Neurocomputing 205 (2016) 274–286

Contents lists available at ScienceDirect

Neurocomputing

journal homepage: www.elsevier.com/locate/neucom

Multi-spectral palmprint recognition based on oriented multiscale log-Gabor filters

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ARTICLE INFO

Article history:
Received 29 November 2015
Received in revised form
2 May 2016
Accepted 2 May 2016
Communicated by Z. Wang
Available online 11 May 2016

Keywords:
Palmprint recognition
Multi-spectral biometrics
2D log-Gabor filter
Competitive coding
Kullback–Leibler divergence
Feature map fusion

ABSTRACT

Among several palmprint recognition methods proposed recently, coding-based approaches using multi-spectral palmprint images are attractive owing to their high recognition rates. Aiming to further improve the performance of these approaches, this paper presents a novel multi-spectral palmprint recognition approach based on oriented multiscale log-Gabor filters. The proposed method aims to enhance the recognition performances by proposing novel solutions at three stages of the recognition process. Inspired by the bitwise competitive coding, the feature extraction employs a multi-resolution log-Gabor filtering where the final feature map is composed of the winning codes of the lowest filters' bank response. The matching process employs a bitwise Hamming distance and Kullback–Leibler divergence as novel metrics to enable an efficient capture of the intra- and inter-similarities between palmprint feature maps. Finally, the decision stage is carried pout using a fusion of the scores generated from different spectral bands to reduce overlapping. In addition, a fusion of the feature maps through two proposed novel feature fusion techniques to allow us to eliminate the inherent redundancy of the features of neighboring spectral bands is also proposed. The experimental results obtained using the multi-spectral palmprint database MS-PolyU have shown that the proposed method achieves high accuracy in mono-spectral and multi-spectral recognition performances for both verification and identification modes; and also outperforms the state-of-the-art methods.

1. Introduction

Biometric security is increasingly becoming an important tool to enhance security and bring greater convenience to services requiring authentication and protection of data. Deploying biometric security using physical or behavioral traits for personal verification and identification [1] is useful in various applications such as forensic science or access control thus resulting in an increase of research interest. Several modalities have been studied and developed including iris, face, gait, key-stroke, finger-print and palmprint [1] where some of them are already well known and widely used depending to the application domain.

The main factors of merits of palmprint images include reliability, stability, user friendliness, non-intrusiveness, flexibility and discriminating ability. These factors arise from a large selection of unique palmprint features including principal lines, wrinkles, ridges, minutiae points and texture. Although, palmprint recognition has been investigated during the last decade, this paper aims to further improve the recognition accuracy, specifically by using multi-spectral imagery that provides more discriminating information in the feature extraction. The multi-spectral palmprint images are collected under different spectra (called also spectral bands) peaking at different light wavelengths. The absorptive and reflective of human skin properties make different wavelengths penetrate the skin layers differently, hence highlight particular features [2].

Various palmprint recognition methods have been proposed recently, and among them, coding-based approaches using multi-spectral palmprint images are attractive owing to their high recognition rates. In this research work, we propose a novel multi-spectral palmprint recognition approach based on oriented multiscale log-Gabor filters with the aim to further improve the performance of these approaches. The proposed approach enhances the recognition performances by proposing novel techniques at the three stages of a typical biometric cognition process: (i) using bitwise competitive coding, the feature extraction is based on a

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http://dx.doi.org/10.1016/j.neucom.2016.05.005
0925-2312/

multi-resolution log-Gabor filtering where the final feature map is composed of the winning codes of the lowest filters' bank real response. (ii) Matching is performed by using the bitwise Hamming distance and the Kullback–Leibler divergence as novel metric to capture efficiently the intra- and inter-spectral similarities between palmprint feature maps, at this stage, we have performed, through two novel features fusion techniques, a fusion of the feature maps in order to eliminate the inherent redundancy of neighboring spectral bands features. (iii) Finally, the decision is carried out either from the obtained fused features similarity scores or from the classic fusion of the scores of different spectral bands aiming reduce overlapping. The experimental results obtained using the multi-spectral palmprint database MS-PolyU have shown that the proposed method achieves high recognition accuracy for mono-spectral and multi-spectral datasets for both verification and identification achieving up to 0.0087 in terms of Equal Error Rate (EER) and 99.77% in terms of highest Identification Rate (IR) at rank-1. In addition, the proposed method outperforms related state-of-the-art methods especially the similar method proposed in [2] by up to -0.0034 in terms of EER for MS-PolyU database; and also the methods proposed in [2–8].

The remainder of this paper is as follows: Section 2 depicts related and relevant state-of-the-art works. Section 3 describes in detail the proposed methodology including the principle of a multi-spectral palmprint recognition system, the feature extraction, the matching and the fusion strategies while the experiments and results carried out to validate the proposed methodology are given in Section 4. Finally Section 5 concludes the paper.

