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A novel hierarchical approach for multispectral palmprint recognition

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ABSTRACT

Palmprint is one important biometric feature with uniqueness, stability and high distinguishability, and its study has attracted much attention in the past decades. Although many palmprint-based recognition methods have been proposed and successfully applied for identity authentication, most of the previous researches usually only use the images captured in natural light. It is hard, if not impossible, for further improvement of recognition accuracy based on these palmprint images due to limitations of using the natural light. In order to obtain high recognition rate with more discriminative information, we propose to use multispectral palmprint instead of natural light palmprint in this paper, and develop a multispectral palmprint recognition method based on a hierarchical idea. First, we extract the Block Dominant Orientation Code (BDOC) as a rough feature, and the Block-based Histogram of Oriented Gradient (BHOG) as a fine feature. Second, a hierarchical recognition approach is proposed based on these two types of features. Technically, we fuse different features obtained from different bands in the proposed scheme in order to improve the recognition accuracy. Finally, experimental results show that the recognition accuracy of the proposed method is not only superior to previous high-performance methods based on the PolyU palmprint database with the natural light but also it can further improve the state of the art performance achieved by some approaches based on the PolyU multispectral palmprint database.

1. Introduction

Verifying a personal identity with high accuracy is crucial in various applications, such as some national institutions access control, e-banking, exit and entry, etc. Biometric identification technology is a kind of methods to effectively authenticate the identity of a person based on physiological or behavioral characteristics [1]. In comparison with identification card or password card, biometric identification technology is more convenient, effective and secure with much broad applications. In the past decades, various kinds of biometric recognition approaches have been developed and applied in identity verification, including face [2,3], fingerprint [4], iris [5], palmprint [6–13], finger-knuckle-print [14], hand geometry [15], etc. Palmprint-based biometrics methods have been attracting much interest because they can achieve high accuracy as reported in [6]. However, most of the existing palmprint recognition methods are based on images captured in natural light. Although these methods have obtained much high recognition accuracy, it is difficult, if not impossible, to further improve its performance for applications with high requirements because natural light image cannot acquire more discriminative information. An alternative solution to this problem is to use multispectral images, which are captured in a variety of spectral bands.

Multispectral images can be captured in Red, Green, Blue, near-infrared (NIR) illumination sources by utilizing the characteristics that palm has different absorption capacity for different bands of light. Thus, in comparison with the natural light image, each band of multispectral image represents particular features of a palm, making it possible to obtain more multifarious information to improve distinguishability of image features. Multispectral technology has been applied in many biometric recognition systems, such as face recognition [16], fingerprint recognition [17], iris recognition [18], etc. Recently, multispectral idea has been successfully introduced into palm-related recognition. Hao et al. [19] designed a contact-free multispectral palmprint recognition system with image fusion. The recognition accuracy is not high as expected because of the limited low image quality. Rowe et al. [20] developed a prototype of a multispectral full-hand recognition system. The defect of this system was the requirement to obtain palmprint with very high-resolution images, and this is not possible for many real-time applications. Moreover, the no effective utilization of multispectral information and the poor fusion technique also make its recognition accuracy not high as expected.

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Wang et al. [21] fused a palm image in the nature light and a palm vein image captured by using one near-infrared (NIR) light to recognize human's identity. That method requires a registration procedure taking about 9 s. Also based on the idea of fusing palmprint and palm vein, Zhang et al. [22] proposed an online joint palmprint and palm vein verification approach with a better recognition accuracy. Hao et al. [23] studied many fusion methods about multispectral palmprint and proposed a non-contact multispectral palmprint system; their work can contribute to follow-up studies in the development of multispectral palmprint system. Han et al. [24] proposed a multispectral palmprint recognition method based on wavelet transform. Their method fused different bands information by using wavelet transform. Xu et al. [25] used a quaternion principal component analysis method to recognize multispectral palmprint. Their method paved a way to fuse multispectral palmprint in a unified space domain. Zhang et al. [26] developed an online system of a multispectral palmprint system by a score level fusion scheme via integrating multispectral information. Their experimental results show the fusion method can achieve significant high recognition accuracy. Tahmasebi et al. [27] used a rank-level fusion scheme for multispectral palmprint identification system, which achieves a result comparable with the score level fusion scheme. Guo et al. [28] presented a study on feature band selection by analyzing hyperspectral palmprint. Though some good results about recognition accuracy were reported, the feature band selection from a mass of hyperspectral palmprint hinders them from real-time implementations. Afterwards, Amel et al. [29] and Meraoumia et al. [30] put forward a series of multispectral palmprint recognition methods based on frequency transform, such as Ridgelet transform and Contourlet transform. Their major work is to improve previous methods on feature extraction. However, recognition results have not improved significantly. In summary, multispectral palmprint recognition is a popular research topic currently and there is still plenty of room for improvement, especially in the aspects of extracting new features and designing new classifiers in order to improve recognition accuracy.

