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Integration of multiple orientation and texture information for finger-knuckle-print verification

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ABSTRACT

The Competitive Coding (CompCode) scheme, which extracts and codes the local dominant orientation as features, has been widely used in finger knuckle print (FKP) verification. However, CompCode may lose some valuable information such as multiple orientation and texture of the FKP image. To remedy this drawback, a novel multiple orientation and texture information integration scheme is proposed in this paper. As compared with CompCode, the proposed scheme not only considers more orientations, but also introduces a multilevel image thresholding scheme to perform orientation coding on each Gabor filtering response. For texture features extraction, LBP maps are first obtained by performing Local Binary Pattern (LBP) operator on each Gabor filtering response, and then a similar coding scheme is applied on these LBP maps. Finally, multiple orientation and texture features are integrated via score level fusion to further improve FKP verification accuracy. Extensive experiments conducted on the PolyU FKP database show the effectiveness of the proposed scheme.

1. Introduction

Biometrics authentication is drawing more and more attention, and is much more preferable and reliable to those applications concerning high security, such as building access control, airport, e-banking, computer system login, and national ID card. In the past decades, researches have exhaustively studied various kinds of biometrics traits, including face, fingerprint, iris, palmprint, hand vein, voice, gait, etc. Furthermore, hand-based biometrics identifiers have been attracted considerable attention in the biometrics community. Techniques, such as palmprint [1–12], hand geometry [13], fingerprint [14–18], hand vein [19], have been developed and investigated in literature.

Recently, researchers have reported that finger-knuckle-print (FKP), the inherent skin pattern of the outer surface around the phalangeal joint of one's finger, is highly unique and can serve as a distinctive biometric identifier for online personal verification [12,20–29]. Fig. 1(a) shows the FKP image acquisition device and the use of the system in [20–24]. After an FKP image is captured (Fig. 1(b)), the region of interest (ROI) is extracted from it for feature extraction and matching. Fig. 1(c) and (d) shows the ROI of two FKP images from different fingers. One can see that FKP ROI images from different fingers have clear difference.

Both Feature extraction and matching also play important roles in FKP based verification system. In [20], Zhang et al. adopted the Gabor filter based competitive coding (CompCode) scheme, which was originally designed for palmprint recognition [2], to extract and code the local orientation information as FKP features. Later, this scheme was extended by combining the magnitude information extracted by Gabor filters [21]. In [22], the Fourier transform based band-limited phase only correlation (BLPOC) was adopted to extract the transform coefficients as the global features of FKP images for matching. In the local-global information combination (LGIC) scheme [23], the local orientation was taken as the local feature while the Fourier transform coefficients were taken as the global feature. This scheme achieved very promising accuracy for FKP verification. In [25], real Gabor filter was used to enhance the FKP image and then the scale invariant feature transform (SIFT) was applied to extract features. An adaptive steerable orientation coding (ASOC) scheme was proposed in [26], where high order steerable filters were first employed to extract continuous orientation feature map, and then the multilevel image thresholding method was used to code a FKP image. In [24], a set of phase congruency induced local features were defined. By fusing these local features in the matching score level, the proposed local feature integration (LFI) scheme led to much better results than other local feature based methods such as CompCode [20] and

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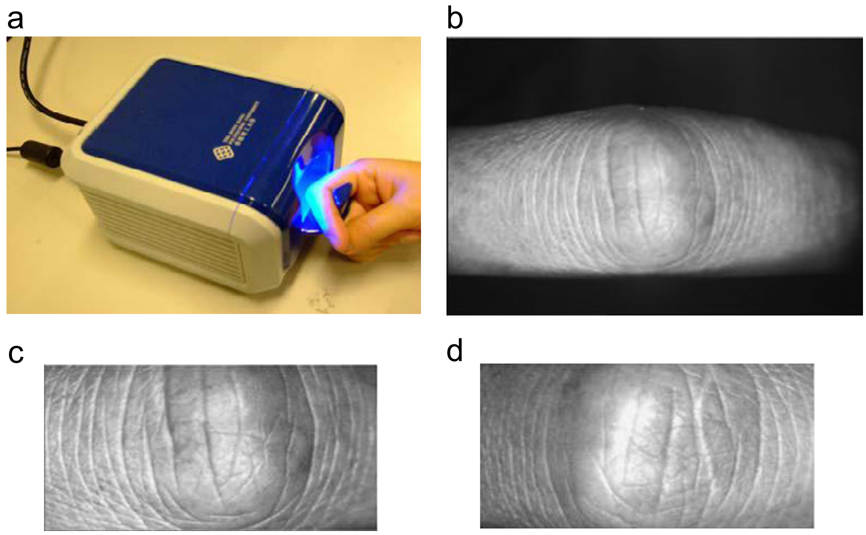

Fig. 1. (a) The FKP image acquisition device; (b) a typical FKP image; and(c), (d) two FKP ROI images from different fingers.

improved CompCode [21]. Recently, Riesz transforms are utilized to encode the local patterns of biometric images [12]. The experiments in [12] show that the proposed methods achieve quite similar verification accuracies with CompCode while need much less time at the feature extraction stage.

