An Improved Iris Recognition System Using Feature Extraction Based on Wavelet Maxima Moment Invariants

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Abstract. Human recognition technology based on biometrics has received increasing attention over the past decade. Iris recognition is considered to be the most reliable biometric authentication system and is becoming the most promising technique for high security. In this paper, we propose a multiscale approach for iris localization by using wavelet modulus maxima for edge detection, a fast and a compact method for iris feature extraction based on wavelet maxima components and moment invariants. The features are represented as feature vector, thus allowing us to also propose a fast matching scheme based on exclusive OR operation. Experimental results have shown that the performance of the proposed method is very encouraging and comparable to the well known methods used for iris texture analysis.

Keywords: biometrics, iris recognition, multiscale edge detection, wavelet maxima, moment invariants.

1 Introduction

Consistent automatic recognition of individuals has long been an important goal, and it has taken on new importance in recent years. The use of biometric signatures, instead of tokens such as identification cards or computer passwords, continues to gain increasing attention as a means of identification and verification of individuals for controlling access to secured areas, materials, or systems because an individual's biometric data is unique and cannot be transferred. Biometrics is automated methods of identifying a person or verifying the identity of a person based on a physiological or behavioral characteristic. Examples of physiological characteristics include hand, finger images, facial characteristics, and iris recognition. Signature verification and speaker verification are examples of behavioral characteristics [2,3]. Biometrics have the potential for high reliability because it is based on the measurement of an intrinsic physical property of an individual

The iris is an overt body that is available for remote (i.e., noninvasive) assessment. The variability of features of any one iris is well enough constrained to make possible a fully automated recognition and verification system based upon machine vision, and even identical twins have distinct iris features[2].

The iris is an annular area between the pupil and the white sclera in the eye; it has a rich texture based on interlacing features, called the texture of the iris. This texture is well known to provide a signature that is unique to each subject. Compared with other biometric signatures mentioned above, the iris is generally considered more stable and reliable for identification [3].

The authentication system based on iris recognition is reputed to be the most accurate among all biometrics methods because of its acceptance, reliability and accuracy. Ophthalmologists originally proposed that the iris of the eye might be used as a kind of optical fingerprint for personal identification [1]. Their proposal was based on clinical results that every iris is unique and it remains unchanged in clinical photographs. The human iris begins to form during the third month of gestation. The structure is complete by the eighth month of gestation, but pigmentation continues into the first year after birth. It has been discovered that every iris is unique and no two people even two identical twins have uncorrelated iris patterns [3], and is stable throughout the human life. It is suggested in recent years that the human irises might be as distinct as fingerprint for different individuals, leading to the idea that iris patterns may contain unique identification features.

A number of groups have explored iris recognition algorithms and some systems have already been implemented and put into commercial practice by companies such as Iridian Technologies, whose system is based on the use of Daugman's algorithm.

1.1 Related Work

Most works on personal identification and verification using iris patterns have been done in the 1990s; Daugman [1] developed the feature extraction process based on information from a set of 2-D Gabor filter. He generated a 256byte code by quantizing the local phase angle according to the outputs of the real and imaginary parts of the filtered image, the Wildes system made use of Laplacian pyramid constructed with four different resolution levels to generate iris code [4]. It also exploited a normalized correlation based on goodness-of-match values and Fisher's linear discriminant for pattern matching. Boles [5] implemented the system operating the set of 1-D signals composed of normalized iris signatures at a few intermediate resolution levels and obtaining the iris representation of these signals via the zerocrossing of the dyadic wavelet transform. Tan [6] generates a bank of 1D intensity signals from the iris image and filters these 1D signals with a special class of wavelet. The positions of local sharp variations are recorded as the features.

1.2 Outline

In this paper, we first present a multiscale approach for edge detection based on wavelet maxima which can provide significant edges where noise disappears with an increase of the scales (to a certain level), with less texture points producing local maxima thus enabling us to find the real geometrical edges of the image thereby yielding an efficient detection of the significant circles for inner and outer iris boundaries and eyelids. A new approach has been proposed for feature extraction to making a feature vector compact and efficient by using wavelet maxima components and moment invariants technique to present our feature vector which is invariant to

translation, rotation, and scale changes. A fast matching scheme based on the exclusive OR operation has been carried out.

