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The biometric recognition on contactless multi-spectrum finger images

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HIGHLIGHTS

- Presents a novel multimodal biometric system based on contactless multi-spectrum finger images.
- Presents an efficient way to perform ROI extraction on contactless fingerprint, finger vein, and knuckleprint.
- The proposed system achieves an equal error rate of 0.109%, and also satisfies the real-time requirements of the applications.

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ABSTRACT

This paper presents a novel multimodal biometric system based on contactless multi-spectrum finger images, which aims to deal with the limitations of unimodal biometrics. The chief merits of the system are the richness of the permissible texture and the ease of data access. We constructed a multi-spectrum instrument to simultaneously acquire three different types of biometrics from a finger: contactless fingerprint, finger vein, and knuckleprint. On the basis of the samples with these characteristics, a moderate database was built for the evaluation of our system. Considering the real-time requirements and the respective characteristics of the three biometrics, the block local binary patterns algorithm was used to extract features and match for the fingerprints and finger veins, while the Oriented FAST and Rotated BRIEF algorithm was applied for knuckleprints. Finally, score-level fusion was performed on the matching results from the aforementioned three types of biometrics. The experiments showed that our proposed multimodal biometric recognition system achieves an equal error rate of 0.109%, which is 88.9%, 94.6%, and 89.7% lower than the individual fingerprint, knuckleprint, and finger vein recognitions, respectively. Nevertheless, our proposed system also satisfies the real-time requirements of the applications.

1. Introduction

Social developments lead to increasing demands for information security. For such security, technological progress implies that the main trend in personnel identification and authentication is of approaches based on specific behaviors or physiological characteristics of human beings; such approaches include face, fingerprint, finger vein, ear, and gait recognitions [1]. However, these types of aforementioned unimodal biometrics have their own advantages and disadvantages, and none is perfect. For example, fingerprint recognition is relatively mature, with a high distinction ability, but such systems are easily affected by surface stains and low anti-counterfeit abilities; finger vein recognition has low exterior disturbance and high anti-counterfeit ability but is slightly weaker on distinction ability; also, it has relatively low recognition precision; knuckleprints and palmprints have been emerging as the new biometrics, with easy-acquired distinct textures and rich information, but the uniqueness of such prints has not been proved. Therefore, a single biometric cannot satisfy the increasing requirements of information security.

Recently, a number of researchers have considered the fusion of two or more biometrics to improve recognition performance and authentic security. Because of convenience and the low cost of acquisition, multimodal biometric recognition, which mainly relies on the fusion of multiple features captured by cameras, has become more popular. Such a system falls into either of the following two groups: (1) systems based on single spectrum images, such as fingerprint and palmprint [2,3], palmprint and hand shape [4,5], palm vein and hand geometry [6], finger vein and finger shape [7,8], and gait and body structure [9] and (2) systems based on multi-spectrum images, such as fingerprint and finger vein [10,11], finger vein and finger dorsal texture [12], palmprint and palm vein [13,14], and face-visible image and infrared image [15,16].

The information contained in different spectrum images is well known to be complementary. Under near-infrared (NIR) light and

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visible light, different features can be extracted from different parts of a finger, such as finger vein, fingerprint, finger shape, and knuckleprint. Since the biometric features on fingers are both easy-acquired and affine, a tiny device has been proposed for the acquisition of NIR images [17], and score-level fusion strategy is performed for the extracted finger-shape contour and vein texture. In [18], where the aim is to take full advantage of multimodal biometric features, a multi-spectrum image acquisition instrument has been devised for the acquisition of finger-part biometrics: finger vein, fingerprint, and finger shape images, and score-level fusion has been performed on those, with an equal error rate (EER) of 0.254%. Inspired by [18], we present a novel biometric recognition system based on contactless multi-spectrum finger images; the system is able to simultaneously acquire visible light and NIR images. After preprocessing, three types of biometric features (contactless fingerprint, knuckleprint, and finger vein) are extracted, and then score-level fusion is performed. Compared with the instrument of [18], our instrument obtains more intact visible-light images, that include richer information from the knuckleprint. So, in addition to fingerprints and finger veins, knuckleprints are also utilized in the system described in this paper; this helps achieve better distinction than the case with the extraction of finger contours from NIR images, as in [18]. Furthermore, in our system different feature-extraction methods are chosen according to what is most suitable for different biometrics; this helps ensure precision and effectiveness.