The orientation based coding approaches have many merits such as high accuracy, robustness to illumination variations and fast implementation. These algorithms share a common “competition” rule: the image is first convolved with several filters with different orientations. Then the “dominant” orientation is determined by some criterions. By simply coding the local orientation of the FKP, acceptable verification accuracy could be obtained with high matching speed. However, the line structures in FKP images are very complex. Multiple lines may intersect at some regions. If only one “dominant” orientation is extracted in these regions, much valuable discriminatory information will be lost.

To handle the aforementioned problems in traditional dominant orientation coding scheme, a novel multiple orientation coding scheme is first proposed in this paper. As compared with CompCode, the proposed method tries to use all the orientation information generated from the Gabor filtering responses rather than only “dominant” features. The multilevel image thresholding method [26] is introduced to perform orientation coding on each Gabor filtering response. Then all the coded maps are combined in the matching stage.

To the best of our knowledge, there is no investigation about texture information that has been reported for FKP verification in literature. We can make full use of this information to further improve the FKP verification accuracy. For texture feature coding, the conventional LBP [30] method is first performed on each Gabor filtering response, and then the similar thresholding based coding method is used on these LBP maps. Zhang et al. [11] pointed out that the fragile mask can be used for improving palmprint verification performance. A location in a palmprint′s code map is consistent if it has the same value for most images of that palmprint; otherwise, it is fragile. In this paper, we find that the fragile location is also existed in FKP images. Therefore, in coding stage, fragile masks are evaluated and used. For matching, the modified Hamming distance is calculated by masking out these fragile locations. The texture information can bring complementary discrimination for improving FKP verification performance. We thus integrate the multiple orientation and texture information via score level fusion.

Comparative experiments on the PolyU finger-knuckle-print database [31] show that the proposed multiple orientations coding scheme can obtain comparative performance with state-of-the-art methods and the proposed integration scheme, which integrates orientation and texture information, can further improve the verification accuracy.

The rest of this paper is organized as follows. Section 2 briefly reviews the CompCode scheme and indicates its problems. Section 3 presents the proposed feature extraction, matching and the integration scheme. Section 4 performs extensive experiments, and Section 5 concludes the paper.

2. Brief review of competitive coding (CompCode)

Gabor filters have been widely used for extracting orientation or edge information in face, iris, fingerprint, palmprint, as well as FKP verification systems. A 2D Gabor filter is usually defined as

$$G(x,y)=\exp\left(-\frac{1}{2}\left(\frac{x'^2}{\sigma_x^2}+\frac{y'^2}{\sigma_y^2}\right)\right)\cdot\exp(i2\pi f x') \quad (1)$$

where $x'=x\cdot\cos\theta+y\cdot\sin\theta$, $y'=-x\cdot\sin\theta+y\cdot\cos\theta$, f is the frequency of the sinusoid factor, θ is the orientation of the normal to the parallel stripes, and σ_x and σ_y are the standard deviations of the 2D Gaussian envelop.

Let G_R be the real part of a Gabor filter, and I_{ROI} be an FKP ROI (region of interest) image. With a bank of Gabor filters sharing the same parameters, except the parameter orientation, at each location $I_{ROI}(x,y)$, the dominant orientation feature can be extracted and coded as follows:

$$CompCode(x,y)=\arg\min_j\{I_{ROI}(x,y)*G_R(x,y,\theta_j)\} \quad (2)$$

where * stands for the convolution operation, and $\theta_j=j\pi/6$, $j=\{0,\ldots,5\}$. Obviously, each $CompCode(x,y)$ is assigned as an integer within 0–5.

For matching two CompCode maps P and Q, the normalized Hamming distance based angular distance is commonly adopted [2]:

$$d=\frac{\sum_{x=1}^{Rows}\sum_{y=1}^{Cols}h(P(x,y),Q(x,y))}{3S} \quad (3)$$