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Designing an accurate hand biometric based authentication system fusing finger knuckleprint and palmprint

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ABSTRACT

This paper proposes an accurate and efficient multi-modal authentication system that makes use of palm and knuckleprint samples. Biometric images are transformed using the proposed sign of local gradient (*SLG*). Corner features are extracted from *vcode* and *hcode* and are tracked using geometrically and statistically constrained Lucas and Kanade tracking algorithm. The proposed highly uncorrelated features (*HUF*) measure is used to match two query images. The proposed system is tested on publicly available PolyU and CASIA palmprint databases along with PolyU Knuckleprint database. Several sets of chimeric bi-modal as well as multimodal databases are created in order to test the proposed system. Experimental results reveal that the proposed multi-modal system achieves *CRR* of 100% with an *EER* as low as 0.01% over all created chimeric multimodal datasets.

1. Introduction

There is a need to have automated, secure and accurate human access control mechanisms for reliable identification of people in several social applications such as law enforcement, secure banking, immigration control, *etc*. The best mode in which the identity management can be realized is the biometric based authentication system which uses physiological (fingerprint [9,37], face [41,40,26,27], iris [11,29], etc.) or behavioral (signature, gait, etc.) characteristics. Biometrics based solutions are better than the traditional token or knowledge based identification systems as they are harder to spoof, easier to use and never be lost. In past few years, society have noticed great attention in hand based biometric recognition systems (*e.g.* palm print [5], fingerprint [9] and finger knuckleprint [47,28,30]) because of their low cost acquisition sensors, high performance, higher user acceptance and lesser need of user cooperation. The pattern formations at finger knuckle bending [47] as well as palmprint region [5] are supposed to be stable (as shown in Fig. 1) and hence can be considered as discriminative biometric traits.

1.1. Motivation

Palmprint: The inner part of the hand is called palm and the extracted region of interest in between fingers and wrist is termed as palmprint as shown in Fig. 1(a). Pattern formation within this region are suppose to be stable as well as unique. Even monozygotic twins are found to have different palmprint patterns [16]. Hence one can consider it as a well-defined and discriminative biometrics trait. Palmprint's prime advantages over fingerprint includes its higher social acceptance because it is never being associated with criminals and larger ROI area as compared to fingerprint. Larger ROI ensures abundance of structural features including principle lines, wrinkles, creases and texture pattern (as it is evident in Fig. 1(a)) even in low resolution palmprint images. This enhances system's speed, accuracy and reduces the cost. Some other factors favoring palmprint are lesser user cooperation, non-intrusive and cheaper acquisition sensors.

Knuckleprint: The horizontal and the vertical pattern formation in finger knuckleprint images (as shown in Fig. 1(b)) are believed to be very discriminative [47]. The knuckleprint texture is developed very early and lasts very long primarily because they are on the outer side of the hand, hence safely preserved. Its failure to enroll rate (*FTE*) is observed to be lower as compared to fingerprint and can be acquired easily using an inexpensive setup with lesser user cooperation. The user acceptance favors knuckleprint as unlike fingerprint they are never being associated to any criminal investigations. A comparative study between palmprint and knuckleprint based over the biometric properties is presented in Table 1.

Multimodal: The performance of any unimodal biometric system is often got restricted by variable and uncontrolled environmental conditions, sensor precision and reliability. Several trait specific challenges such as pose, expression, aging, *etc*. for face recognition degrades the system performance. Hence they can only provide low

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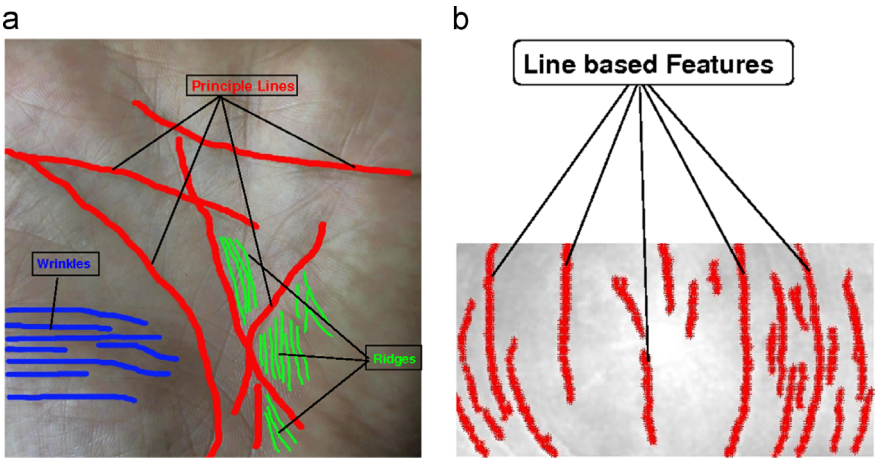

