Neurocomputing 135 (2014) 218–228

Contents lists available at ScienceDirect

Neurocomputing

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

Exploring soft biometric trait with finger vein recognition

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ARTICLE INFO

Article history:
Received 4 July 2013
Received in revised form
9 December 2013
Accepted 18 December 2013
Communicated by Prof. X. Gao
Available online 18 January 2014

Keywords:
Finger vein recognition
Soft biometric trait
Width of phalangeal joint
Hybrid framework

ABSTRACT

Soft biometric trait has been used as ancillary information to enhance the recognition accuracy for face, fingerprint, gait, iris, etc. In this paper, we present a new investigation of soft biometric trait to improve the performance of finger vein recognition. We first propose some extraction criteria of soft biometric trait for comprehensively understanding this kind of ancillary information. And then based on these criteria, the width of phalangeal joint is employed as a novel soft biometric trait, which can be directly extracted from finger vein image. Finally, three frameworks are developed to conduct the combination of the width measurement and finger vein pattern, i.e., the fusion framework, the filter framework and the hybrid framework. We perform rigorous experiments both on the open and self-built finger vein databases, and experimental results illustrate that soft biometric trait can make promising improvement of finger vein recognition performance.

1. Introduction

Biometrics is an automatic user authentication technology, which uses human physiological and/or behavioral characteristics with several desirable properties like universality, distinctiveness, permanence and acceptability. In recent years, there has been an increasing interest in finger vein recognition, which is motivated by the advantages of finger vein in living-body identification, non-invasive and non-contact image capture, and high security over other biometric recognition techniques (e.g., fingerprint, face, iris, voice, gait, etc.) [1].

Many efforts are contributed to develop an effective feature extraction method in finger vein recognition. The related works can be classified into three groups. The methods in the first group were based on the segmentation of finger vein, for example, the repeated line tracking method [2], the maximum curvature point method [3], the mean curvature [4] and the Gabor filter [5]. In these methods, the vein network is segmented firstly, and then the geometric shape or topological structure of the network is extracted for matching. However, the segmentation results of low quality images are often unsatisfying. Principal component analysis (PCA) [6], linear discriminant analysis (LDA) [7] and two-directional and two-dimensional principal component analysis ($(2D)^2$PCA) [8] were used to extract finger vein feature in the second group. These kind of methods were based on the dimensionality reduction technique, which will transform the image matrix to a one-dimensional or two-dimensional feature matrix by a trained projection matrix. But, the more users in database, the more complicated is the training process of projection matrix, which limits the application of these methods. Finger vein texture descriptors based on the binary code were used in last group, which included the local binary pattern (LBP) [9], the local line binary pattern (LLBP) [10], the personalized best bit map (PBBM) [11], etc. These methods are sensitive to the translation and rotation of finger in image. In addition, there are many other problems in finger vein recognition, such as the various qualities of finger vein images affected by user's physiological factor and the imaging conditions, high intra-class variation introduced by unconstrained imaging, low inter-class variation of some users and non-ideal population coverage.

To overcome these problems, a multimodal biometric system was employed, which combined the evidences obtained from finger vein and other traits. Some typical studies on multimodal biometrics are given as examples of recent works. The scores of finger vein, fingerprint and face were fused using weighted sum rule and support vector machines (SVM) in [12]. Unfortunately, the experimental results were from a virtual multimodal database, which combined fingerprint and face images of one person with finger vein image of another person. Hand-based multimodal biometric systems were introduced in the remainder studies. Yang and Zhang proposed the supervised local-preserving canonical correlation analysis method (SLPCCAM) to generate fingerprint-vein feature vectors in feature-level fusion [13]. Finger vein and finger dorsal texture were fused using the proposed holistic fusion and non-linear fusion methods at the score level in [5]. Kang and Park integrated finger vein and finger geometry by means of SVM-based score level fusion [14]. However, along with the higher recognition accuracy, a variety of limitations appear in multimodal

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0925-2312/$ - see front matter
http://dx.doi.org/10.1016/j.neucom.2013.12.029

biometric system, such as, the longer recognition time, the higher cost for multiple high quality sensors and the more inconvenience to user.

A preliminary study about soft biometric trait was presented by Jain et al. [15]. Soft biometric trait was defined as characteristic which provided some information about the individual, but lacked the distinctiveness and permanence to sufficiently differentiate any two individuals, like height, gender and ethnicity. The experimental results suggested that these characteristics can assist user recognition. Inspired by this literature, we think that it may be a good solution to use soft biometric trait to improve the performance of finger vein recognition in a reliable and user-friendly way.

This paper explores the usage of soft biometric trait in finger vein recognition. To deeply understand soft biometric trait and its usage, we firstly summarize and analyze soft biometric trait-related main works. In order to discriminate the dependence of soft biometric trait on primary biometric trait, we classify this kind of ancillary information into three categories. Furthermore, the extraction criteria of the ancillary information are presented to define the applicable soft biometric trait. Based on these criteria and thorough research of finger vein image, we propose a new soft biometric trait, i.e., the width measurement of phalangeal joint, to supplement the primary information of vein pattern. This new soft biometric trait has strong dependence on finger vein, which can be directly extracted from finger vein image.

