Computer Engineering and Intelligent Systems
ISSN 2222-1719 (Paper) ISSN 2222-2863 (Online)
Vol.4, No.9, 2013

Iris feature extraction: a survey

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Abstract

Biometric as a technology has been proved to be a reliable means of enforcing constraint in a security sensitive environment. Among the biometric technologies, iris recognition system is highly accurate and reliable because of their stable characteristics throughout lifetime. Iris recognition is one of the biometric identification that employs pattern recognition technology with the use of high resolution camera. Iris recognition consist of many sections among which feature extraction is an important stage. Extraction of iris features is very important and must be successfully carried out before iris signature is stored as a template. This paper gives a comprehensive review of different fundamental iris feature extraction methods, and some other methods available in literatures. It also gives a summarised form of performance accuracy of available algorithms. This establishes a platform on which future research on iris feature extraction algorithm(s) as a component of iris recognition system can be based.

Keywords: biometric authentication, false acceptance rate (FAR), false rejection rate (FRR), feature extraction, iris recognition system.

1. Introduction

In various computer vision applications, widely used is the process of retrieving desired images from a large collection on the basis of features that can be automatically extracted from the images themselves. Feature extraction is the process of generating features to be used in the selection and classification tasks [1]. Feature is defined as a function of one or more measurements, each of which specifies some quantifiable properties of the object, and is computed such that it quantifies some significant characteristics of the object. Features are classified as follows:

- General features: these are application independent features such as colour, texture, and shapes. According to the abstraction level, they can further be divided into:
    i. Pixel-level features: Feature calculated at each pixel, e.g. colour, location.
    ii. Local features: Features calculated over the results of subdivision of the image band on image segmentation or edge detection.
    iii. Global features: features calculated over the entire image or just regular sub-area of an image.
- Domain-specific features: Application dependent features such as human faces, fingerprints, and conceptual features. These features are often a synthesis of low-level features for a specific domain.

2. Iris features extraction

Feature extraction is a special form of dimensionality reduction and contains more information about the original image [2]. Features are extracted, using the normalized iris image. The most discriminating information in an iris pattern must be extracted. Only the significant features of the iris must be encoded so that comparisons between templates can be made conveniently and correctly. From literatures, feature extraction techniques in iris can be roughly classified into four broad categories [3]. First is texture based method, secondly phase based method, thirdly Zero crossing based method and finally, intensity variation based method. Complexities of iris image structure and the various sources of intra-class variations result in the difficulty of iris representation [4]. It was discovered that half of an iris can give a correct detection of an individual as well as full iris can do [5]. Complexity of features to be extracted influences the complexity of the program and execution time of the iris recognition system [6, 7]. Dolly and his colleagues in their survey of feature extraction methods for iris recognition elucidated on the following algorithms: corner detection based iris encoding; Haar wavelet; Gabor filter and multichannel Gabor filter methods of segmentation [8]. Moreover, comparison of the work of Singh et al.,[9], Gupta et al.,[10], Greco et al., [11], Amel Saeed Tuama [12] and Li Ma et al., [13] was made based on the overall accuracy of the system. The database on which the accuracy level was determined was not mentioned. This necessitated a more comprehensive and an elaborate review of available algorithms in iris feature extraction.

2.1 Gabor filter

A Gabor filter is constructed by modulating a sine/cosine wave with a Gaussian. This is able to provide the optimum conjoint localization in both space and frequency, since a sine wave is perfectly localized in frequency, but not localized in space. Modulation of the sine wave with Gaussian provides localization in space, though with loss of localization in frequency. Decomposition of a signal is accomplished using a quadratic pair of Gabor filters. A real part is specified by a cosine modulated by a Gaussian and an imaginary part is specified by a sine modulated by a Gaussian. The real and imaginary filters are also known as the even symmetric and odd symmetric components respectively.

