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Multimodal biometric authentication based on score level fusion of finger biometrics

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ABSTRACT

In this article, we propose a novel finger multimodal biometric authentication that combines finger vein, fingerprint, finger shape and finger knuckle print features of a single human finger. The proposed multimodal biometrics provides score-level fusion approach based on triangular norm with four finger biometric traits, instead of two or three ones combined in the previous approaches. The experimental evaluations and analysis are conducted on a merged multimodal biometrics database. The results show that the proposed score-level fusion approach using triangular norm obtains a larger distance between genuine and imposter score distribution as well as achieves lower error rates. Moreover, the comparison results suggest that the proposed score level fusion of finger biometrics using triangular norm outperforms the state-of-the-art approaches.

1. Introduction

In biometric system, unimodal biometric systems have been proven their superior performance to adapt the increasing demand of accurate and efficient identification in such a rapid developing society [1]. These systems rely on the person physiological traits such as face, fingerprint, iris, vein, plamprint, etc. [2]. However, unimodal biometric systems have several inherent problems such as large intra-class variations, non-universality, and spoofing attacks [3–5]. In addition, the performances of unimodal biometric system are seriously affected by the conditions of the users health, illumination, type of sensor, etc. [6–8]. Multimodal biometrics, which is able to effectively overcome most of the above weaknesses in unimodal biometric systems, is attracting the attention of many researchers in multifaceted disciplines [9–12]. Its performance is superior to unimodal biometric systems such as higher accuracy, noise resistance, universality, anti-spoofing attacks, and more robust than unimodal ones.

To the best of our knowledge, there have been no previous studies on the fusion of four traits of a finger. In this article, we aim to propose an effective fusion method that combining information from four single unimodal biometric systems instead of two or three only like other previous approaches. The main reasons for the fusion of four finger features can be summarized as follows.

First, human fingers are easier to present and provide with a variety of traits that are convenient to be imaged by a variety of illuminations (visible, near-infrared light, etc.). Fingerprints, finger shape, finger knuckle prints can be acquired under visible illumination, and finger vein features can be acquired under near-infrared illumination. And even the fingerprint, finger vein features of a single finger can be obtained simultaneously by a capturing image device [13]. Second, finger veins are hidden structures and extremely difficult to be stolen with a high degree of privacy [14]. The use of finger vein patterns can offer strong anti-spoofing capabilities that ensure liveness in biometric authentication process. Third, finger shape recognition, its nonintrusive, low cost characteristics and less data storage requirement, make it easy to select most likely candidates in authentication applications for coarse matching appropriately [15]. Like fingerprints, the finger knuckle prints, refer to the skin patterns of the upper surface around the phalangeal joint, also have high discriminative ability to be utilized in the personal identification [16,17]. Finally, the utility of above biometric traits can be specified with low resolution image in the capture device, which make it is economical and user-friendly in the enrollment and authentication procedure.

The crucial point in multimodal biometrics is the fusion of various biometric modality data. Information from different biometric traits can be integrated at the feature level (integrating the features of different biometrics), score level (combining the genuine and

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imposter scores), or decision level (combining the decisions) [9]. Although feature sets are the rich source of information, features from these modalities may not be compatible and large dimensionality of a feature space may lead to be irrelevant and redundant. Moreover, fusion at the decision level is considered to be the rigid due to the lack of information content. Compared with the feature-level and decision-level fusion, the score level fusion is easy to be utilized to obtain effective performance by the discriminated availability between genuine and imposter scores.

1.1. Review of the related work

In recent years, there have also been several approaches that combined two or three biometric traits of a finger at score-level to address the problem of finger unimodal biometrics in literatures. They can be divided into three categories:

(1) Transformation-based fusion: the matching scores are first transformed into a common domain and then combined using Sum, weighted Sum, Max, Min and triangular norms rules.

Ghulam et al. [18] investigated an approach for personal authentication using both fingerprint and plam features. The consolidated matching scores using the sum and product rule, respectively, improved the recognition performance. CUI et al. [19] proposed multimodal biometrics recognition based on score-level fusion of fingerprint and finger vein by a simple weighted sum rule. However, the choice of combining the weights requires extensive empirical evaluation assuming that the data distributions of matching scores are independent. Hanmandlu et al. [20] proposed different triangular norms including Hamacher, Yager, Frank, Schweizer-Sklar, and Einstein product to confirm the effectiveness of score level fusion on palmprint, hand vein and finger knuckle databases.