In this paper, we propose a hierarchical approach for multispectral palmprint recognition. We first propose and extract the Block Dominant Orientation Code (BDOC) feature to achieve a rough recognition, and then the rough recognition result was tuned in fine level by using the Block-based Histogram of Oriented Gradient (BHOG). Also a new feature fusion technique is proposed for utilizing the BDOC and BHOG features from the four bands. Finally, hierarchical recognition is achieved by combining the rough recognition with the fine recognition. In comparison with the previous high-performance palmprint recognition methods, the proposed method can achieve superior recognition accuracy. In detail, the recognition accuracy of the proposed method conducted on the PolyU multispectral palmprint database is much higher than that with the state of art approaches on the PolyU natural light palmprint database. This implies that the multispectral palmprint images have more discriminative information than the natural light images. In addition, the recognition accuracy is further improved by a feature fusion scheme via integrating different bands information, and the result is higher than those achieved by the existing multispectral palmprint recognition methods.

The remainder of this paper is organized as follows. Section 2 presents feature extraction of the BDOC and BHOG. Section 3 describes the idea of the hierarchical classification and develops a feature level fusion scheme. Section 4 shows the experimental results. Section 5 concludes the paper.

2. BDOC and BHOG

In this section, we first introduce the multispectral palmprint database, and then introduce related methods of feature extraction. Finally, feature extractions for the BDOC and BHOG are proposed.

2.1. Related Methods for Feature Extraction

A large variety of proposed algorithms on palmprint recognition can be roughly classified in four categories: subspace learning [7,13], principal line extraction [11,13], texture coding [6,8–12], and feature statistic [32,33]. The methods of texture-based coding are the best with the highest recognition accuracy and fastest matching speed among these algorithms. The PalmCode proposed in [6] is a representative result of texture-based coding. Many other algorithms are proposed on the basis of PalmCode algorithm, including FusionCode [8], DoGCode [9], Competitive Code [10], and so on. The core idea of texture-based coding is to filter palmprint images by using Gabor filter, and then encode them with some schemes. Gabor filter is a method in frequency domain, which takes a palmprint image as a 2D signal to extract texture features. However, palmprint texture features are also well presented in the spatial domain. There are some methods for extraction of texture features in the spatial domain, such as Gray Level Co-occurrence Matrix (GLCM) [31], Local Binary Pattern (LBP) [32] and other spatial patterns [33]. Although these methods have been successfully developed for biometrics, the extracted features are not as good as expected as these features lack characteristics of orientation. Therefore, we need to develop an algorithm which can better describe orientations for textures. Dalal et al. [34] presented Histograms of Oriented Gradient (HOG) for human detection; they used horizontal and vertical gradients of each pixel to represent their orientation map of gradients. Also, the orientation map is divided into some spatial regions (cell), for every cell, one accumulates a local 1-D histogram of gradient orientation over pixels in the cell. HOG is a spatial descriptor being sensitive to orientations. Hence, it is expected to be very effective to extract HOG texture features for palmprint recognition.

2.2. BDOC and BHOG

In order to describe texture information effectively in the spatial domain, we first adopt the HOG to extract orientation features for palmprint recognition. The HOG feature can be extracted as follows. Let

$$G_{\mathbf{x}}(i,j) = I(i,j) * W \tag{1}$$

$$G_{\mathbf{y}}(i,j) = I(i,j) * W^{\mathrm{T}} \tag{2}$$

$$Mag(i,j) = \sqrt{{G_{\mathbf{x}}}^2 + {G_{\mathbf{y}}}^2} \tag{3}$$

$$Ang(i,j) = \tan^{-1}(G_{\mathbf{y}}/G_{\mathbf{x}}) \tag{4}$$

where I stands for an image with size of $M \times N$, $G_{\mathbf{x}}$ is the horizontal gradient image, $G_{\mathbf{y}}$ is the vertical gradient image, '$*$' is an operator of convolution and $W=[-1,0,1]$ is a mask of convolution. $Mag(i,j)$ and $Ang(i,j)$ is the gradient magnitude and angular orientation for each pixel point with

$$-\pi/2 < Ang(i,j) < \pi/2, \quad 1 \le i \le M, \quad 1 \le j \le N.$$

As $Ang(i,j)$ is changing in $(-\pi/2, \ \pi/2)$, we transform it to $(0, 2\pi)$ for easy manipulations. For such a purpose, we define Ang_m as follows:

$$Ang_m(i,j) = \begin{cases} Ang(i,j) & 0 < Ang(i,j) < \pi/2 \\ Ang(i,j) + 2\pi & -\pi/2 < Ang(i,j) < 0 \end{cases} \tag{5}$$