The centre frequency of the filter is specified by the frequency of the sine/cosine wave. The bandwidth of the filter is specified by the width of the Gaussian. Daugman made use of a 2D version of Gabor filters in order to encode iris pattern data. A 2D Gabor filter over an image domain (x, y) is represented as:

$$G(x,y) = e^{-\pi\left[\frac{(x-x_0)^2}{\alpha^2} + \frac{(y-y_0)^2}{\beta^2}\right]} e^{-2\pi i[u_0(x-x_0)+ v_0(y-y_0)]} \qquad (1)$$

where (x_0, y_0) specify position in the image, (α, β) specify the effective width and length and (u_0, v_0) specify modulation.

2.2 LoG Gabor filter

A disadvantage of the Gabor filter is that the even symmetric filter will have a DC component whenever the bandwidth is larger than one octave. However, zero DC components can be obtained for any bandwidth by a Gabor filter which is Gassian on a logarithmic scale. It is known as the Log-Gabor filter. The frequency response of a Log-Gabor filter is given as:

$$G(f) = e^{-\frac{(\log(f/f_0))^2}{2(\log(\sigma/f_0))^2}} \qquad (2)$$

where f_0 represents the center frequency and σ gives the bandwidth of the filter.

2.3 Zero crossing of 1D wavelets

Boles and his research associates made use of 1D wavelet for encoding iris pattern data. The mother wavelet ψ is defined as the second derivative of a smoothing function $\theta(x)$.

$$\psi(x) = \frac{d^2\theta(x)}{dx^2} \qquad (3)$$

the zero crossings of dyadic scales of these filters are then used to encode features. The wavelet transform of a signal $f(x)$ at a scale s and position x is given by equation 4

$$W_s f(x) = f * \left(s^2 \frac{d^2\theta(x)}{dx^2}\right)(x) \qquad (4)$$

$$= s^2 \frac{d^2}{dx^2}(f * \theta_s)(x) \qquad (5)$$

Where $\theta_s = (1/s)\theta(x/s)$

$W_s f(x)$ is proportional to the second derivative of $f(x)$ smoothed by $\theta_s(x)$ and the zero crossings of the transform correspond to points of inflection in $f * \theta_s(x)$. The motivation for this technique is that zero-crossings correspond to significant features with the iris region.

2.4 Haar encoding (Wavelet method)

Lim et al., [13] also used the wavelet transform to extract features from the iris region. Both Gabor transform and the Haar wavelet are considered as the mother wavelet. From multi-dimensionally filtering, a feature vector with 87 dimensions is computed. Since each dimension has real value ranging from -1.0 to +1.0, the feature vector is sign quantized so that any positive value is represented by 1 and negative value is represented by value 0. This results in a compact biometric template consisting of only 87 bits. Lim et al., compared the use of Gabor transform and Haar wavelet transform and showed that the recognition rate of Haar wavelet transform was slightly better than Gabor transform (i.e. by 0.9%).

3. Review of literatures on iris feature extraction

Seung-in et al. identified that wavelet transform, as feature extraction method does not have the shift-in-variant property, the iris features are inconsistently extracted due to the eye image rotation and the inexact iris localization [14]. They therefore proposed a method of iris feature extraction (dyadic discrete wavelet frame decomposition) where two features (global and local features) were obtained. The global feature is insensitive to iris image deformation and local feature represents the iris local texture. If the global feature between the two templates is less than the threshold value, it is added to the candidate and the Hamming distance is performed [14]. Estimated Error Rate (EER) against data size was used for validation and their system performed more than Gabor system. Rydgren et al., developed a wavelet packet analysis to iris feature extraction [15]. An energy measure was used to identify the particular packet that carries discriminating information about the texture. The wavelet packets used 3-level wavelet packet decomposition that generates 64 output sub-images. Each sub-image contains the following details: approximation (A), horizontal (H), vertical (V), and diagonal (D) details. Sub-images in the wavelet packet hold information about both frequencies (scale) and localization as opposed to Fourier that holds only the frequency information. Energy level for each sub-image is calculated. The system was compared with Gabor wavelets method and the system was found to produce 100% recognition accuracy. Meanwhile, there are some limitations such as in time for execution and calculation complexity. Patil and Patilkulkarani developed an iris recognition system which employed the higher level wavelet approximation for feature extraction of the iris image [16]. The edge was first detected, followed by Hough transform through which circles in the image were detected. The image was de-noise and then extraction of features (using high level wavelet approximation) followed. The algorithm was implemented using MATLAB and tried with CASIA. Recognition accuracy of the developed algorithm was 98.91% and 97.98% Euclidean norm-1 measure and Euclidean distance respectively. Kekre et al., [17] developed an iris recognition system which uses vector quantization for iris recognition method and it gave recognition accuracy of 89.10% over DCT method which gave 66.10%. Later he used Haarlet pyramid for iris image feature extraction. The features were extracted from Haar wavelets at various levels of decomposition. Haarlet wavelet feature extraction algorithm was applied on Palacky University iris database and was found to perform well [18]. The algorithm is a data compression algorithm. Patil and Patilkulkarani developed lifting wavelet-based iris feature extraction method. It was able to enhance iris images, reduce the noise to the maximum extent possible and extract important features possible. Recognition accuracy of the algorithm when employed on iris database (CASIA) was 99.78%. Ayra et al., in their study discovered that in the family of wavelet feature extraction methods, Haar wavelet has the greatest correct recognition rate when implemented on MATLAB platform [19]. The developed Haar wavelet feature extraction method was evaluated using CASIA (version 3).

