Chapter 6
Robust 3D Face Identification in the Presence of Occlusions

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ABSTRACT
The face is one of the most natural biometrics, and as such, its acceptance by users is high. While biometrics such as fingerprint and iris can only be acquired with active cooperation of the user, the face can be acquired from a distance. This makes it an attractive modality for uncooperative scenarios. However, in such scenarios, occlusion is a common problem. The focus of this chapter is to illustrate the problems caused by 3D occlusion, and to go over solutions. The authors review 3D face identification approaches with focus on occlusion scenarios, introduce 3D databases containing occlusions, and present a prototype system with solutions for occlusion at landmarking, registration, feature extraction, and matching stages.

INTRODUCTION
The term biometrics refers to automated systems where physiological or behavioral characteristics of an individual are used for identification purposes. Face, fingerprint, iris, retinal image, vein, or voice can be listed among the physiological features used in biometric systems. Among others, face is the most familiar-to-human modality, since our cognitive system often utilizes facial data to recognize people. Moreover, face modality is highly preferred for automated systems, since the biometric data can be acquired in a contactless manner and it can be employed for non-cooperative scenarios. Due to these advantages, face recognition has a wide application domain, including surveillance, access control and human-computer interaction practices. Hence, it has been a popular research topic for the last three decades. Further research in the last decade showed that, face...
recognition in constrained acquisition scenarios can reach the performance levels of high security modalities such as fingerprint and iris (Phillips, 2007).

Initially, the face recognition studies focused on identifying people from their two dimensional (2D) facial images (Zhao, 2003). However, when non-cooperative and uncontrolled scenarios are considered, recognizing individuals from their 2D face scans remains as a challenging task. The main challenges including illumination differences, pose variations, and presence of facial expressions; triggered the shift of face representation from 2D modality to 3D. In the 3D domain, illumination differences, pose and expression variations can be better handled since the true geometric information residing in the 3D data is utilized. This shift was supported by the emerging sensor technology allowing acquisition of the 3D facial geometry. With the advances in sensing technology, large evaluation 3D face datasets became publicly available. In 2006, the Face Recognition Grand Challenge (FRGC) (Phillips, 2005) was presented as the first large evaluation set. The interest in 3D face recognition systems caused an enormous growth in research studies focusing on the 3D modality. A thorough survey of previously proposed 3D face recognizers can be found in (Bowyer, 2006; Scheenstra, 2005; Abate, 2007a) and details of some fundamental concepts can be overviewed in (Gokberk, 2008; Abate, 2007b; Papatheodorou, 2007). Besides the problem of expression handling, which has been extensively studied in recent years (Mian, 2008; Faltemier, 2008; Kakadiaris, 2007; Alyuz, 2010; Queirolo, 2010; Wang, 2010; Spreeuwers, 2011), occlusion variations remains as a challenging task. Although occlusions appear as a practical problem for realistic scenarios, they are not investigated well in the literature. Mainly, there are two types of occlusions. First of all, pose variations can cause self-occlusions during acquisition, where a part of the facial surface hinders acquisition of another region shadowed with respect to the sensor. These occlusions appear as missing data in the facial surface. The other type of occlusions can be caused by external objects such as hand, hair, scarf, eyeglasses and other objects. The second class of occlusions is more complex to handle, since the occluding objects alter the 3D facial geometry. In this chapter, we mainly focus on the second class of occlusions, where exterior objects partially cover the facial surface. Hereafter, the term “occlusion” will refer to occlusions caused by exterior objects. In the literature review section, we summarize the approaches handling exterior occlusions. Moreover, we briefly mention the classification approaches used for the first type of occlusions, since these classification approaches can be useful after the occlusions are detected and removed.

The recognition problem includes two different scenarios: (1) verification, and (2) identification. In verification, the probe face is presented with a claimed identity, and the system checks if the claimed identity is correct. In identification, the probe face is compared against a set of gallery images, and the identity is searched among the gallery subjects. In this paper, we mainly focus on the identification problem, using identification and classification terms interchangeably to refer to this scenario. In the literature, the term “recognition” is sometimes used to refer to identification, which we omitted here to avoid any confusion when identification is considered.

BACKGROUND

Face Identification Concepts and the Occlusion Challenge

In the presence of occlusions over the facial surface, alterations of the geometry complicate the identification process, affecting different stages of face identification systems. The main steps of a face identifier can be listed as: face detection, landmark localization, coarse and fine registra-
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Overview
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