels, the 1st-level image is a region around the nose, the 2nd is a region including the eyes,

hierarchical image and parallel processing structure, and section 4 the face database used in the experiment, the experimental methods, and the results. Finally, section 5 presents the conclusion.

2. PCA(PRINCIPAL COMPONENT ANALYSIS)

The PCA method is based on the analysis technique of materials examining the relationship between variables in a low dimension through dimension reduction. The technique is based on Pearson and Hotelling's introduction from the viewpoint of geometry and algebra. Turk and Pentland [9] extracted unrelated features between components by principal element analysis, and applied this method, classified as the nearest neighborhood algorithm, to face recognition.

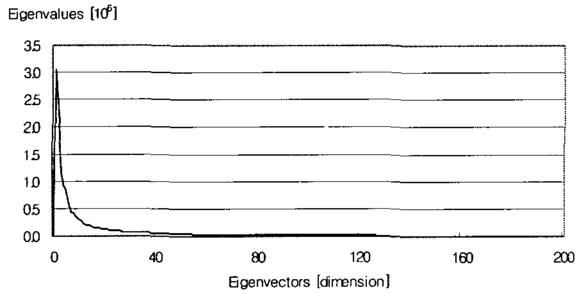


Fig. 1. Relationship between eigenvalues and eigenvectors in PCA

Principal element analysis forms a new axis for the largest dispersion expressed by the data sample. As these axes meet perpendicularly, the value expressed by some high-ranking

component analysis[2-4] and LDA[5-6]. Recently, Yang et al. [7] proposed 2D-PCA. While previous methods use 1D image vector, 2D-PCA

a fixed low dimension are used rather than those of all dimensions. It is particularly difficult for the existing PCA to obtain a recognition rate of 50 % in dimensions 1 and 2, which has limited its application in applied fields such as the gradual search of wanted men. In case of recognition of the corresponding face with a probability of 50% in a large database, more than 5 dimensions must be used for PCA.

In order to obtain a recognition rate of over 50% in low-dimensional PCA, the study introduces a parallel-process using 3 levels of images by PCA technique, after making facial images of 3 fixed-size levels. Parallel Processing is a computing method to be performed on systems containing two or more processors opera

nose, and mouth, and the 3rd is the whole face. According to each level, PCA and the proposed method are compared and evaluated for their recognition function by using a face database.

The study is organized as follows. Section 2 explains the existing PCA method, section 3 the proposed method using

axes contains most of the information that the input vector contains. For example, in the case of ORL database using 200 images as training images, a total of 200 eigenfaces are made and the dimensions of the eigenvectors are under 200. When 200 eigenvectors are arranged in a row according to the order of eigenvalues, Fig. 1 shows that some high-ranking eigenvalues exhibit the features of the whole face.

3. THE PROPOSED METHOD

The proposed recognition method produces 3 levels of hierarchical images by facial geometric features of face for raising recognition rate by low-dimensional PCA. The 1st level image is composed of the central region of the face image including the nose, the 2nd of a region including important parts like the eyes, nose, and mouth, and the 3rd step image presents an image of the whole face. For quick processing, the regions were divided according to their fixed size and position.

Fig. 2 shows the total composition of the face recognition system, including the pre-processing technique proposed by the study.

First of all, the input image is made into images of 3 fixed-size levels. Each level parallel-processes PCA differently, and stores eigenvectors as the order of eigenvalues. If the PCA dimension is smaller than the threshold value (experimental value: dimension 7), the Euclidian distance measure of each-level image is combined as in Eq. (1), and their similarities are compared.

$$D_{Total} = (W_{L1} * D_{L1}) + (W_{L2} * D_{L2}) + (W_{L3} * D_{L3}) \quad (1)$$

Here, D_{L1} is the Euclidian distance of the 1st level image and its weighted value W_{L1} is 0.1, D_{L2} is the Euclidian distance of the 2nd level image and its weighted value W_{L2} is 0.1, and D_{L3} is the Euclidian distance of the 3rd level image and its weighted value W_{L3} is 1.0. The weighted values in the study are experimental ones. D_{Total} is the sum of the similarities from each level. As D_{Total} shows little variation with recognition rate only for 3rd level image in the over threshold dimension (experimental value: dimension 7), similarity is calculated with the Euclidian distance of the 3rd level image. Therefore, the face with the largest similarity is recognized as that of the same person according to each level.

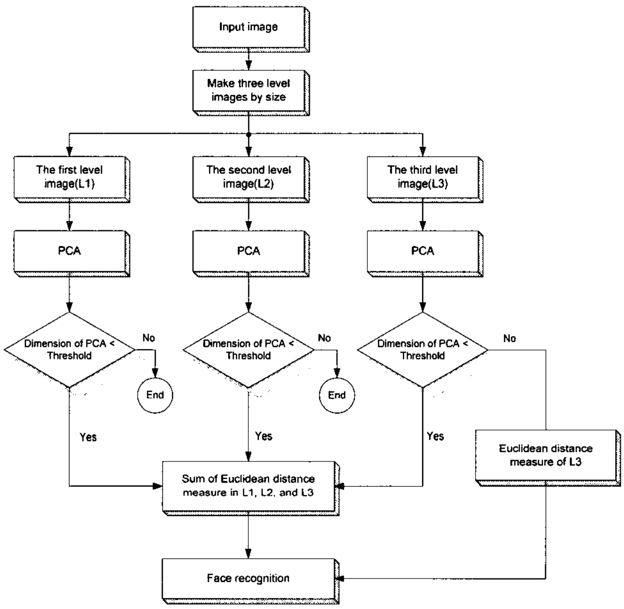
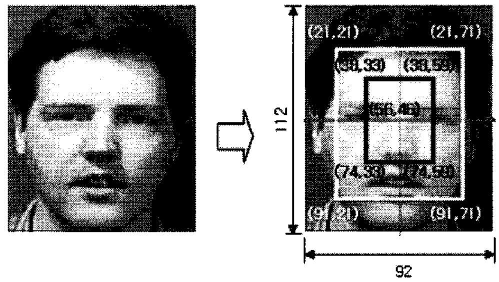