The major drawback/limitation of wavelet transform is their limited ability in capturing directional information [20]. Another development in the class of wavelet transform is the contourlet transform which uses two dimensions, multi-scale and directional filter banks. Gabor wavelet method was discovered to possess greatest recognition accuracy among Daugman [21], Li et al., [13], Tan et al.,[22], Maheswari [23], Birgale and Kokare (2009) [24]. It has recognition accuracy of 99.95%.

Kazuyuki et al., developed an iris recognition system that made use of Discrete Fourier Transform (DFT) method [25]. The algorithm produced an accuracy level of 0.58 EER accuracy when used on CASIA. Xiaoyan and Pengfei, developed a feature extraction method which employed 2D phase congruency to extract features from the iris image [26]. This was employed with the sole aim of overcoming invariant changes in intensity or contrast in the captured iris image. The algorithm was employed on iris database of Shanghai Jiao Tong University (SITU-IDB), it gave 98% recognition accuracy.

Vivekanand et al., developed an iris feature extraction method using the global Independent Component Analysis (ICA). CASIA and WVU databases were used to validate the system [27]. The ICA was used to extract local features while PCA was used as a pre-processing function. Moreover, the algorithm was able to compensate for tilting of the head at the point of image capture.

Hunny et al., developed a multi-algorithmic system for iris authentication where they used Haar wavelet to extract texture features from normalised iris strip and phase features were extracted using LoG Gabor Wavelet. The system was tested on BATH database and produced 95.6% and 97.66% respectively [28]. In 2008, Nabti et al., developed an iris recognition system which make use of a combined multiscale feature extraction technique [4]. A multiscale edge detection technique was employed as a pre-processing step to efficiently localize the iris followed by a new feature extraction technique which is based on a combination of some multiscale feature extraction techniques. This combination uses special Gabor filters and wavelet maxima components. This lead to a compact and efficient feature vector representation generated from using moment invariant method.

The multi-scale method is discovered to have being holistic more than multi-resolution feature extraction methods such as Wildes [29], Boles and Boashash [30], Daugman [31] which has their specification and situation in which they are suitable. The algorithm was applied on CASIA public iris database and was able to produce a recognition rate of 99.60% for moment invariants and 99.52% for statistical features as against Daugman [31] with (99.9%), Ma [22] with (99.23%), Boles and Boashash [30] with (93.2%) accuracy.

Bhawna and Shailja, developed an iris statistical feature extraction method using Laplacian of Gaussian filter for iris recognition. The aim was to reduce noise to the maximum in the iris image [32]. The algorithm was used on CASIA and the resulting recognition accuracy was 97%.

Donald and his group developed an iris extraction method using Discrete Cosine Transform. The algorithm employed difference of DCT coefficients of overlapped angular patches from normalized iris images. The feature extraction capabilities of the DCT are optimized on the two largest public iris databases (CASIA and BATH) and the recognition accuracy was found to be 100% Correct Recognition Rate (CRR) and perfect Receiver-Operating Characteristics (ROC) curve with no registered false accepts or rejects [33].

