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Survey

Near infrared face recognition: A literature survey

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ABSTRACT

As a primary modality in biometrics, human face recognition has been employed widely in the computer vision domain because of its performance in a wide range of applications such as surveillance systems and forensics. Recently, near infrared (NIR) imagery has been used in many face recognition systems because of the high robustness to illumination changes in the acquired images. Even though some surveys have been conducted in this infrared domain, they have focused on thermal infrared methods rather than NIR methods. Furthermore, none of the previous infrared surveys provided comprehensive and critical analyses of NIR methods. Therefore, this paper presents an up-to-date survey of the well-known NIR methods that are used to solve the problem of illumination. The paper includes a discussion of the benefits and drawbacks of various NIR methods. Finally, the most promising avenues for future research are highlighted.

Contents

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1. Introduction

Among the various recognition tasks in biometric technology, face recognition (FR) has received much attention in the field of computer vision. The first research on FR was conducted in the 1950s [1] and 1960s [2] and reported in the psychology and engineering literature, respectively. Despite significant developments and substantial progress in this domain, automatic FR is still a difficult task because of the wide range of variations in human faces caused by illumination, eyeglasses, head positions and facial expressions. Hence, methods that result in highly accurate feature extraction with high robustness to variations are crucial. Because FR is a main task of the human vision system, most researchers have concentrated on FR in the visible domain [3–22]. The main drawback of these studies, however, is the high dependency of their FR systems on illumination variations and even skin color [23]. Several illumination-invariant FR methods have been proposed, which fall into two main categories: passive methods and active methods (Fig. 1) [24].

In passive methods, visible spectrum images are studied to overcome the problem caused by illumination variation. Comprehensive surveys of illumination invariant methods, especially passive methods, were reported in [25,26]. The passive method can be categorized into four groups: illumination variation modelling [27–32], illumination invariant features [18,24,33–39], photometric normalization [40–43], and a 3D morphable model [44,45]. One major drawback of this approach, however, is the loss of useful information about facial images in illumination compensation.

For active methods, active imaging techniques are employed to overcome illumination variation. These methods are used to obtain facial images of illumination-invariant modalities or to acquire facial images taken in consistent illumination conditions. Active methods can be divided into those that use 3D information [45–48] and those based on infrared [49,50]. Infrared methods can be divided into thermal infrared [51–62] and near infrared [63–72]. The major drawbacks of active methods are increased costs and the high computational complexity of systems when 3D images are used. The other drawbacks of active methods, when thermal images are employed, include their high sensitivity to environmental temperatures, health conditions and perspiration [46,73].

Recently, near infrared imagery (NIR) has been used in many FR systems because of the high robustness of NIR cameras to illumination variations and the high quality of the acquired images [74,75]. As shown in Fig. 2, the NIR band falls between the visible light band and the thermal infrared band. NIR images have a main advantage in comparison with visible images. They are entirely free from the influence of external light. Hence, NIR images taken in the dark or under low illumination are much more informative than images acquired in the visible spectrum under the same conditions (see Fig. 3) [65,74]. As a result, FR systems based on NIR imagery are more accurate than those based on visible imagery.

Many surveys of the literature on the FR domain have been conducted. In particular, surveys of FR methods were performed by [25,46,47,53,76–80]. However, these surveys mainly focused on 3D active approaches, thermal active approaches or passive approaches. Active NIR approaches were not comprehensively described and critically analysed. A more recent review of active methods based on infrared illumination was reported in [50]. Especially noteworthy in [50] is the description of the main databases of infrared facial images. Some previous studies that addressed NIR FR were also presented in [50]. Nevertheless, this study might have been much more interesting if the authors had discussed NIR methods as comprehensively as they did thermal methods.

In this paper, we present an up-to-date overview of NIR FR methods. Our focus is on NIR methods that are used to compensate the illumination problem by means of active NIR illumination. The rest of the paper is organized as follows: in Section 2, the most recent methods are discussed and analysed, and recent works on unimodal NIR are emphasized. Previous surveys of infrared FR methods are also discussed and analysed. In Section 3, the specifications of NIR databases are given. Section 4 concludes the paper.

2. NIR methods

In this section, we describe and categorize NIR methods. In the FR domain, categorization is a critical task and is usually based on the target application, online or offline systems, initial principles, and publication dates. In this paper, we categorize the NIR FR methods according to their basic principles and mathematical tools, which enable us to determine the pros and cons of various approaches. We established five categories: (1) frequency-based methods; (2) LBP methods; (3) moment-based methods; (4) orientation-based methods; and (5) appearance-based methods (Fig. 4). Table 1 provides a chronological record of the selected methods. Our survey deals only with face recognition techniques, in which the system detects the location of the face in the image. If this is not the case (e.g., if the image contains several faces and/or other objects in unknown positions), the image must be preprocessed by using a face detection algorithm. Although face detection algorithms are beyond the scope of this paper, one was designed particularly for NIR images in [81].

2.1. *Frequency-based methods*

The first method in this category was used by Wen-Hung et al. [82]. In this study, frequency-based methods were used to correct and enhance NIR images. The problem of an artefact created in the process of NIR image formation was addressed, and an effective approach was introduced