The remainder of this paper is organized as follows. Section 2 describes iris localization step using our proposed multiscale edge detection approach. Mapping and normalization step are presented in Section 3. Feature extraction and matching are given in Section 4 and Section 5, respectively. Experimental results and discussions are reported in Section 6. Section 7 concludes this paper.

2 Iris Localization

Image acquisition captures the iris as part of a larger image that also contains data derived from the immediately surrounding eye region. Therefore, prior to performing iris pattern matching, it is important to localize that portion of the acquired image that corresponds to the iris. Figure 1 depicts the portion of the image derived from inside the limbus (the border between the sclera and the iris) and outside the pupil (iris is from CASIA iris database).

Fig. 1. Eye image

If the eyelids are occluding part of the iris, then only that portion of the image below the upper eyelid and above the lower eyelid should be included. The eyelid boundary also can be irregular due to the presence of eyelashes. From these suggestions, it can be said that, in iris segmentation problems, a wide range of edge contrasts must be taken in consideration, and iris segmentation must be robust and effective.

2.1 Multiscale Edge Detection

In our proposed method [10], a multistage edge detection is used to extract the points of sharp variations (edges) with modulus maxima and where the local maxima are detected to produce only single pixel edges. The resolution of an image is directly related to the appropriate scale for edge detection. A high resolutions and a small scale will result in noisy and discontinuous edges; low resolution and a large scale will result in undetected edges. The scale controls the significance of edges to be shown. Edges of higher significance are more likely to be preserved by the wavelet transform across the scales. Edges of lower significance are more likely to disappear when the scale increases.

Mallat, and Hwang [7, 8] proved that the maxima of the wavelet transform modulus can detect the location of the irregular structures. The wavelet transform characterizes the local regularity of signals by decomposing signals into elementary building blocks that are well localized both in space and frequency. This not only explains the underlying mechanism of classical edge detectors, but also indicates a way of constructing optimal edge detectors under specific working conditions.

2.2 Proposed Method

Assume $f(x, y)$ is a given image of size $M \times N$. At each scale j with $j > 0$ and $S_0 f = f(x, y)$, the wavelet transform decomposes $S_{j-1} f$ into three wavelet bands : a lowpass band $S_j f$, a horizontal highpass band $W_j^H f$ and a vertical highpass band $W_j^V f$. The three wavelet bands ($S_j f$, $W_j^H f$, $W_j^V f$) at scale j are of size $M \times N$, which is the same as the original image, and all filters used at scale j ($j > 0$) are upsampled by a factor of 2^j compared with those at scale zero.

In addition, the smoothing function used in the construction of a wavelet reduces the effect of noise. Thus, the smoothing step and edge detection step are combined together to achieve the optimal result.

At each level of wavelet decomposition the modulus $M_j f$ of the gradients can be computed by:

$$M_j f = \sqrt{|W_j^H f|^2 + |W_j^V f|^2} \quad (1)$$

and the associated phase $A_j f$ is obtained by:

$$A_j f = \tan^{-1} \left(\frac{W_j^V}{W_j^H} \right) \quad (2)$$

A Hough transform is then used to localize iris and pupil circles. The eyelids are isolated using the horizontal multiscale edges (figure2-b) with a linear Hough transform while the eyelashes are isolated using a thresholding technique (figure 3).

Fig. 2. Edge detection, (a) pupil edge detection, (b) Edges for eyelids detection

Fig. 3. Iris localization, Black regions denote detected eyelid and eyelash regions

3 Iris Normalization

After determining the limits of the iris in the previous phase, the iris should be isolated and stored in a separate image. The dimensional variations between eye images are mainly due to the stretching of the iris caused by pupil dilation from varying levels of illumination, images capture distances, head incline, and other factors. Regarding this reasons it is necessary to normalize iris region, for this purpose all the points within the boundary of the iris are remapped (figure 4) from Cartesian coordinates to polar coordinates (r, θ) as:

$$I(x(r, \theta), y(r, \theta)) \longrightarrow I(r, \theta) \quad (3)$$

where r is on the interval $[0,1]$ and θ is angle $[0,2\pi]$.

