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Local line directional pattern for palmprint recognition

Yue-Tong Luo [a], Lan-Ying Zhao [a], Bob Zhang [b], Wei Jia [c,d,*], Feng Xue [a], Jing-Ting Lu [a], Yi-Hai Zhu [e], Bing-Qing Xu [a]

[a] School of Computer and Information, Hefei University of Technology, Hefei 230009, China
[b] Faculty of Science and Technology, University of Macau, Macau, China
[c] Hefei Institutes of Physical Science, Chinese Academy of Science, Hefei 230031, China
[d] Biometrics Research Centre, Department of Computing, Hong Kong Polytechnic University, Hong Kong
[e] Tableau Software, Seattle, WA 98103, USA

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ABSTRACT

Local binary patterns (LBP) are one of the most important image representations. However, LBPs have not been as successful as other methods in palmprint recognition. Originally, the LBP descriptor methods construct feature vectors in the image intensity space, using pixel intensity differences to encode a local representation of the image. Recently, similar feature descriptors have been proposed which operate in the gradient space instead of the image intensity space, such as local directional patterns (LDP) and local directional number patterns (LDN). In this paper, we propose a new feature input space and define an LBP-like descriptor that operates in the local line-geometry space, thus proposing a new image descriptor, local line directional patterns (LLDP). Moreover, the purpose of this work is to show that different implementations of LLDP descriptors perform competitively in palmprint recognition. We evaluate variations to LLDPs, e.g., the modified finite radon transform (MFRAT) and the real part of Gabor filters are exploited to extract robust directional palmprint features. As is well-known, palm lines are the essential features of a palmprint. We are able to show that the proposed LLDP descriptors are suitable for robust palmprint recognition. Finally, we present a thorough performance comparison among different LBP-like and LLDP image descriptors. Based on experimental results, the proposed feature encoding of LLDPs using directional indexing can achieve better recognition performance than that of bit strings in the Gabor-based implementation of LLDPs. We used four databases for performance comparisons: the Hong Kong Polytechnic University Palmprint Database II, the blue band of the Hong Kong Polytechnic University Multispectral Palmprint Database, the Cross-Sensor palmprint database, and the IIT Delhi touchless palmprint database. Overall, LLDP descriptors achieve a performance that is competitive or better than other LBP descriptors.

1. Introduction

In recent years, as one of emerging biometrics technologies, palmprint recognition has drawn wide attentions from both academy and industry. Generally speaking, palmprint recognition is using the person's palm to identify or verify who the person is [1,2]. In the early stage of the research for palmprint recognition, inked palmprint was used for offline recognition [3]. Later, Zhang et al. [4] proposed the first online palmprint recognition system using 2D low resolution imaging for civilian applications, in which the palmprint images were captured by the contact manner. At a low resolution palmprint image, i.e., about 75 dpi, palm lines including principal lines and creases could be clearly observed [1–4]. Zhang et al. [5,6] also proposed the first 3D palmprint recognition system, which has more robust recognition performance. However, such system needs an expensive capturing device. Recently, some work focused on high resolution palmprint recognition [7,8]. At a high resolution palmprint image, i.e., about 400–500 or greater dpi, ridges, minutiae and pores could be detected [7,8]. Up to present time, palmprint recognition at high resolution is limited to forensic applications. Due to the importance for civilian applications, the research for 2D low resolution palmprint recognition is still very active. After the work of [4], contact-free [9,10], multimodal [11,12] and multispectral [13,14] 2D low resolution palmprint recognition systems were investigated in depth. In this paper, our work also focuses on 2D low resolution palmprint recognition.

So far, many approaches have been proposed for 2D low resolution palmprint recognition. Existing methods can be roughly

* Corresponding author at: Hefei Institutes of Physical Science, Chinese Academy of Science, Hefei 230031, China.
E-mail address: icg.jiawei@gmail.com (W. Jia).

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divided into several different categories such as texture based methods, line based methods, subspace learning based methods, correlation methods, coding methods and local descriptor based methods [1,2]. For texture based methods, Gabor wavelet [15], discrete cosine transform [16], dual-tree complex wavelets [17], region covariance matrices [18], discrete orthonormal S-transform [19], co-occurrence matrices [20], fractal dimension [21] and other statistical methods have been used for palmprint texture feature extraction. Line based methods are also very important in palmprint recognition field. Wu et al. [22] proposed a palm line detection method using the first and the second-order derivatives of Gaussian function. Liu et al. [23] proposed a wide palm line detector using an isotropic nonlinear filter, which is based on the isotropic responses via circular masks. In [24], Jia et al. proposed a principal line extraction method based on modified finite radon transform (MFRAT). So far, coding methods have achieved very promising recognition performance in terms of accuracy and matching speed. Ordinal code [25,26], robust line orientation code (RLOC) [27], competitive code [28,29,74] and binary orientation co-occurrence vector (BOCV) [30] are representative coding methods. Recently, correlation methods such as optimal tradeoff synthetic discriminant function (OTSDF) filter [31] and band-limited phase only correlation filter (BLPOC) [32] have also been successfully adopted for palmprint recognition. In the past two decades, the study on subspace learning techniques has made a great progress. Many different representative subspace learning methods have been applied to palmprint recognition. As two simple and representative subspace learning methods, principal component analysis (PCA) [33] and linear discriminant analysis (LDA) [34] requires that the 2-D image data must be reshaped into 1-D vector, which can be referred to as the strategy of “image-as-vector”. In recent years, kernel method [35], manifold learning method [36], matrix and tensor embedding method [37,38], sparse learning [39] and low rank representation based method [40], were also applied for palmprint recognition.

