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A keypoints-based feature extraction method for iris recognition under variable image quality conditions

Yuniol Alvarez-Betancourt, Miguel Garcia-Silvente*

CITIC-UGR. Department of Computer Science and Artificial Intelligence, University of Granada, Granada, Spain

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ABSTRACT

Iris recognition is a very reliable biometric modality for human identification. The immutable and unique characteristics of the iris are the foundations for that claim. Currently, research interest in this field points to challenges regarding less-constrained iris recognition systems. In response, we propose a robust keypoints-based feature extraction method for iris recognition under variable image quality conditions. To this end, three detectors have been used to identify distinctive keypoints: Harris-Laplace, Hessian-Laplace, and Fast-Hessian. Once the three sources of keypoints are obtained, they are described in terms of SIFT features. The proposed method combines the three information sources of SIFT features at matching score level. The combination of these sources reinforces the discriminative power of the proposal for recognition on highly or less textured iris images. The fusion is carried out using a proposed weighted sum rule relies on the ranking of three performance measures. The proposed fusion rule computes weights, which represent the reliability degree to which each individual source must contribute in order to determine the more discriminative matching scores. Our experiments rely on iris standard databases which as a whole constitute a challenging and perfect example of variable image quality conditions. According to the results, our proposal is very competitive and outperforms the state-of-the-art algorithms on the topic. In addition, it is demonstrated that the proposed keypoints-based feature extraction method is feasible and that it could be used even in real-time applications if the database is previously processed.

1. Introduction

In the last years, biometric technologies have arisen as the most reliable access control systems (e.g. fingerprints, hand geometry, face, ears, retina, and the iris) [28]. Among these biometric technologies, iris recognition has gained more popularity due to its characteristics: its rich texture is endowed with many degrees of freedom; it remains unchanged despite the aging process; it is protected by a structure which, if modified, may compromise the health of the individual, and it may be easily accessed with a non-invasive device [4]. Therefore, many leading companies in the field of security are betting on the future of this technology because of the diversification of its applications.

Currently, researchers in the field are faced with the challenge of non-ideal iris recognition [27,43,49]. Non-ideal iris recognition takes place in less constrained environments, which imply the relaxation of some factors such as: distance, person movements, lighting conditions [4]. In the literature we can find various surveys [4,9] which summarize novel approaches and trends in this field of research. A conventional iris recognition system consists of the 4 following stages: (1) image acquisition [28,33]; (2) preprocessing (spoofing detection [10]; image quality assessment [24]; iris segmentation [14,18,50]; and normalization [14]); (3) feature extraction [14,30,39,40,44,57]; and (4) pattern matching [14,39]. Roughly speaking, the process starts with the acquisition of the iris image and concludes with the decision to accept or reject the claimed identity.

The feature extraction stage has been studied in depth but it requires additional research in order to gain in robustness and accuracy. To a certain extent, this is due to the fact that recognition in less-constrained environments involves challenges concerning the quality of iris images such as: illumination, occlusion, blur, scale, rotation, point of view, etc., because they may produce severe texture deformations. The iris texture is characterized by the random distribution of local features such as: furrows, crypts, freckles, pigment spots and pigment frill. The success of both the iris segmentation and the feature extraction stages is closely related to the quality factors of iris images. The systems which are very dependent on texture details are the most prone to failure in the execution of these stages. Therefore, the global performance of the biometric system could be

* Corresponding author. Tel.: +34 958240807; fax: +34 958243317.
E-mail addresses: yuniol@decsai.ugr.es (Y. Alvarez-Betancourt), m.garcia-silvente@decsai.ugr.es (M. Garcia-Silvente).

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compromised. Consequently, iris feature extraction under variable image quality conditions remains a challenge worthy of investigation.

Until now, contributions to the topic of iris feature extraction have been based on two main approaches according to the type of representation of iris texture: binary iris code or real-valued feature vectors [9]. This is the most used classification of feature extraction methods in iris research. The work by Daugman [12] underlies the approach of the binary iris code. In that work, the binary iris code is obtained by means of an encoding process on phase information from a transformation of 2-D Gabor wavelets. Other studies obtain the binary representation using several transformations such as: a Hilbert transform [58], a dyadic wavelet transform [31], a 2D Log-Gabor filters [61], a discrete cosine transform [40], a 2D Fourier phase code transformation [39], and a multilobe differential filters [57]. As to the methods based on real-valued feature vectors, they use transformations similar to the ones mentioned previously, that is keeping the transformation output with the original real-valued feature vector. However, they do not go through a binary coding process. As examples of real-valued feature representations obtained with some transformations, let us mention: a 1D wavelet transform [8], a 1D dyadic wavelet transform [52], an independent component analysis [20], a symmetric Gabor filters [30], a principal component analysis [11], a Daubechies-4 wavelet packet decomposition [16], and a 2D weighted principal component analysis [63].

