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Integration of multiple soft biometrics for human identification☆

Olasimbo Ayodeji Arigbabu[a,*], Sharifah Mumtazah Syed Ahmad[a], Wan Azizun Wan Adnan[a], Salman Yussof[b]

[a] Faculty of Engineering, Universiti Putra Malaysia (UPM), 43400 Serdang, Selangor, Malaysia
[b] Department of Systems and Networking, Universiti Tenaga Nasional (UNITEN), Selangor, Malaysia

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We propose a computational approach to human identification based on the integration of face and body related soft biometric traits. In previous studies on soft biometrics, several methods for human identification using semantic descriptions have been introduced. Though the results attained exhibit the effectiveness of such techniques in image retrieval and short term tracking of subjects, semantics literally limits the ability of a biometric system to provide conclusive identification. This paper presents a new framework for biometric identification based solely on multiple measured soft biometric traits. The paper describes techniques for extracting/estimating face and body based soft biometric traits from frame set. Furthermore, we utilized a sequential attribute combination method to perform attribute selection prior to integration at match score level. Finally, an evaluation of five score fusion techniques is performed. The results show that the proposed framework can be utilized to model an adequate soft biometric system with rank-1 identification rate of 88%.

1. Introduction

Biometrics is an area of research in the domain of computer vision that has attracted significant amount of interests due to its numerous applications in information security. Biometric recognition is mainly divided into two types, namely, verification and identification [23]. Verification involves one-to-one process of confirming the identity of a known individual as genuine or impostor. Identification on the other hand involves finding an unknown target in a cluster of known and unknown individuals. In this paper, we focus on biometric identification, which is an interesting mode of ascertaining human identity. Conventional approaches for solving an identification problem include the use of physical attributes of humans such as face, iris, fingerprint [1,17,24] or behavioral attributes such as gait [38]. These attributes are regarded as traditional biometrics, and they possess advantages such as permanence, distinctiveness, uniqueness, and universality. The disadvantages of using traditional biometric attributes include obtrusiveness and requirement of human compliance. Moreover, the performance of a system developed using traditional biometrics can deteriorate significantly under pose, illumination, occlusion, and expression variations.

Recent advances in studies on biometrics have resulted in a new identification method termed soft biometrics [5,22] which utilize labels, measurements, and descriptions of individuals for identification [5,22]. Some examples of soft biometrics are gender, ethnicity, weight, height, and skin color [16]. Soft biometric traits naturally lack distinctiveness and permanence, and a single soft biometric attribute cannot uniquely identify an individual [12]. An intelligent combination of multiple soft attributes can produce an adequate level of identification. Soft traits possess some advantages over their traditional biometrics counterpart such as low computational cost and time, data collection in a freely and naturalistic manner. Furthermore, the attributes are human compliant, exhibit low obtrusiveness, and can be inferred from far distance. Thus, soft biometrics were initially introduced as added characteristics to accompany traditional biometrics, for either fusion of traditional and soft biometrics [22] or search space reduction [14]. Considering the advantages and disadvantages of traditional and soft biometrics, we make a logical subjective conclusion that traditional biometrics are more suitable for constrained identification scenarios. For instance, the widely used fingerprint recognition system requires the user to making contact with the fingerprint scanner for recognition. Also, the performance of face or iris recognition system can deteriorate as the distance to the acquisition device increases.

However, some soft biometrics can easily be inferred from great distance in an unconstrained manner such as estimating the height of a person or extracting the skin color information of individuals without cooperation of the targets [19,40]. We briefly mention here that this paper is not concerned with replacing traditional biometrics with soft biometrics, but only gain an insight into the level of reliability of soft traits and the extent to which the attributes can be solely used for biometric identification from video recordings.

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* Corresponding author. Tel.: 60143976379.
E-mail address: oa.arigbabu@gmail.com (O.A. Arigbabu).

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As such, some aspects of this paper include specification of a work scope/operational scenario and the possible application of this enquiry. The remainder of the paper is organized as follows. Section 2 provides review of previous works from two different perspectives to highlight the problem of the study. Section 3 describes the utilized dataset and scope/operational scenario of this work. In Section 4, we present an in-depth explanation of the materials and methods. Section 5 presents the evaluation protocols, results attained, and performance analysis. Finally, conclusion is drawn in Section 6.

2. Related works

We briefly discuss the earlier studies on soft biometrics, in order to substantiate the essence of the problem being investigated in this paper.