Fig. 1. Biometric trait's anatomy. (a) Palmprint Anatomy. (b) Knuckleprint anatomy.

Table 1
Biometric properties (M=*medium*; H=*high*).

Property	Meaning	Palmprint	Knuckleprint
Universality	Every individual must possess	M	M
Uniqueness	Features should be distinct across individuals	H	M
Permanence	Characteristics should be constant over a long period of time	H	H
Collectability	Easily acquired	M	H
Performance	Possess high performance as per performance parameters (*CRR*, *EER*)	H	M
Acceptability	Acceptable to a large percentage of the population	M	H
Circumvention	Difficult to mask or manipulate	M	H

or middle level security. Fusing more than one biometric traits in pursuit of superior performance can be a very useful idea, termed as multi-modal [10] systems. Any such system makes use of multiple biometric traits to enhance system's performance especially when a huge number of subjects are enrolled. The false acceptance rate grows rapidly with the database size [4]; hence multiple trait data can be utilized to achieve better performance.

1.2. Contribution

In this paper palmprint and knuckleprint *ROI's* are extracted and transformed using the proposed sign of local gradient (SLG) method to obtain robust *vcode* and *hcode* image representations. Corner features are extracted from *vcode* and *hcode* by performing eigen analysis of the Hessian matrix at every pixel. The matching is performed using the proposed *HUF* dissimilarity measure. Finally scores obtained for both traits (*i.e.* palm and knuckleprint) are fused to get multi-modal fusion score using the *SUM rule*. The overall architecture of the proposed multi-modal biometric system is shown in Fig. 2.

This paper is organized as follows: the comprehensive literature survey is presented in Section 2. In Section 3 extraction of region of interest (*ROI*) from biometric sample is explained. Section 4 describes the proposed algorithm. Section 5 presents the detailed experimental results of the proposed system on publicly available palmprint and knuckleprint along with their fused self-created chimeric multimodal databases. Last section presents the concluding remarks.

2. Literature review

2.1. Palmprint

Palmprint recognition systems are broadly based on structural or statistical features. In [13], line-like structural features are extracted by applying morphological operations over edge-maps. In [12], structural features such as points on principle line and some isolated points are utilized for palmprint authentication. In [44], single fixed orientation Gabor filter is applied over the palmprint and the resulting Gabor phase is binarized using zero crossing. In [15], bank of elliptical Gabor filters with different orientations is employed to extract the phase information of the palmprint image and merged according to a fusion rule to produce a feature called the FusionCode. In [39], a recognition system fusing the phase (FusionCode) and orientation information has been proposed. In [14], the palmprint is processed using the bank of Gabor filters with different orientations. The highest filter response is preserved as features represented in three bits. In [39], the palmprint is processed using the bank of orthogonal Gabor filters and their differences which are coded into bits are considered as the features of palmprint. All the above-mentioned systems use hamming distance for matching and classification. Many statistical techniques such as *PCA*, *LDA*, *ICA* and their combinations are also applied to palmprints in order to achieve better performance [19,35,42]. Several other techniques such as Stockwell [6], Zernike moments [7], Discrete Cosine Transforms (DCT) [8] and Fourier [5] transforms are also applied to achieve better performance.

2.2. Knuckleprint

On the other hand, finger knuckleprint is relatively newer biometric trait and very limited amount of work is reported. In [45], Zhang et al. have extracted the region of interest using convex direction coding. Correlation between two knuckleprint images is used for identification which is calculated using band limited phase only correlation (BLPOC). In [24], knuckleprints are enhanced using CLAHE to address non-uniform reflection and SIFT key-points are used for matching. In [43], the knuckleprint based recognition system that extract features using local Gabor binary patterns (LGBP) has been proposed. In [46], the Gabor filter bank is