An overview of the system is shown in Fig. 1. According to previous research, fingerprints acquired with a contact system present better contrast between ridges and valleys than those acquired with contactless systems [19]. Hence, the minutiae-extraction method used with contact fingerprint images is not suitable for the blurred contactless fingerprint images. The local binary patterns (LBP) algorithm is well known for its ability to represent original texture and distribution information without minutiae extraction; hence, we adopted it for feature extraction on contactless fingerprint images. Additionally, the LBP algorithm has also been proved to be an efficient method, with good performance for vein recognition [10]. For similar reasons, we too chose it for finger vein recognition in our system. In a contactless system, a knuckleprint differs from a fingerprint or a finger vein on the basis of obtaining clear and rich information; thus, it makes extracting feature points easy. The Oriented FAST and Rotated BRIEF (ORB) algorithm has been shown to have promising performance and high computing speed, and for these reasons we chose it for knuckleprint recognition in our system.

The rest of the paper is organized as follows. In the next section, our biometric feature acquisition system is introduced. Section 3 gives the details of image preprocessing. In Section 4, the corresponding feature extraction and matching algorithms are presented for the three types of chosen biometrics: fingerprint, finger vein, and knuckleprint. Score-level fusion strategy is also presented in Section 4. The experimental results and discussions are given in Section 5. Finally, the conclusions are given in Section 6.

2. Image acquisition system

As mentioned above, since this is a novel study, no literature is available on biometric recognition based on the fusion of contactless fingerprint, knuckleprint, and finger vein; corresponding

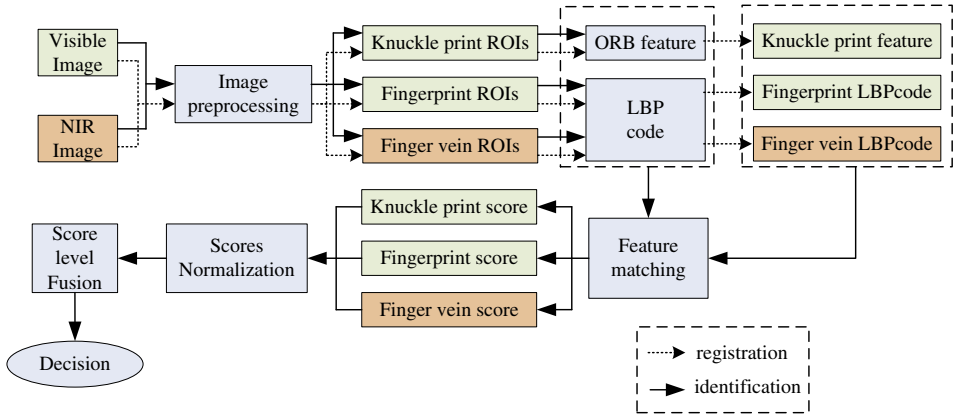

Fig. 1. Overview of our proposed method.

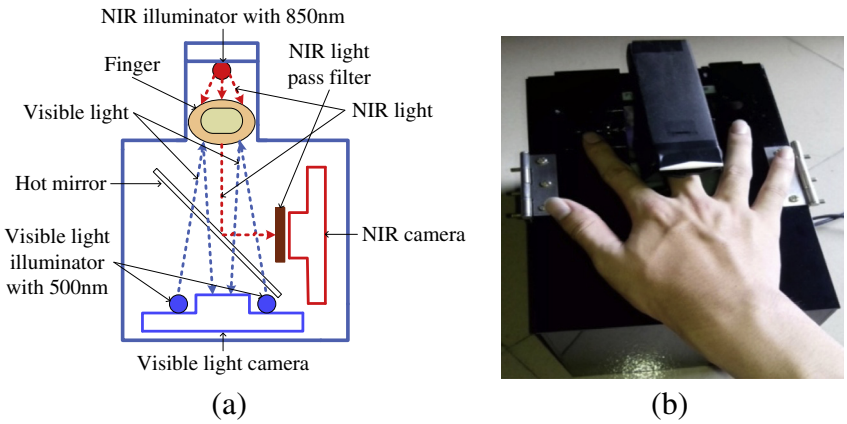

Fig. 2. Proposed acquisition system: (a) principle of acquisition device and (b) acquisition instance.