Facial Individuality and Expression Analysis by Eigenspace Method or Multiple Discriminant Analysis

Kurozumi Takayuki

School of Information Science,
Japan Advanced Institute of Science and Technology

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It is known that a face plays an important part in human communication. Moreover, we consider that human communication via network can be closer and more efficient if facial individuality and expression can be transmitted. This research aims at the analysis of individuality and expression from a facial image to realize such a communication.

Principal Components Analysis (PCA) is a typical method that individuality and expression are analyzed from facial images. PCA finds axes to maximize the variance of projected value of feature vectors (gray level of facial images, facial forms, facial optical flows and so on), subjecting to the constraints on those axes are orthogonal each other. However, the variance is affected by individuality, expression, lighting and so on. For example, when it is necessary to analyze facial individuality, it is desirable to choose the axes whose inter-class variance by the individuality is bigger than the intra-class variance by the expression, the lighting and so on. However, PCA have a problem with the possibility that mixed individuality, expression, lighting, and so on appear in those components.

Multiple Discriminant Analysis (MDA) is expanded into multiple classes for Fisher's Linear Discriminant as the way of reducing influences described above. The method chooses the axes whose ratio of the inter-class variance to the intra-class variance is the biggest. Moreover, this paper presents Eigenspace Method based on Class features (EMC) which choose the axes whose difference between the inter-class variance and the intra-class variance is the biggest. Then, we provides the axes (namely eigenvectors on EMC and MDA) which is better shown individuality or expression. We apply each of EMC and

MDA for classification of facial images into 50 classes of individuals or into seven classes of facial expression, and verify their effectiveness with some experimental results.

Methods for Class Features Analysis

Let F be a set of classes to analyze. For example, if it is necessary to analyze individuality, then F is sets of each individual class, and if it is necessary to analyze expression, then F is sets of each expression class. The facial pattern of M_f images is given in each class $f \in F$. The $m = 1, 2, \cdots, M_f$ th facial pattern is a N-dimension vector $\boldsymbol{x}_{fm}$ whose component is gray level of a N-size image.

Let z_{fm} be the projected value of the m-th image in the class f, let S_B be the inter-class variance and let S_W be the intra-class variance. We consider that it is favorable for the analysis that it projects feature vectors to eigenvectors whose inter-class variance is bigger than intra-class variance. We use EMC and MDA that select such eigenvectors.

EMC find eigenvectors to maximize the difference between inter-class variance and intra-class variance, subjecting to the constraints on those eigenvectors are orthogonal each other. On the other, MDA find eigenvectors to maximize the ratio of inter-class variance to the intra-class variance, subjecting to the constraints on those projected value is uncorrelated each other.

Experimental Results

Used Facial Images Database

50 people and 7 expression (Neutral, Happiness, Sadness, Anger, Disgust, Surprise, Fear), total 350 images were used as the data base of facial images for experiments. The position of the face, the normalization of the position, the size and the inclination were done for the purpose of matching of the face image as a treatment before the experiment based on the eye and the bottom of the nose.

Facial Individuality Analysis and Identification

We apply EMC and MDA to all facial images into database. We make synthesized facial images which are inverse transformed the value of a constant multiplied by standard deviation about transformed value of closed data by the k-th eigenvector. As to the synthesized facial image by an eigenvector about EMC, individuality tend to appear in the component of the low dimension, other factors tend to appear in the component of the high dimension. However, as for the tendency of the synthesized facial image by an eigenvector about MDA, The characteristics of the variation in each components don't appear. It is considered that the cause of the result is the big weight of the gray level which has small variance and big ratio of inter-class variance to the intra-class variance.

Then, we performed facial identification experiment by using some eigenvectors. Closed data was selected 6 expression into database, open data (test data) was selected another

1 expression. The classification result is the f which is the nearest distance between the vector $\overline{\boldsymbol{z}}_f$ (the average of $\boldsymbol{z}$ about m in closed data) and the input vector $\boldsymbol{z}$ in open data. Our used distance is the Euclid distance. EMC and MDA got a high correct classifications rate together by small number of used dimensions in comparison with PCA. Correct classifications rate was improved especially using MDA in case of by small number of used dimensions. It is considered that the cause of the result is the effect which enlarges inter-class variance by eigenvectors being unorthogonal each other.

Facial Expression Analysis and Classification

We asked 18 observers to classify the expression of each image into seven classes. We used the images for which at least 6 of observers agreed.

We apply EMC and MDA to those selected facial images. We make synthesized facial images which are inverse transformed the value of a constant multiplied by standard deviation about transformed value of closed data by the k-th eigenvector. As to the synthesized facial image by an eigenvector about EMC, expression tend to appear in the component of the low dimension, other factors tend to appear in the component of the high dimension. However, as for the tendency of the synthesized facial image by an eigenvector about MDA, The characteristics of the variation in each components didn't appear. It is considered that the result is by the similar cause.

Then, we performed expression classification experiment by using some eigenvectors. Closed data was selected 49 people into database, open data was selected another 1 person. EMC and MDA got a high correct classifications rate together by small number of used dimensions in comparison with PCA. Correct classifications rate was improved especially using EMC in case of by small number of used dimensions. It is considered that the cause of the result is the imbalance of the intra-class variance of each dimensions.