2.1. Improving traditional biometric identification

Previous studies have shown that soft biometrics can either be measured or derived as semantics for improving the performance of traditional biometric systems [11,14,29,30,33]. Several literature studies have examined the possibility of fusing soft biometric information such as height, weight, body fat, gender, and ethnicity with face, iris, and fingerprint. [4,22]. In fact, it has been reported that integrating soft biometrics into fingerprint recognition system improved the system's accuracy by ~6% [22]. The total error rate of a fingerprint recognition system also reduced from 3.5% to 1.5% by integrating body fat and weight [4]. Furthermore, soft biometrics can be deployed to narrow down the search from a large database, to speed up identification process [14,43]. In addition, the usability of quantitative semantic descriptions has been investigated to improve both face and gait recognition [36,42]. It is obvious from the literature that soft biometrics can be adequately used to improve traditional biometrics. However, in the described systems, the soft traits were mainly used as secondary identifiers. Hence, an evaluation of the importance and reliability of the attributes for identification has not been thoroughly explored.

2.2. Utilizing soft biometrics for identification

Some studies have performed identification solely based on multiple soft biometrics, extracted as semantics [26,34,39]. In this respect, it is important to note that soft biometrics are not aimed towards performing shrewd authentication or verification, but rather to locate a target in the list of people with close resemblance in the database. Examples of application of such systems are crime investigation, identification at a distance, and data retrieval [15]. Dantcheva et al. [13] investigated the usability semantic descriptions of facial soft biometric traits such as eye color, hair color, skin color, beard, moustache, and glasses. These descriptions were further used to evaluate the level of interference that occurs, when different subjects share similar descriptions. The probability of collision between two randomly chosen authentication groups was computed to evaluate the system's performance. Similarly, an analytical approach based on the comparative analysis of face descriptions has been examined by Reid and Nixon [35]. Though verbal (semantic) descriptions are effective for crime analysis, but in practical biometric system, conclusive identification cannot be attained with semantics. In addition, semantic descriptions can be very subjective depending on the perception by the human observer.

With regard to this, we propose to measure face and body related soft biometric information for human identification. Our interest in this paper is to enable identification of targets from video recordings using attributes that can be measured directly from frame set rather than relying on descriptions by an eyewitness. To this end, each attribute is basically considered as an independent entity and the individual match scores resulting from each model are combined for biometric identification. The attributes used in this study include facial shape, height, body weight, and skin color. We understand that height and weight have previously been explored for biometric identification [3]. However, the authors made use of weighing scale and manually collected the height information of the subjects, which is not practicable in automated systems. Besides, height and weight are not sufficient for biometric identification.

2.3. Main contributions

There are two different approaches for extracting soft biometric information. One is based on verbal (semantic) descriptions, while the other method involves direct extraction (measured) from the image [36]. Considerable amount of research effort has been invested on investigating fusion of several semantic descriptions for human identification [15,36,42]. However, to the best of our knowledge, in-depth analysis on integration of face and body based soft biometric traits that are directly measured from video recordings has not been explored.

The novelty of this paper is to demonstrate with experimental evidence how face and body based soft biometric information that are automatically measured from video recordings can be used to model an identification system with adequate performance. Particularly, the main contributions of the paper are stated as follows:

- A new local feature descriptor is proposed to perform facial shape representation. The descriptor is an improvement over pyramid histogram of oriented gradient (PHOG). We show the trend in performance of the descriptor through comparisons with related state-of-the-art methods on standard still and video surveillance based face recognition datasets.
- We propose a multi-soft biometric identification system that combines both facial and body information. Our framework eschews the use of color related attributes, making the system more useful for long term identification task.
- We present an experimental comparison of five score fusion techniques (sum rule, weighted sum, fuzzy logic, Bayesian, and support vector machine). From our results, fuzzy logic is discovered as the most reliable fusion method for soft biometric identification.

3. Experimental dataset and operational scenario

This paper is concerned with crime situations, where a single camera is employed for capturing the misconduct of offenders. Several of such occurrences are common in real situations, where short video clip of a recently occurred crime event is captured by a human observer. This very low quality and rather informal recording of crime events has proven to be essential in immediate tracking of criminals. We mimicked such recording setting by capturing arbitrarily walking subjects with a single mounted camera [6]. The database "UPM SOFTBIO" is a compilation of 101 walking subjects, which spanned over three different sessions. The subjects have different appearances in each session in terms of clothes, and for some subjects, a minor change in hair style and shoes [6]. In the mentioned database, 58 subjects are male and 43 are female. 51 subjects are from South Asia (29 Chinese and 22 Malay), 28 subjects are from the Middle East, 16 from Central Asia, and 6 are Africans. 62 subjects are between 20 and 30 years, while 39 subjects are between 31–45 years. The minimum standing height of the subjects is 144 cm and the maximum is 197 cm, while the minimum body weights is 40 kg and maximum is 119 kg [6].

In this paper, we utilized the datasets of 70 subjects, whereby, the data recorded in session 1 are selected for training (gallery set) and session 3 data are used for testing (probe set). In other words, the data recorded in session 2 are not considered in most of our experiments, in order to incorporate wider time and appearance variations