2. Related works

A crucial step in a typical palmprint recognition system revolves around the feature extraction process which aims to provide and capture the most discriminating information from the extracted Region Of Interest (ROI). To achieve this, several available algorithms can be grouped as follows: structural-based approaches (e.g. minutiae based on SIFT or SURF features, lines based on Sobel/Canny features, and local line directional patterns) [9,10], appearance-based approaches (e.g. sub space-based on EigenPalm and PCA) [11], statistical-based approaches (e.g., Gabor and Wavelet) [12,2], coding-based approaches (e.g. phase such as palm-code) [13], and finally hybrid-approaches since they use various techniques (e.g. 2D FLPP) [14,15].

The success of coding-based methods, which encode the responses of a bank of filters into bitwise features, have attracted our interest, particularly, the multi-scale scheme, where the palm lines can be represented at higher scales. Various algorithms inspired by this approach have been proposed. For example, Zhang et al. proposed an effective Palm-code algorithm in [12] based on a normalized 2D Gabor filter. In [16], Kong et al. presented their competitive coding approach where the dominant orientation is encoded. In [3], Jia et al. proposed the line orientation code based on a modified Finite Radon transform which is similar to the competitive code; while Zuo et al. proposed in [17] a competitive coding using multi-scale oriented 2D log-Gabor filters. Zhang et al. [2] proposed a multi-spectral approach where the features are extracted by competitive coding using six oriented 2D Gabor filters for each spectral band followed by a score fusion at the recognition stage. In [4], the authors presented a joint palmprint and palm-vein verification scheme where the authors fused the features extracted by Gabor and matched filters from palmprint and vein-palm. Zuo et al. proposed in [18] a sparse competitive code based on second derivative of Gaussians with a bank of eighteen multi-scale oriented filters. In [5], Tahmasebi et al. proposed a Rank-Level Fusion for multi-spectral palmprint system using Gabor filter. More recently, based on a hierarchical approach in [19], Hong et al. fused a rough feature extraction using a block dominant orientation code which is then refined using a block-based histogram of oriented gradients from the different spectral bands. Cui et al. in [20] exploited a bidirectional representation based on pattern classification. On the other hand, Zhang et al. in [21] collected the recent advanced research works on multi-spectral Biometrics including multi-spectral palmprint recognition. In [22] Xu et al. proposed a novel multispectral palmprint recognition method based jointly on multiclass projection extreme learning machine and digital Shearlet transform. Fei et al. proposed in [7] a palmprint recognition method based on a double half-orientation where a bank of half-Gabor filters are defined for the half-orientation extraction. Another palmprint recognition method was proposed in [8] using a double-orientation code based on Gabor filters and nonlinear matching scheme. The proposed methods in [7,8] have been assessed on multi-spectral palmprint MS-PolyU database.

Competitive coding is the association of a filtering process which exploits neurophysiology-based Gabor function to capture the discriminative orientation information with a competitive rule: winner-takes-all using the palm line contrast. It is a state-of-the-art texture-based feature extraction algorithm widely used and is inspired from human vision's system [16] which tends to compare palm lines as a method/tool to compare palm images. These lines (i) are specific multi-scale features since the principal ones are robust and well represented at large scales whereas wrinkles at smaller ones may appear or disappear with changes of lighting, and (ii) can be categorized as *positive* when they are bright or as *negative* when they are dark [23].

In the spatial domain, a 2D Gabor function is a Gaussian multiplied by a complex exponential and can be seen as a Gaussian shifted from the origin in the Fourier domain. Its mathematical properties such as the smooth infinitely differentiable shape, the monomodal modulus and the highly joint localization in space, orientation and frequency make it a good choice for various image processing applications. In addition, 2D Gabor function can be used as a model which follows as much as possible the neuroscience knowledge on the simple cells receptive field's properties of the Primary Visual Cortex (V1) of primates on the statistics of natural images [24].

However, this function has a few drawbacks: (i) non-orthogonality which implies non-invertibility witch is not really a problem in our feature extraction use, (ii) its deficiency to cover uniformly the mid-frequencies as it is a bandpass filter, (iii) its bad coverage of low and high frequencies due to an excessive overlapping, and (iv) the non-zero DC component which increases as the bandwidth is widened resulting from the tails' overlapping of the sum of two Gaussians centered at plus and minus the central frequency.

It is worth noting that natural images are better encoded using filters having transfer functions which are Gaussian viewed on the logarithmic frequency scale [25]. Therefore, a log-Gabor can be a better alternative to the Gabor filtering since its transfer function is viewed on the logarithmic frequency scale including the constraint of the maximum bandwidth which limited to approximately one octave on Gabor filters which is not optimal if one is seeking a broader spectral information with maximal spatial localization. Therefore, that log-Gabor filters can offer attractive power especially in image feature discrimination.

In this paper, we have chosen a multi-resolution approach which is justified by the properties of the palmprint lines discussed previously and by a physiological basis claiming that, for each location of a palmprint image, there are cells that cover at least three scales over a minimum of four octaves [26] in addition of an improved principal line's representation at large scales.