In image processing field, local image descriptor plays an important role for object detection, image recognition, image retrieval, image registration, scene analysis, medical image processing, and video surveillance, etc. Up to now, a lot of local image descriptors have been proposed, which include local binary pattern (LBP) [41], scale-invariant feature transform (SIFT) [42], speeded up robust features (SURF) [43], histogram of oriented gradients (HOG) [44], DAISY [45], binary robust independent elementary features (BRIEF) [46], and local difference binary (LDB) [47], etc. Some of them have been used for palmprint recognition. Badrinath et al. [48] and Chen et al. [49] proposed the palmprint recognition methods based on SIFT, respectively. Recently, Wu et al. exploited SIFT and iterative RANSAC algorithm for contactless palmprint recognition [50]. Badrinath et al. [51] also proposed a palmprint recognition method using SURF descriptor, which has faster feature extraction speed than SIFT. Ghandehari et al. [52] proposed a palmprint recognition method using pyramidal HOG feature and fast tree based matching. Jia et al. [53] proposed the histogram of oriented lines (HOL) descriptor recently, which is one of variants of HOG. In [54], discriminative histogram of local dominant orientation (D-HLDO) is presented for palmprint recognition. Guo et al. [55] adopted hierarchical multiscale LBP, and Shen et al. [56] proposed a method integrating LBP and Gabor response for palmprint recognition. In [57], Mu et al. proposed a palmprint recognition method combining LBP and complex directional wavelet.

Among all kinds of local image descriptors, it is well-known that LBP is a popular and powerful one, which has been successfully adopted for many different applications such as face recognition, texture classification, object recognition, and scene recognition [58]. Huang et al. [58] has made a survey on LBP and its applications to facial image analysis. Based on original LBP, a lot of variants have been proposed including local ternary pattern (LTP) [59], dominant LBP (DLBP) [60], center-symmetric LBP (CSLBP) [61], local derivative pattern (LDP) [62], and completed LBP (CLBP) [63], etc. In order to extract spatial structure of an object, some researcher proposed methods combining Gabor wavelet representation and LBP. Zhang et al. [64] proposed a LBP descriptor in Gabor transform domain (LGBP). Then, Zhang et al. [65] proposed to combine Gabor phase information with LBP (LGPP). Later, Xie et al. [66] proposed local XOR pattern integrating with Gabor transform (LGXP).

Currently, a new trend of the research on LBP is to encode the directional information instead of intensity information. Jabid et al. [67] proposed the local directional pattern (LDP), which uses the edge response derived from the Kirsch gradient operator in eight directions around a pixel. Later, Zhong et al. [68] presented the enhanced local directional pattern (ELDP) utilizing the directions of the most prominent edge response value and the second most prominent one. Ahmed [69] proposed the gradient directional pattern (GDP), which encodes the texture information of local region by quantizing the gradient directional angles to form a binary pattern. Rivera et al. [70] presented the local directional number pattern (LDN) by computing the edge response of the neighborhood using a compass mask, and by taking the most positive and negative directions of those edge responses. Since edge gradient is more stable than the pixel intensity, these descriptors based on edge gradient could provide better recognition performance than original LBP for face and expression recognition.

As we know, palm lines including principal lines and wrinkles are essential and basic features of palmprint at a low resolution palmprint image. At the same time, palm lines are very complicated sometimes. For example, different palm lines have different widths and directions, and some lines may be interconnected and intertwined. Thus, edge gradient may not be a good tool to capture the robust feature of palmprint. In our previous work [53], we have proved that the HOG descriptor based on gradient cannot obtain desirable recognition performance. If the gradient is replaced by line features, the new descriptor called as HOL could achieve promising performance [53].

Motived by HOL [53] and LDP [67] descriptors, in this paper we propose a new LBP-structure descriptor, local line directional pattern (LLDP), for palmprint recognition. LLDP encodes the structure of a local neighborhood by analyzing line directional information. Consequently, we compute the line responses in the neighborhood, in 12 different directions using MFRAT or Gabor filters. The main contributions of this work are as follows: (1) a novel LBP-structure local feature descriptor, LLDP, is proposed, which is very suitable for palmprint recognition. In LLDP, we propose to use a new feature space, i.e., the line feature space, instead of the gradient space or the intensity feature space, to compute robust code; (2) we exploit different coding schemes to produce meaningful descriptors, which are based on bit strings and line direction numbers, respectively. We show that the coding scheme based on line direction index numbers can achieve better recognition performance than that of bit strings; (3) on four palmprint databases, especially on the Hong Kong Polytechnic University Palmprint Database II (PolyU II) and the blue band of the Hong Kong Polytechnic University Multispectral Palmprint Database (PolyU M_B) [71], the proposed LLDP descriptor achieves rank 1 identification rates of 100% in identification experiments, and EERs of 0.0216% and 0.0264% in verification experiments, respectively, which are much better than all other existing LBP-structure descriptors.

The rest of this paper is organized as follows: Section 2 presents the coding schemes of the proposed LLDP descriptor. Then, in Section