Chapter 2
A Multi-Linear Statistical Method for Discriminant Analysis of 2D Frontal Face Images

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ABSTRACT

This chapter describes a multi-linear discriminant method of constructing and quantifying statistically significant changes on human identity photographs. The approach is based on a general multivariate two-stage linear framework that addresses the small sample size problem in high-dimensional spaces. Starting with a 2D data set of frontal face images, the authors determine a most characteristic direction of change by organizing the data according to the patterns of interest. These experiments on publicly available face image sets show that the multi-linear approach does produce visually plausible results for gender, facial expression and aging facial changes in a simple and efficient way. The authors believe that such approach could be widely applied for modeling and reconstruction in face recognition and possibly in identifying subjects after a lapse of time.

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INTRODUCTION

Multivariate statistical approaches have played an important role of analyzing face images and characterizing their differences. The importance of using multivariate techniques to analyze face images is related to the well-known fact that face images are highly redundant not only owing to the evidence that the image intensities of adjacent pixels are often correlated but also because every individual has some common facial features such as mouth, nose, and eyes. As a consequence, an input image with *n* pixels can be projected onto a lower dimensional space without significant loss of information.

The most straightforward and successful statistical methods for visual interpretation of well-framed face images have been based on Principal Component Analysis (PCA). Since the pioneering works of Sirovich and Kirby (Sirovich & Kirby, 1987), and Turk and Pentland (Turk & Pentland, 1991), published approximately 20 years ago, several subsequent works have projected face images on a Principal Component Analysis (PCA) feature space to not only reduce the dimensionality of the original samples for further classification and analysis but also to interpret and reconstruct the most expressive components (Swets & Weng, 1996) described by all the training images. Impressive results on this latter goal have been achieved by the Active Appearance Model (AAM) proposed by Cootes et al. (Cootes et al., 1995; Cootes et al., 1998; Cootes et al., 2000; Cootes & Lanitis, 2004). Unfortunately, since the AAMs rely on PCA directions ranked by the principle of maximum variance, the first principal components with the largest eigenvalues do not necessarily represent important discriminant directions to separate sample groups.

Thus, in the last years, a number of novel multivariate statistical approaches inspired by AAM and its variants has been proposed to model human facial changes due not only to pose, lighting and expression, but also to aging on face recognition problems. For instance, Ramanathan and Chellapa (Ramanathan & Chellapa, 2006) have proposed a craniofacial growth model that estimates the shape variations of frontal face images of subjects under 18 years of age. Using specific facial landmarks based on anthropometric studies (Farkas, 1994), their method can be used to predict a subject's appearance across years and to perform face recognition of young faces taking into account the unique age progression of each subject (Ramanathan & Chellapa, 2006). Another recent work related to automatic age estimation based on facial features has been proposed by Geng et al. (Geng et al., 2007). In this work, a method named AGES (Aging PattErn Subspace) combines the 2D facial landmarks extracted by AAM with the time information of each sequence of a particular individual's face images, building an aging pattern composed of personal characteristics sorted in temporal ascending order. The performance of their method on automatically estimating the age of face images has been shown to be comparable to that of the human observers (Geng et al., 2007). The degradation in accuracy of automatic face recognition systems owing to temporal variance has also been investigated using 3D models. In 2010, Park et al. (Park et al., 2010) has extended the shape and texture face modeling from 2D to 3D domain, modeling and simulating an age invariant face recognition system on three different publicly available databases with good practical results.

In this chapter, we describe a multi-linear discriminant method of constructing and quantifying statistically significant unseen views of human identity photographs. Given a single photograph of an unseen subject it is possible to construct new images with, for example, a range of different expressions or with different gender characteristics. The method could be widely applied for modeling and reconstruction in face recognition and possibly in identifying subjects after a lapse of time. It is based on the use of two-stage method focused on a separating hyper-plane strategy and called

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