Information Sciences 268 (2014) 20–32

Contents lists available at ScienceDirect

Information Sciences

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

Comparative competitive coding for personal identification by using finger vein and finger dorsal texture fusion ☆

Wenming Yang *, Xiaola Huang, Fei Zhou, Qingmin Liao

Department of Electronic Engineering, Graduate School at Shenzhen, Tsinghua University, Beijing, China
Shenzhen Key Laboratory of Information Science and Technology, Guangdong, China
Visual Information Processing Lab, Tsinghua-PolyU Biometrics Joint Lab, China

ARTICLE INFO

Article history:
Available online 21 October 2013

Keywords:
Personal identification
Multimodal biometric
Finger veins
Finger dorsal texture
Comparative competitive code

ABSTRACT

In this paper, we present a multimodal personal identification system that fuses finger vein and finger dorsal images at the feature level. First, we design an image acquisition device, which can synchronously capture finger vein and finger dorsal images. Also, a small dataset of the images has been established for algorithm testing and evaluation. Secondly, to utilize the intrinsic positional relationship between the finger veins and the finger dorsal, we perform a special registration on two kinds of images. Subsequently, the regions-of-interest (ROIs) of both kinds of images are extracted and normalized in both size and intensity. Thirdly, we develop a magnitude-preserved competitive code feature extraction method, which is utilized in both the finger vein and finger dorsal images. Furthermore, according to the preserved magnitude, a comparative competitive code (C^2Code) is explored for finger vein and dorsal fusion at the feature level. The proposed feature map of C^2Code, which contains new features of junction points and positions from the finger vein and finger dorsal image pairs, is extremely informative for identification. Finally, the C^2Code feature map is fed into a nearest neighbor (NN) classifier to carry out personal authentication. Experimentally, we compare the performance of the proposed fusion strategy with that of state-of-the-art unimodal biometrics by using the established dataset, and it is found that there is higher identification accuracy and lower equal-error-rates (EERs).

1. Introduction

Biometrics, such as fingerprints, face, irises, palmprints, veins, finger-knuckle-prints (FKPs), ears, voice, signature, etc. [14,15,26,37,44,45], is the most secure and popular means used to determine personal identification and verify requirements for public security and privacy protection. Due to increased flexibility and higher user acceptance, hand-based biometrics has attracted more attention from researchers and engineers in comparison to other types of biometrics in the past decades.

It is well known that fingerprint recognition is not only the most early and classic means of hand-based biometrics, but also the most mature in real-world applications, such as [45,7,9,10,24]. Although fingerprint identification has a longer history and there are larger available related databases, the lack of anti-counterfeiting capability, caused by ease of fingerprint

☆ This work is supported by Shenzhen Fundamental Research Project (No. JC201006030866A).

* Corresponding author. Address: Room 102B, Building F, Tsinghua Campus, The University Town of Xili, Lishui Road, Nanshan District, Shenzhen 518055, China. Tel.: +86 755 26036461; fax: +86 755 26036443.

E-mail addresses: yangelwm@163.com (W. Yang), hxl0913@126.com (X. Huang), flying.zhou@163.com (F. Zhou), liaoqm@tsinghua.edu.cn (Q. Liao).

0020-0255/$ - see front matter © 2013 Elsevier Inc. All rights reserved.
http://dx.doi.org/10.1016/j.ins.2013.10.010

copying and forgery, means that fingerprint identification is not the most ideal in circumstances where high security is required.

Palmprint identification [46], as a potential alternative means of identification, has been another widely researched type of hand-based biometrics. It has achieved great success in the past decade. Moreover, many algorithms on palmprint identification with high accuracy were explored to meet both low-resolution and real-time requirements [46,47]. However, its anti-counterfeiting capability is also lacking because palmprint features that are similar, such as principle lines, wrinkles and ridges, may appear on the hands of different people [46]. Also, the forgery of palmprints is not very difficult although it is relatively more difficult to do so than in the case of fingerprints [47].

