Chapter 11
Discriminant Learning Using Training Space Partitioning

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ABSTRACT
Large training databases introduce a level of complexity that often degrades the classification performance of face recognition methods. In this chapter, an overview of various approaches that are employed in order to overcome this problem is presented and, in addition, a specific discriminant learning approach that combines dynamic training and partitioning is described in detail. This face recognition methodology employs dynamic training in order to implement a person-specific iterative classification process. This process employs discriminant clustering, where, by making use of an entropy-based measure, the algorithm adapts the coordinates of the discriminant space with respect to the characteristics of the test face. As a result, the training space is dynamically reduced to smaller spaces, where linear separability among the face classes is more likely to be achieved. The process iterates until one final cluster is retained, which consists of a single face class that represents the best match to the test face. The performance of this methodology is evaluated on standard large face databases and results show that the proposed framework gives a good solution to the face recognition problem.

INTRODUCTION
During the past 30 years, machine recognition of human faces using still images and video sequences has become an active research area in the communities of video and image processing, pattern recognition, and computer vision. Face recognition (FR) technology has many practical applications, which can be categorized into the law enforcement and the commercial field. In the law enforcement area, this technology can be used to identify faces in a picture, to help, for example, police search a database of mug shots in order to identify a person shown in an incriminat-
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The automatic recognition of human faces presents a significant challenge to the aforementioned research communities. Typically, human faces are very similar in structure with minor differences from person to person. Furthermore, varying lighting conditions, facial expressions and pose orientations further complicate the FR task, making it one of the most difficult problems in pattern analysis. Several algorithms have been developed that attempted to overcome these difficulties. A central issue to all these algorithms is which features to use in order to represent a face. A second main issue is which classification scheme to implement in order to recognize a new face image, based on the chosen feature representation. Usually, a set of selected features is used to derive an optimal subset of features that would lead to high classification performance with the expectation that similar performance can also be displayed on future trials using novel test data. In addition to high recognition accuracy and robustness to various types of test data, FR methods need to have relative computational simplicity so that they can be applied to as many real-world applications as possible.

The most popular and successful FR methods usually utilize Principal Component Analysis (Kirby 1990, Turk 1991, Xudong 2008), Linear Discriminant Analysis (Lu 2003, Etemad 1997, Kyparountas 2007), Independent Component Analysis (Hyvärinen 2001, Bartlett 1998, Gao 2009), Non-negative Matrix Factorization (Lee 2001, Li 2001, Buciu 2008), Neural Networks (Lawrence 1997, Jain 2000, Wolfrum 2008), Graph Matching (Wiskott 1997, Tefas 1998, Tefas 2002), Support Vector Machines (Tefas 2001, Hotta 2008), Template Matching (Bruneli 1993, Fukunaga 1990), or Hidden Markov Models (Samaria 1993, Nefian 2000, Bevilacqua 2008). The aforementioned variations that appear in facial images limit the effectiveness of all these methods. Moreover, the FR problem becomes much more complex when large numbers of individuals are represented in a database, where more of the aforementioned variations are expected to be found. To make matters worse, it is often not the case that a sufficient number of training images are available for each individual. As a result, the intra-class variations cannot be modeled properly, making the FR problem more difficult to solve.

In this chapter, a Face Recognition methodology is presented that was designed to overcome the problems relating to large databases and insufficient numbers of training samples. Initially, state-of-the-art methods that target the problem of training a FR system using a large database are presented. Specifically, we overview divide-and-conquer and hierarchical space-tessellation methods that attempt to partition the training space in order to improve the recognition performance. Next, we present a method that dynamically partitions the training space throughout multiple classification steps. The performance of this method is evaluated experimentally and compared against other state-of-the-art solutions.

BACKGROUND AND RELATED WORK

During the last several years, great attention has been given to the active research field of face classification. For the Face Recognition (FR) problem, the true match to a test face, out of a number of \( N \) different training faces stored in a database, is sought. The FR problem becomes more complex
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