Amir and Hamid, (2009) developed an iris feature extraction method based on contourlet transform [20]. A contourlet transform captures the intrinsic geometrical structures of the iris, decomposes it into a set of directional sub-bands with texture details captured in different orientations at various scales. This reduces the feature vector dimension and this is used to extract only significant bit and information from normalised iris image. The proposed algorithm and some existing algorithms were implemented on Matlab 7 and used on CASIA (version 1). Its accuracy level was found to be 94.2% as against Daugman [21] (100%), Wildes [29] (94.18%), Ma [22] (95.02), Ma et al., [34] (92.16%), and Jafar Ali (2003) (92.16%). This algorithm was employed in an iris recognition system [36]. In 2009, Xiuli and Ping, developed an iris feature extraction method using complete 2DPCA algorithm [37].

Nozomi and Akira, (2010) developed an iris feature extraction method that used morphological skeleton for its recognition [38]. In order to attenuate the fluctuation of quality of iris images, the mean value and standard deviation of the iris image is adjusted to the satisfied value before features of the iris was extracted.

Somnath and Debasis, developed an iris feature extraction method which employed Daubechies D_4 wavelet with 4 levels to extract features from the iris images [6]. These features are enclosed with 2 bits by quantizing into 4 quantization levels. With this algorithm, the iris template was represented with only 304 bits in contrast with many existing approaches which used as much as 1024 bits to represent the iris template.

In 2012, Suganthy and Ramamoorthy employed Principal Component Analysis (PCA) at image pre-processing stage of an iris recognition system [2]. At this stage, redundant and unwanted data are removed from the image. Features are extracted using wavelet packet transform (WPT). The matching is finally done using KNN. The algorithm was applied on CASIA iris database (v 1.0 and v3.0).

4. Comparison of Feature Extraction method and their accuracies

Table 1 gives a summary of major algorithm reviewed in this paper based on the fundamental algorithm employed, author(s) algorithm accuracy level and public iris database that was used for their validation. Table 1 summarises different reviewed iris feature extraction methods, their author(s), database on which they were used and their recognition accuracy in percentage values.

5. Conclusion

Since every individual has distinct iris pattern, iris recognition system can therefore be used as a mean of individual recognition. Different available iris feature extraction had been studied in this review paper. This summarised review can serve as a platform for development of other iris feature extraction methods. Many of the reviewed algorithm had not been used on many other public iris databases such as UBIRIS, and other not well distinguished pupillary vs iris boundary irises.

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Table 1: Summary of iris feature extraction methods and their accuracy.

Background algorithm & yr	Author(s)	Algorithm	Accuracy
(a) Haar wavelet			
2004	Rydgren et al.,	Wavelet packet analysis	100% recognition
2005	Seung-In et al.,	Dyadic Discrete wavelet method	it performs more than Gabor algorithm
2009	Patil and Patilkulrani	Higher level wavelet	98.91% on CASIA
2010	Kekre et al.,	Haar wavelet	89.10%
2010	Somnath & Debasis	Daubechies D4	
2010	Patil & patilkulkarani	Lifting wavelet	99.78%
2012	Suganthy and Ramamoorthy	Wavelet packet transform	(CASIA)
(b) Discrete Fourier Transform			
2005	Xiaoyan & Pengfei	2D phase congruency	98% on SITU iris database
2005	Kazuyuki et al.,	DFT	CASIA
(c) Logarithm of Gaussian (LoG)			
2007	Hunny et al.,	LoG	97.66% on BATH database
2008	Nabti et al.,	Multi-scale (Special Gabor & wavelet maxima	99.6%
2010	Bhawna and Shailja	LoG Gabor	97%
(d) Contourlet Transform			
1993	Daugman (1993)		100%
2009	Amir and Hamid		94.2% on CASIA database.
(e) Others			
1999	Xuili and Ping	2D- PCA	
2005	Vivekanand	PCA + ICA	
2010	Nozomi & Akira	Morphological skeleton	

[15,14,16,1826,25,4,32,20,27,32]