Last, in order to maximize the recognition performance of soft biometric trait, three frameworks are developed for combining soft biometric trait and primary biometric trait, i.e., the fusion framework, the filter framework and the hybrid framework of filter and fusion. We compare the performance of these frameworks in both the recognition accuracy and speed, and the experimental results display that the hybrid framework outperforms the two other frameworks.

The remainder of this paper is organized as follows. In Section 2, we focus on the introduction of soft biometric trait, including a survey of previous works, the soft biometric trait extraction criteria and the proposed soft biometric trait. Following it, the usages of soft biometric trait in the developed frameworks are presented in detail in Section 3. Section 4 describes the experimental databases and settings, and shows the experimental results and analyses of these results. Last, the key conclusions of this paper are summarized in Section 5.

2. Soft biometric trait

2.1. The related work

In many literatures, the usage of soft biometric trait in biometrics has been investigated, and the promising improvement of recognition performance has been reported. According to the dependence of soft biometric trait on primary biometric trait, we divide this kind of ancillary information into three categories. In the first category, there is no dependence between soft biometric trait and primary biometric trait, in other words, the soft biometric trait needs to be captured by the additional device, such as height in fingerprint recognition. In the second category, the dependence is limited, and soft biometric trait can be derived from primary biometric trait, for example, gender and ethnicity in face recognition. In the last category, soft biometric trait has strong dependence on primary biometric trait, which appears on the image of primary biometric trait, for example, stride length in gait recognition.

About soft biometric trait without dependence on primary biometric trait, three typical literatures are presented. Jain et al. presented a framework for integrating soft biometric trait with the primary biometric by the Bayes formula [16]. An improvement of 5% was obtained for fingerprint recognition performance with the ethnicity, gender and height information. Although fingerprint was used as the primary biometric trait, face image was also captured for estimation of the ethnicity and gender information, which makes inconvenience for user. In addition, the other problem is that the height information, which was randomly drawn from a Gaussian distribution in above literature, is needed to be measured by a specific device in practical application,

Ailisto et al. examined whether fusing weight and fat percentage can improve the fingerprint performance in verification mode [17]. The total error rate (TER) decreased from 3.9% to 1.5%. In their case, the primary biometric trait has no direct relationship with soft biometric traits. Besides, the result for the fat percentage was very poor with minimum TER 35%, which indicated that the fat percentage was questionable in distinctiveness.

Jain and Verma proposed a three-level recognition scheme [18]. In this scheme, if the weight matching was successful in level one, the matching in level two continued by the finger geometry. Otherwise, the claimed identity was seen as "impostor" in level one. Similarly, if the matching was also successful in level two, the fingerprint matching was thirdly performed in last level, and if not, the claimed identity was rejected as "impostor" in level two. Although the finger geometry was extracted while scanning fingerprint, weight need to be measured by an additional device. What is more, the greatest regret is that there was no experiment to verify the effectiveness of the proposed scheme in their work.

In the following literatures, the ancillary information can be derived by a classifier in the machine learning process. Lyle et al. used local appearance features extracted from the periocular region images for gender and ethnicity (i.e., Asian and non-Asian) classification, and further employed the gender and ethnicity information to enhance the periocular recognition [19]. Giot and Rosenberger derived the user gender from keystroke typing pattern using non-linear classifier SVM [20]. The improvement on keystroke dynamics authentication by supplementing gender information through pattern and score fusion was proved. These two works verified that the soft biometric information derived from the primary biometric trait is helpful for identity recognition, but the classification accuracies of ancillary information were limited, with 93% and 91% of the gender and ethnicity [19], and approximate 91% of the gender [20].

Different from the above gender and ethnicity information derived from the primary biometric trait, some ancillary information appear on the image of primary biometric trait, which can be directly extracted from the image. Laplacian-of-Gaussian (LoG) and morphological operators were used to detect facial marks (e.g., freckles, moles and scars) from face image [21]. This work showed three usages of facial marks. (1) To supplement primary features in an existing face matcher. (2) To enable fast retrieval from a large database. (3) To enable matching or retrieval from a partial or profile face image with marks. The rank-1 identification accuracy improved from 92.96% to 93.90% and from 91.88% to 93.14% on FERET and Mugshot images, respectively. Besides, Park and Jain classified facial marks into 10 semantic categories based on morphology and color of the marks [22]. The class label of facial mark was used to supplement the face feature, along with the location, gender and ethnicity information. Facial marks were also used to differentiate identical twins in this work. Jain et al. used facial marks to search a large face database with partial or low-quality face images in forensics applications [23].

Apart from the application of facial marks in face recognition, macro-features on the iris image and user height and stride length on the gait sequence were separately used as soft biometric traits in [24,25]. The visible macro-features, such as, moles, freckles, nevi