(2) Classifier-based fusion: scores from multiple matchers are treated as a feature vector and a classifier is constructed to discriminate genuine and impostor scores.

Kang et al. [21] treated the finger vein and finger geometry recognition scores as a two-dimensional feature vector, and applied support vector machine (SVM) for classification. Kang et al. [22] also implemented a weighted sum rule-based and three SVMs to fuse the matching scores of finger vein, fingerprint and a shape of finger. He et al. [11] examined the performance of sum rule-based and SVM-based score-level fusion of fingerprint, face, and finger vein. Their results show that recognition accuracy is significantly enhanced using SVM-based methods.

(3) Density-based fusion: this is based on the likelihood ratio test and it requires explicit estimation of genuine and impostor match score densities.

Nandakumar et al. [23] proposed a framework for the combination of matching scores, in which the density distributions of genuine and impostor matching scores were respectively modeled as finite Gaussian Mixture Model (GMM). Nanni et al. [24] further presented the GMM to modal the parameters of the genuine and impostor score densities during the fusion step, and the GMM method outperforms both sum rule-based and SVM-based approaches on fingerprint, palm, finger texture, hand geometry and face databases.

Generally, transformation-based approaches, such as Max, Min, Sum and weighted Sum rules, fail to take the distribution distance of different biometric modal matching scores into account. Furthermore, classifier-based methods need data training process. In fact, the unbalanced genuine and imposter training score sets fail to generate effective training process. The key performance indicators of recognition performance are insufficient to be computed by SVM-based methods. Although density-based algorithms can achieve optimal performance at any desired discriminative operating point, the density function of scores is usually unknown and hard to be estimated accurately.

1.2. Scope of the present work and organization

In this article, we aim to avoid the above disadvantage of previous works on score-level fusion and improve the overall recognition performance of finger-based multimodal biometrics. Inspired by the work of triangular norms [20], we explore different triangular norms (t-norms) for the score-level fusion and evaluate them on a merged finger multimodal biometric database of finger vein, finger shape finger print and finger knuckle print images. Moreover, we adopt the t-norm based-method that can obtain better discriminability of genuine and imposter scores compared to existing score-level fusion approaches.

The rest of this article is organized as follows: Section 2 introduces the proposed finger multimodal biometric authentication approach. Section 3 presents the proposed score-level fusion method based on t-norms. Section 4 is devoted to the experimental results and analysis including comparisons with other approaches in detail. Finally, the conclusion is drawn in Section 5.

2. An overview of finger-based multimodal biometric authentication

Fig. 1 shows a block diagram illustrating the overall procedure of a multimodal biometric authentication that combines information from multiple finger biometric sources. The finger vein, fingerprint, finger shape and finger knuckle print are merged as a virtual multimodal biometric system and the procedure of the recognition are listed as follows:

- Finger vein images are obtained from a capturing device consisting of near-infrared illuminators. Fingerprint images and finger knuckle print images are captured under a visible light environment. We have done image preprocessing in order to extract biometric features accurately.
- The finger geometry are obtained by detecting edge lines between the finger region and the background region from the finger vein images by our pervious work [25]. The finger shape features are obtained by the method that combines the Fourier descriptors (FD) and LDA [22].
- The finger vein features in our pervious work [26] are extracted by Gabor wavelet and Local Binary Pattern (GLBP). GLBP feature representation of finger vein can enhance the finger vein recognition performance.
- The fingerprint features are extracted using a hybrid shape and orientation descriptor algorithm [27,28], and the finger knuckle print features are extracted by the phase congruency model [29].
- All the matching scores of the four biometric features are normalized into the range of [0; 1]. Then, the user authentication is implemented by the score-level fusion of t-norm.

2.1. Finger vein recognition with Gabor wavelets and local binary patterns

In our previous work [26], a finger vein image is modeled as a feature vector by the following procedure: (1) an input finger vein image is normalized and filtered by multi-scale and multi-orientation Gabor wavelet kernels to obtain the multiple Gabor Magnitude Pattern Maps (GMP); (2) Each GMP Map is further divided into non-overlapping rectangle blocks with specific size, and converted to Local Binary Pattern Map (GLBP); (3) The gray-level histogram of GLBP Map is computed for each block region;