Ravikanth and Kumar [31] proposed a new biometric identifier for personal authentication, called finger-back surface [31] or finger knuckle surface [16]. The finger-back texture, which refers to the patterns of the upper surface around the phalangeal joint, is unique and has been utilized for personal identification [2,3]. Based on this such, Kumar and Ravikanth [14] and Kumar and Zhou [17] designed a series of new feature extraction algorithm and recognition methods. Another state-of-the-art technique applies a scale-invariant feature transform (SIFT) algorithm to finger-knuckle-print (FKP) images filtered by a 2D Gabor filter [28]. In [44,48–50], Zhang et al. utilized Gabor filters and phase-only-correlation (POC) to extract local and global information of FKP images and designed an integral biometric system. In comparison with palmprints, this FKP system uses a smaller device with greater flexibility in image acquisition. Actually, FKPs are also based on the skin surface and their lack of anti-counterfeiting capability still remains a challenge. Obviously, some other highly discriminative biometrics, not within the scope of skin biometrics, need to be explored which would have to include high anti-counterfeiting capabilities.

In recent years, vein identification has been emerging as a promising research topic in biometrics. The network pattern and structure of blood vessels underneath the skin are unique and consistent. This is especially the case for veins, which are internal and relatively more difficult to forge than external traits. Thus, hand [18,23,33], finger [26,27,38–41] and palm veins are attracting increasing more attention. Wang et al. [34] and Kumar and Prathyusha [19] utilized hand veins as a characteristic to perform personal authentication. Unimodal palm vein identification based on multiscale filtering has been proposed in [51]. Zhou and Kumar [52] presented two new approaches to improving the performance of palm vein based identification systems. Undoubtedly, these methods based on hand and palm veins have achieved great success in moving vein recognition technology forward. However, in terms of alternatives and flexibility, finger veins should be preferable. Miura et al. [27] proposed a repeated line tracking method to extract finger vein features for identification. In 2007, a method of calculating local maximum curvatures in cross-sectional profiles of a vein image was developed which significantly improved the accuracy and robustness of finger vein identification [26]. Yang and Yang [39,40] and Yang and Shi [41] proposed a series of enhanced finger vein image localization methods for personal authentication. Thus, finger veins have become a popular area in research.

However, each biometric has its own set of intrinsic weaknesses. The users of unimodal biometric systems often contend with a variety of problems during algorithm designing, such as noisy data, intra-class variations, restricted degrees of freedom, non-universality, spoof attacks and unacceptable error rates [35]. The utilizing of more features and fusing of multiple modalities have mainly been the tendency in the development of biometrics. A considerable number of biometric combinations have consequently resulted. These combinations include fingerprint and face [8], face and voice [1], palmprint and hand geometry [20], fingerprint, palmprint and hand shape [21], palmprint and face [29], palmprint and palm veins [35,36], hand veins and knuckle surface [18], finger veins and finger-dorsal texture [37], fingerprint and finger veins [42], finger veins and finger texture images [17], etc. In terms of choosing the type of biometric and combination, different combinations lead to different performances. A comparison is shown in Table 1. *Flexibility* means the number of alternatives that exist in a person. So the flexibility of the face is lower than that of the palmprint, which is lower than that of the finger. *Imaging simplicity* means the number of imaging devices and the complexity of the capturing procedure. For instance, the use of fingerprints and the face needs two different cameras to capture the images of the different characteristics in these two places, so the imaging simplicity is lower than that of the palmprint and palm veins. *Mutual correlation* means the intrinsic relationship and correlation of the two or three biometrics selected. Obviously, the mutual

Table 1
Performance comparison of biometric combinations.

Combination	Performance			
	Flexibility	Anti-counterfeiting	Imaging simplicity	Mutual correlation
Fingerprint + face	Medium	Low	Low	Low
Fingerprint + voice	Medium	Medium	High	Low
Palmprint + hand geometry	Medium	Medium	High	Medium
Fingerprint + palmprint + hand shape	Medium	High	Low	Medium
Palmprint + face	Low	Low	Low	Low
Palmprint + palm veins	Medium	High	High	High
Hand vein + knuckle surface	Medium	High	Medium	Medium
Finger veins + Fingerprint	High	High	High	Medium
Finger veins + finger dorsal texture	High	High	High	High