Image and Vision Computing 52 (2016) 25–41

Contents lists available at ScienceDirect

Image and Vision Computing

journal homepage: www.elsevier.com/locate/imavis

On designing practical long range near infrared-based face recognition systems[☆]

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ARTICLE INFO

Article history:
Received 14 February 2014
Received in revised form 25 December 2015
Accepted 24 April 2016
Available online 4 May 2016

Keywords:
Forensics
Face recognition
Near infrared
Cross-scenario face matching
Demographic information
Night-time
Long-distance
Score level fusion

ABSTRACT

Although automated face recognition (AFR) is a well-studied problem with a history of more than three decades, it is still far from being considered a *solved problem* for the case of difficult exposure conditions, such as during night-time, in environments with unconstrained lighting, or at large distances from the camera. However, in practical forensic scenarios, it is often the case that investigators operate in difficult conditions, where cross-session data need to be matched and where, grouping of the data in the context of demographic information (constitute the grouping in terms of gender, ethnicity) may be used in order to assist law enforcement officials, forensic investigators and security personnel in human identification practices. In this paper, we discuss the challenges in designing a practical near infrared (NIR) FR system and, more specifically, study the problems of intra-spectral, cross-spectral, i.e. VIS–NIR, intra-distance and cross-distance NIR FR, in indoors, outdoors, day-time and night-time environments. Furthermore, we propose the usage of a multi-feature scenario dependent fusion scheme that can enhance recognition performance. We also investigate which scenarios used, related to datasets, features useful for face matching or their combination, are most beneficial to the identification accuracy of NIR FR systems, when the gallery set is composed of either visible or NIR band face images. Thus, we illustrate that the selection of specific feature extraction techniques and their fusion are often the key design aspects that can turn practically non-functional systems to effective systems with real-world applicability. As a result, such a strategy can significantly extend the range of conditions under which automated NIR FR systems can operate.

1. Introduction

Face recognition systems have long been a very important tool for security applications. Databases of passport-style photos of millions of people have traditionally been part of the citizen records of most nations. Such photos are usually taken under highly controlled conditions; the light source and direction, face pose, standoff distance (i.e. the distance between the camera (source) and the face (target)), as well as the background, for example, are kept within tightly controlled limits. However, for both security-related as well as consumer-based applications of face recognition, the conditions of the materials to be used for training or testing a human recognition system are much more varied. The variability of illumination sources and background, as well as poses variation and even partial facial occlusions, are usually the norm rather than the exception in freely-taken material, such as surveillance videos, photos posted on the internet. Furthermore, forensic material often needs to be taken in even harsher conditions: for example, during night-time, or at moderately long distances from the subject, often surpassing thirty meters (or about 100 ft) standoff distance.

Under such conditions, traditional face recognition approaches, such as those based on Local Binary Patterns [1] or Linear Discriminant Analysis [2], often provide unsatisfactory results, which can be practically unusable in a court of law, where typically face-based evidence needs to be extremely accurate so that it can provide to law enforcement officers a solid lead, to either identify or rule out suspects. Thus, it is a fact that multiple directions towards improving the design of more efficient and practical FR systems are being explored.

This work is an effort to investigate some of the challenges of unconstrained face recognition by focusing on *three main directions* (see Fig. 1): (i) the usage of both visible and near infrared sensors, (ii) dealing with challenging matching scenarios, where the problem domain is composed of: homogeneous or intra-spectral, and heterogeneous or cross-spectral matching studies, while also the face

☆ This paper has been recommended for acceptance by Massimo Tistarelli.

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http://dx.doi.org/10.1016/j.imavis.2016.04.013
0262-8856/

Fig. 1. Problem overview: matching cross-scenario face data, in which the probe face images are captured in the near infrared band when operating under difficult conditions, is a very challenging task. In this study, we, first, investigate variable face matching scenarios using academic, commercial and our proposed systems. In addition, we performed a study where the expectation is to improve FR performance by utilizing male and female groups in the context of demographic information of data in face matching studies.

images are acquired using different cameras, at day-time or night-time conditions, indoors or outdoors, at different standoff distances (up to more than 100 m away) and (iii) the usage of a multi-feature scenario depended fusion (MFSDF) face matching scheme (our proposed approach), with and without the support of grouping in the context of demographic information, which can assist in improving FR performance at the aforementioned challenging matching conditions.

One example pertaining to the *first two directions*, deals with the problem of identifying people both at day-time and night-time environments, at variable distances and at illumination conditions. This can be accomplished by using various types of visible (e.g. with telephoto lenses) and infrared sensors (Near, Short-Wave, Mid-Wave, and Long-Wave IR), under either single-spectral or multi-spectral recognition settings [3,4]. We also know that there are certain settings and configurations that provide increased identification performance during night-time operations, when using passive IR sensors [3], active IR sensors [5] or visible band sensors that operate during day-time and at medium distances [6].

One example pertaining to the *third direction*, deals with the problem of improving identification performance using our proposed multi-feature (LBP, Gabor and HOG) scenario-dependent fusion scheme. Our proposed scheme is tested on two different dual-band face datasets collected as part of two separate studies [7,8]. This is beneficial for the purpose of this study, since the subjects on each dataset are different and the faces of the subjects were captured

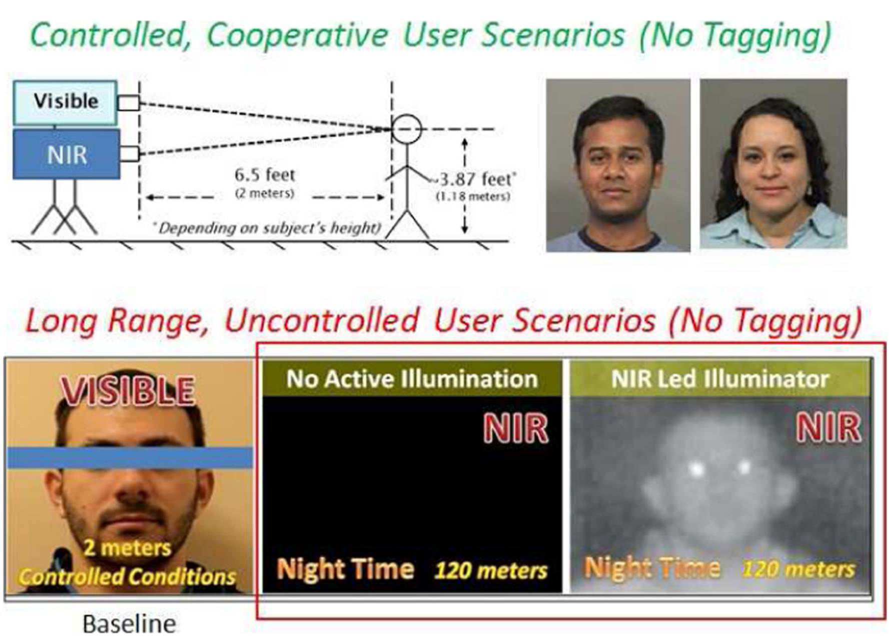

Fig. 2. Data collection scenarios of both visible and infrared face data, under controlled (top image) or uncontrolled (bottom image) conditions. The questions that need to be answered are (i) 'what is the baseline FR performance when performing cross-scenario matching?' and, (ii) 'can FR benefit from context of demographic information of data for the face images collected by surveillance cameras?'.