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Double-orientation code and nonlinear matching scheme for palmprint recognition

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ABSTRACT

Many palmprint authentication approaches have been proposed in recent years. Among them, the orientation based coding approach, in which the dominant orientation features of palmprints are extracted and encoded into bitwise codes, is one of the most promising approaches. The distance between codes created from two palmprint images is calculated in the matching stage. Reliable orientation feature extraction and efficient matching are the two most crucial problems in orientation based coding approaches. However, conventional coding based approaches usually extract only one dominant orientation feature by adopting filters with discrete orientations, which is sensitive to the noise and rotation. This paper proposed a novel double-orientation code (DOC) scheme to represent the orientation feature of palmprint and designed an effective nonlinear angular matching score to evaluate the similarity between the DOC. Extensive experiments performed on three types of palmprint databases demonstrate that the proposed approach has excellent performance in comparison with previously proposed state-of-the-art approaches.

1. Introduction

Biometric authentication is becoming more and more popular because it is an important and effective technology for personal verification and identification [1–4]. In palmprint authentication, the palmprint is defined as the inner surface of a hand. It contains many stable and discriminative features, including not only principal lines and wrinkles but also abundant ridges, minutiae, and textural features [5–7]. Thus the palmprint based authentication approach is able to achieve reliable personal verification and identification. In recent years, the palmprint recognition approach has received increasing research interests and various palmprint recognition algorithms have been presented [8–12] based on different kinds of palmprint features. For example, Huang et al. [13] proposed a principle line based approach for palmprint verification. Dai et al. [14] presented a ridge-based palmprint matching algorithm, which quantitatively investigates the ridge features of high resolution palmprint images and calculates the statistics of ridge features. Morales et al. [15] introduced the scale invariant feature transform (SIFT) based approaches to perform palmprint recognition. The key points of palmprints obtained using SIFT are that they are robust to the image illumination, scaling and rotation variance. Liu et al. [16] proposed a minutiae-based palmprint matching algorithm based on minutiae clustering and minutiae match propagation. Li et al. [17] designed a palmprint recognition approach based on the fusion of 2D and 3D palmprint features. They first extracted correlated features from 2D and 3D palmprint images. Then, these features were fused at the feature level to achieve satisfactory recognition accuracy. Zhang et al. [18] supplied a multi-spectral palmprint recognition approach which captured palmprint images under red, green, blue, and near-infrared light. These spectral features were combined at the matching score level to improve the performance of palmprint identification. In addition, the subspace based approaches, such as the Principal Component Analysis (PCA) and Linear Discriminant Analysis (LDA) [7–9], and the Representation Based Classification (RBC) approaches, such as CRC [19] and TPTSSR [20], can also be exploited for palmprint authentication [21].

Besides the above approaches, orientation based coding approaches are deemed to be the most promising palmprint recognition approaches, since the palmprint is full of line and textural features which carry rich and distinctive orientation information. Zhang et al. [22] proposed an effective Palmcode approach that applied a normalized 2-D Gabor filter to the palmprint image and encoded the filter results as code representation. Inspired by the Palmcode approach, Kong et al. [23] proposed the Competitive code approach which adopted six

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Gabor filters to extract the dominant orientation features of palmprints based on the principle of the biggest response. Similar to Competitive code method, the Robust Line Orientation Code method (RLOC) [24] extract orientation by using a Modified Finite Radon Transform (MFRAT). Based on the idea of the Competitive code, Zuo et al. [25] designed a novel Sparse Multiscale Competitive Code (SMCC) approach to extract more accurate orientation features by using a bank of multiscale Gabor filters and employing a winner-take-all rule. Subsequently, Kong et al. [26] proposed a fusion code approach that encoded the phase with dominant magnitude from four orientation's Gabor filter results. Sun et al. [27] employed three groups of orthogonal Gaussian filters to extract three binary codes, i.e. the ordinal code, in terms of the sign of the filter results. To further extract more orientation features, Guo et al. [28] proposed a Binary Orientation Co-occurrence Vector (BOCV) approach, which obtained all six orientations by convolving the palmprint image with six Gabor filters and encoded all filter results as orientation features. Zhang et al. [29] had improved the BOCV to E-BOCV by making out the fragile bits to further improve the performance of palmprint recognition.

It is well known that the winner-take-all rule, which extract the single orientation with the largest filter response [23], is usually used in the orientation based coding methods. However, in real operations, a bank of Gabor filters with discrete orientations is used to convolve with palmprint. It is possible that no any filter that has the same orientation as palmprint line and no filter can achieve the absolute maximum of filter response. Actually, the palmprint line usually coincides with two filters, which have larger responses than other filters in most conditions. So double-orientation feature with top-two largest responses is more reasonable than the single-orientation extraction, and it is robust to the noise and rotation.

