Chapter V
Face Recognition

In the modern life, the need for personal security and access control is becoming an important issue. Biometrics is the technology which is expected to replace traditional authentication methods that are easily stolen, forgotten and duplicated. Fingerprints, face, iris, and voiceprints are commonly used biometric features. Among these features, face provides a more direct, friendly and convenient identification method and is more acceptable compared with the individual identification methods of other biometrics features. Thus, face recognition is one of the most important parts in biometrics.

Since Kanade (1973) attempted automatic face recognition 30 years ago, many researchers have investigated face recognition. Research into face recognition can be categorized into three approaches. The first approach is the appearance-based method which represents the face image as a one-dimensional vector and applies algebraic or statistical tools for extracting the characteristics of the face image. The face images are represented as a vector and the pattern of these vectors are analyzed by pattern analysis methods such as principal component analysis (PCA) (Turk and Pentland, 1991a, Turk and Pentland, 1991b), linear discriminant analysis (LDA) (Belhumeur et. al., 1997), and independent component analysis (ICA) (Bartlett et. al., 2002). The second approach is the feature-based method which extracts the facial local features such as the eyes, nose, and mouth and analyzes the geometry of the extracted local features. Most early research which was proposed by Kelly (1970) and Kanade (1973) belonged to this category. The third approach is the-model based method which first constructs a model of the human face, then fits the model to the given face image and finally uses the parameters of the fitted model as the feature vector. An explicit modeling of face variations, such as pose, illumination and expression, can handle these variabilities in practice. However, the model construction is complicated and laborious, and facial feature points are difficult to extract automatically with robustness. Bunch

graph (Wiskott et. al., 1997), active appearance models (AAM) (Cootes et. al., 2001d), and 3D mophable model (3D MM) (Blanz and Vetters, 1999) belong to this category.

Among various face recognition methods, the holistic appearance-based approach is most prevalent. However, this approach often fails when the input face has internal and/or external variations. To tackle this problem, there are many examples of previous work presented in this chapter.

First, we review several approaches to cope with the pose variation in face recognition, which are divided into two categories: single-view based approaches and multi-view based approaches. The single-view based approach uses the single-view gallery, in which each probe image is transformed to a fixed, canonical head pose prior to nearest neighbor identification. There are two methods in the single-view based approach: the geometric method and the statistical approach. (1) The geometric method takes a single probe image at one pose and creates a full 3D face model for the subject based on just one image. Then, the 3D face model is used to re-render the face at a canonical pose (Blanz et. al., 2005). Although the geometric method is the state-of-the-art in the pose-invariant face recognition, it takes a lot of time to create a 3D face model from an image due to the iterative optimization. (2) The statistical approach treats the relationship between the frontal and the non-frontal images as a statistical learning problem. Beymer and Poggio (1993), Wallhoff et al., (2001), and Lee and Kim (2005) used this approach. The multi-view based approach uses the multi-view gallery, which consists of the multiple views of various poses for each known person. Pose-invariance is achieved by assuming that, for each probe face, there exists an image with the same face pose as the probe image for each known person in the gallery. Beymer (1994), Biuk and Loncaric (2001), Huang et. al., (2000), and Pentland et. al., (1994) divided the face images into several subsets according to the facial angles and represented each view in a different subspace, estimated the pose angle of each input facial image and projected the image onto the corresponding subspace, and then classified the face image in the projected subspace. The multi-view based approach is preferred because it avoids establishing the 3D face model from each pose image, which often tends to be a more complicated problem.

Second, we review several approaches to cope with the illumination variation in face recognition, which are divided into three categories: the invariant feature, the statistical, and the canonical form approach. The invariant feature approach seeks the features of the face which remains invariant under the illumination variation. 2D Gabor-like filters (Adini et. al., 1997), the retinex algorithm (Land, 1986), and the quotient image (Riklin-Raviv and Shashua, 2001) belong to this approach. The statistical approach learns the extent of the variation in some suitable subspace or manifold and performs the face recognition by choosing the subspace or manifold closest to the input image. Belhumeur and Kriegman (1998) and Georghiades et. al., (1998, 2001) introduced a generative appearance-based method for recognizing the human face under the illumination and viewpoint variation and argued that the images under all possible illumination conditions built a convex cone in the space of images and the reconstructed shape and albedo of the face from a small number of samples served as a generative model for rendering or synthesizing images of the face under the novel pose and illumination conditions. The canonical form approach attempts to normalize the illumination variation by transforming the input image into a normal condition and performs the face recognition using the transformed images. The illumination ratio image (Zhao et. al., 2003) and illumination transformation (Lui et. al., 2005; Lee and Kim, 2006) belong to this category.