Another element to bear in mind is the way in which the feature extraction method is accomplished. This could be summarized under three main categories of iris feature extraction: (1) whole iris region based, (2) regions of interest based, (3) points of interest based. The first one corresponds to the traditional iris recognition systems where global and local features are extracted from the whole iris region [14,31,39,40]. The second one includes the methods which extract local features from regions of interest with the aim to overcome the shortcomings arising mainly from eyelashes and eyelids occlusions. As an example of these systems based on regions of interest, let us mention: the upper portion of a normalized iris image (corresponding to regions closer to the pupil) [30], the annular region before the normalization process [51], the sub-regions without occlusions in the normalized image [38], the six independent biometric signatures from different iris regions [43], the annular collarette area [48]. The third category deals with approaches based on points of interest, also named keypoints-based methods. The methods included in this category extract real-valued feature vectors which describe the appearance around each keypoint. To this end, the features extracted have to be invariant as to scale, rotation, illumination, noise, and viewpoint. The keypoints-based methods are very useful in object recognition applications on images disrupted by occlusion, clutter, or noise [59]. Several keypoints-based methods for iris recognition have been presented in past publications [2,6,15,34,35,47,54,56]. These methods perform well enough in the case of noised images but they still need improvement in terms of accuracy even in studies considered as being state-of-the-art.

That is why, convinced of the intrinsic advantages of the existing keypoints-based methods, we propose a new improved version based on the fusion of keypoints-based information sources. More specifically, our aim is to develop a keypoints-based feature extraction method which, thanks to its flexibility and characteristics, would allow more accuracy in the case of iris recognition under variable image quality conditions. Our proposal does not require conditions such as: accurate iris location, normalization of annular iris region (allowing removal of the aliasing problem [42]), and occlusion detection. We theorize that the strengths of keypoints-based feature extraction methods [59] can be very useful in the case of inaccurate segmentations as result of iris recognition on less-constrained environments. The proposal has the advantage of fusing information from different sources. The unimodal biometric applications are often affected by several practical problems like noisy sensor data, non-universality and/or lack of distinctiveness of the biometric trait, unacceptable error rates, and spoof attacks [21]. Hence the fusion of multiple sources or modalities is an efficient way to overcome them. The proposal combines the three keypoint sources at matching score level with a proposed weighted sum rule based on the ranking of three performance measures. Thereby, exhaustive experiments are developed in the verification and identification modes from which the respective performance measures and curves are obtained. The experiments rely on CASIA-IrisV4-Interval, MMU 2, and UBIRIS 1 databases which contain iris images with a great variability of image quality conditions. The results point to the innovative nature of our methodology.

The remainder of this paper is structured as follows: Section 2 explains how the iris is segmented for the subsequent extraction of the features. Section 3 provides the details of the proposed iris feature extraction method. The description of the experiments and the discussion of the results are presented in Section 4. Finally, in Section 5, we present the conclusions of our work.

2. Iris segmentation

The iris is an internal organ of the eye located behind the cornea and the aqueous humor. It consists of a weave of connective tissues, fibers, rings and colors which constitute a distinctive and unique mark of people. By observing the iris from the center of the circle which models the inner boundary up to its outer boundary, two delimiting borders can be identified (see Fig. 1(a)). The first one, pupil–iris border, is defined by the shift of the intensity lower values (pupil region) of the image to middle intensities which characterize the iris region. The second border, iris–sclera, is characterized by the shift of middle values of intensity to the highest values (sclera region) of the image. Also, its geometric shape (circular or elliptical depending on the point of view) constitutes another feature of great importance for automatic detection [4]. Taking as a base the previous assumptions, we segment the iris the way we did in our previous work [3], that is in two main stages. The first one obtain an initial approximation of the center $P(X_0, Y_0)$ of the iris region. This time, we propose a more accurate method to approximate the iris center. In the second stage, we try to find the circular boundaries from the obtained initial approximation of the iris center, which best represent the inner and outer boundaries of the iris. Overall, the quality of the segmentation stage is reliable on the success of the initial approximation of the iris center.

2.1. Initial approximation of the iris center

The approximation of the iris center starts from the assumption that it is very close to the center of the processed images. The assumption is supported by the fact that the majority of iris capture-devices extract a square region of each eye which are very close to the image center. The iris image databases used in our work are examples of that. The proposed method sets out to look for the biggest dark object in the image which stands for the pupil. Basically, we start an iterative procedure of profile operations from the image center $P(X_I, Y_I)$ (see Fig. 1(a)). The profile operations are executed for each point in the horizontal (denoted as H_P) and vertical (denoted as V_P) directions. The region within which are processed candidate points of the iris center corresponds to the square region delimited by the size $2mX2m$ with center in $P(X_I, Y_I)$ (see the dashed square region in Fig. 1(a)). It is worth noting that in a profile operation, pixel-values are obtained along straight line segments (in our case, lines are in the horizontal and vertical directions). Thereby, the iris center is represented by the point $P(X_0, Y_0)$ in which H_P and V_P have the same number of consecutive pixels lower than a threshold h. The white axes in Fig. 1(a) denote profiles which correspond to the iris center. Besides, Fig. 1(b)