In this paper, a robust double-orientation code (DOC) approach for palmprint recognition is proposed. First, the paper studies the rationale of the palmprint orientation based coding theory and concludes that the DOC is highly reliable and reasonable for palmprint orientation feature representation. Second, the paper presents an effective nonlinear angular matching score metric for the similarity evaluation of DOC. Finally, extensive experiments on three types of palmprint databases are performed to examine the effectiveness of the proposed approach. The extensive experimental results show that the proposed approach can achieve higher verification and identification accuracy than conventional state-of-the-art coding algorithms.

The remainder of this paper is organized as follows: Section 2 briefly describes the main orientation based coding approaches. Section 3 presents the analysis of the double-orientation extraction. Section 4 introduces the double-orientation code based nonlinear matching scheme for palmprint recognition. In Section 5, experiments of the proposed approach are supplied and analyzed. Finally, Section 6 offers the conclusion of this paper.

2. Related works

2.1. Principal line based approach

Palmprint lines are the basic feature of a palmprint, and line based recognition approaches play an important role in palmprint authentication. The principal line based approaches use a line or edge detector to extract the palmprint lines and then use them to perform palmprint recognition. In general, palms have three principal lines which are the most evident lines in the palmprint image and have stable shapes and positions. Thus the principal lines are highly robust to noise and illumination. Palmprint principal lines can be extracted by using the Gobal filter, Radon filter, Sobel operation. Fig. 1 shows some principal line images extracted by using MFRAT approach [13].

In the matching stage, the similarity is simply evaluated in terms of the number of the overlapping pixels of two palmprint principal lines. A recommended matching approach of principal lines is the pixel-to-area [14] matching approach, which calculates the principal line matching score as follows:

$$S(A,B) = \sum_{i=1}^{m}\sum_{j=1}^{n} A(i,j) \cap \overline{B}(i,j)/N_A, \quad (1)$$

where A and B are two palmprint principal line images, "∩" represents the logical "AND" operation, N_A is the number of pixel points of A, m and n are the row number and column number of the palmprint image, and $\overline{B}(i,j)$ represents a neighbor area of $B(i,j)$. The larger the matching score means the greater similarity between A and B.

The principal lines are one of the most stable features of a palmprint. However, using only principal lines is not adequate to represent the uniqueness of a palmprint because different individuals may have similar principal lines. Thus, the recognition accuracy may be low. Moreover, simple using principal line means that many discriminative minutiae are discarded.

2.2. Coding based approaches

In addition to the principal line based approach, the coding based approaches are the most promising methods for palmprint recognition. One or several filters are used to extract palmprint orientation features and these features are then converted into codes. The distance between codes is calculated to perform palmprint recognition. The representative coding based approaches include the Competitive code, Palmcode, Ordinal code, Fusion code, RLOC, BOCV, and E- BOCV approach, and so on.

The Competitive code approach [23] is one of the most popular coding based approaches. Six Gabor filters with different orientations are used to extract orientation features from a palmprint. The orientations are finally determined as $j\pi/6$, where$j = \{0, 1, ..., 5\}$. Six orientation's Gabor templates are convoluted with the palmprint

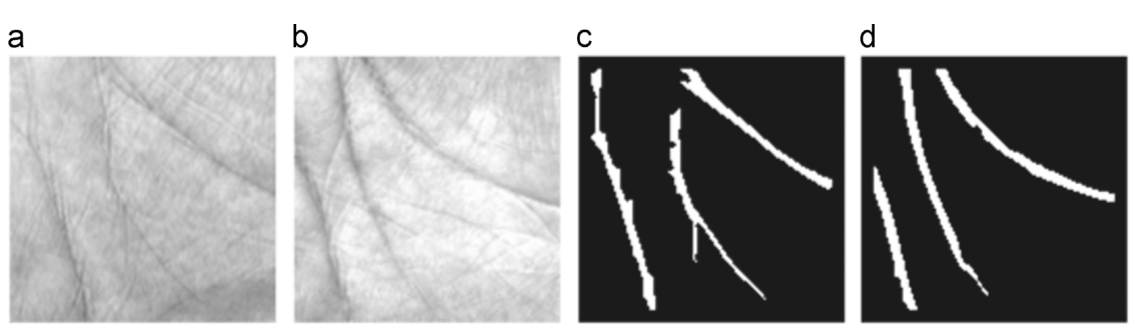

Fig. 1. Palmprint images and theirs principal line images: (a), (b) are two palmprint images from two subjects and (c), (d) are palmprint principal line images of (a), (b).