Fig. 2. System block diagram

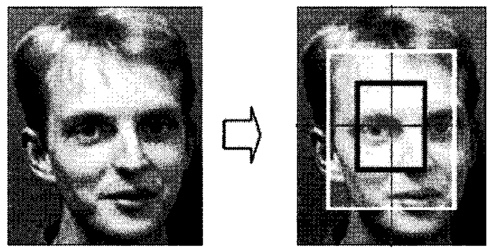
A front face, when the pose is relatively stationary, has a nose in the center, and includes eyes and a mouth when its region is extended. The existing PCA mainly treated the morphological features of the whole face. Everyone has a different figure in their face, as well as a different position of their eyes, nose, and mouth. The hierarchical image, based on this point, was used to divide the whole face into 3 regions and subsequently PCA was applied to them. The image by each level was unrelated with the face size, and was composed in a fixed size in the fixed region, to speed up the treatment.

Fig. 3 presents an example of the hierarchical image of a face in the ORL database. Fig. 3(a) correctly includes the nose region as the first level image. Fig. 3(b) doesn't specifically include the nose region as the first level image, but includes the eyes, nose, and mouth from the second level image. Therefore, the proposed method, despite some change in pose, raised the recognition rate because some errors of the first level image were, to some degree, complemented in the second level image.

The ORL image of the whole face is composed as a size of 112 × 92, and is termed the third level image, i.e., the application of PCA to the third level image is merely the existing method. The first level image is composed as a size of 36 × 22, based on the center of image, while the second level has the fixed size of 70 × 50 in order to shorten the processing time.



(a) The first level image exactly includes the region of the nose



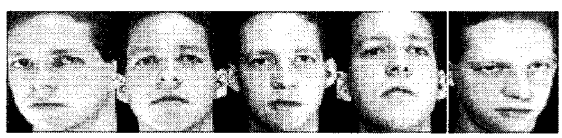
(b) The first level image doesn't exactly include the region of the nose

Fig. 3. Three level images

4. EXPERIMENTAL RESULTS AND ANALYSIS

The study converted an ORL (http://www.cam-orl.co.uk) face database into a regularized, 112× 92 sized, gray image, and this was divided into training and test images by hold-and-out method. That is, of the 10 face images per person, 5 were used as training images, as in Fig. 4(a), and the other 5 as test images, as in Fig. 4(b).

(a) The train images



(b) The test images

Fig. 4. Face images

Face recognition measured the similarity between the feature vectors by using Euclidian distance measure. Regarding the degree of recognition when recognizing one of the corresponding-class faces, the test image was evaluated as being recognized, but was considered to be mis-recognized when recognizing one of the other-class faces.

Simulation was experimented with the first level image, the second level image, the third level image used in the existing PCA, and the proposed method by each level.

Fig. 5 shows the change of recognition rate according to the increasing dimension of PCA in each method. The goal was to improve the recognition rate in the low dimension, but no result was drawn due to the low recognition rate in over dimension 20.

In the PCA results, the first level image produced a recognition rate of less then 50% as far as dimension 8, confirming the difficulty in recognizing a person from only the nose region. The second level image showed a recognition rate of less than 60% as far as dimension 4, and the third level image of the whole face used in the existing PCA didn't exceed the 70% recognition rate achieved under dimension 4. The experimental PCA result using the proposed method with the hierarchical image and similarity combination achieved a high recognition rate of 48%, 58.5%, and 69.5% in dimensions 1, 2 and 3, respectively. This indicated that the proposed method can obtain a higher face recognition rate in low dimension, compared with other methods in the same dimension.

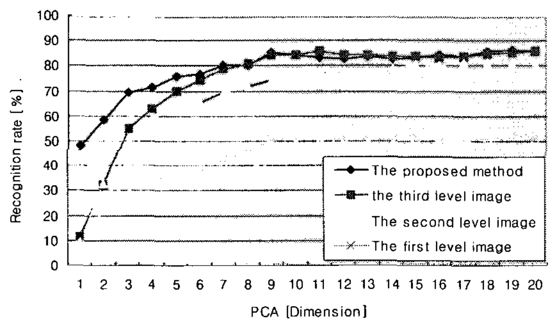


Fig. 5. The simulation result

5. CONCLUSION

The study has proposed a technique by which the existing PCA method can raise the presently inferior face recognition rate in the low dimension by hierarchical image and parallel processing structure. The region of the whole face was recomposed into hierarchical images of 3 fixed-size levels. PCA was then applied to each level as a parallel processing structure in order to maintain the total processing time as constant. As the similarity was measured, the combination of the weighted values by each-level increased the face recognition rate in low-dimensional PCA

The study results confirmed the effectiveness of the PCA method for the recognition of a database with much face data stored. The proposed method is expected to be more effective, especially in applications such as the over-50% search of a suspect rather than exact recognition. The method is robust in some pose change, shows a high function rise of about over 10% in under dimension 5, compared with the existing PCA, and shows a recognition rate of nearly 50% even in dimension 1.

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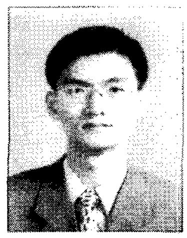

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