In this model a number of data points are selected along each radial line and this is defined as the radial resolution. The number of radial lines going around the iris region is defined as the angular resolution as in (figure 4-a).

In the new coordinate system, the iris can be represented in a fixed parameter interval (figure 4-b).

Fig. 4. Normalized iris, (a) Normalized iris portion with radial resolution of 15 pixels, and angular resolution of 60 pixels, (b) Iris normalized into polar coordinates

4 Feature Extraction

Feature extraction is the crucial step in an iris recognition system, therefore what kind of features should be extracted from images? It is clear that the extracted features should meet at least the following requirements: they should be significant, compact, and fast to compute. For these reasons and to achieve a compact and efficient feature vector, wavelet maxima components and moment invariants techniques are used.

4.1 Wavelet Maxima Components for Feature Extraction

Wavelet decomposition provides a very elegant approximation of images and a natural setting for the multi-level analysis. Since wavelet transform maxima provide useful information about textures and edges analysis [7], we propose to use this technique for fast feature extraction by using the wavelet components.

Wavelet maxima have been shown to work well in detecting edges which are likely the key features in a query; moreover this method provides useful information about texture features by using horizontal and vertical details.

4.2 Proposed Method

As described in [7] to obtain the wavelet decomposition a pair of discrete filters H, G has been used as follows:

Table 1. Response of filters H, G

H	0	0	0.125	0.375	0.375	0.125	0
G	0	0	0	-2	2	0	0

At each scale s , the algorithm decomposes the normalized iris image $I(x,y)$ into $I(x, y, s)$, $W_v(x y, s)$ and $W_h(x,y,s)$ as shown in figures (5,6) .

- $I(x, y, s)$: the image smoothed at scale s .

- $W_h(x, y, s)$ and $W_v(x, y, s)$ can be viewed as the two components of the gradient vector of the analyzed image $I(x,y)$ in the horizontal and vertical direction, respectively.

At each scale s ($s=0$ to $s=S-1$ where S is the number of scales or decomposition) image $I(x, y)$ is smoothed by a lowpass filter:

$$I(x, y, s+1) = I(x, y, s) * (H_s, H_s) \quad (4)$$

The horizontal and vertical details are obtained respectively by:

$$W_h(x, y, s) = \frac{1}{\lambda_s} \cdot I(x, y, s) * (G_s, D) \quad (5)$$

$$W_v(x y, s) = \frac{1}{\lambda_s} \cdot I(x, y, s) * (D, G_s) \quad (6)$$

- We denote by D the Dirac filter whose impulse response is equal to 1 at 0 and 0 otherwise.

- We denote by $A * (H, L)$ the separable convolution of the rows and columns, respectively, of image A with the 1-D filters H and L .

- G_s, H_s are the discrete filters obtained by appending 2^s-1 zeros between consecutive coefficients of H and G .

Fig. 5. Wavelet maxima vertical components at scale 2 with intensities along specified column

Fig. 6. Wavelet maxima horizontal components at scale 2 with intensities along specified column

- λ_s , as explained in [7] due to discretization, the wavelet modulus maxima of a step edge do not have the same amplitude at all scales as they should in a continuous model. The constants λ_s compensate for this discrete effect.

4.3 Moment Invariants for Feature Vector Representation

The theory of moments provides an interesting series expansion for representing objects. This is also suitable to mapping the wavelet maxima to vectors so that their similarity distance can be measured in a simple way [9].

Certain functions of moments are invariant to geometric transformations such as translation, scaling, and rotation. Such features are useful in the identification of objects with unique signatures regardless of their location, size, and orientation [9].

A set of seven 2-D moment invariants that are insensitive to rotation, translation and scaling [9] have been computed for each horizontal and vertical wavelet maxima component from scale 1 to scale 5. Therefore, ten wavelet maxima components (i.e., H1,V1,H2,V2,H3,V3,H4,V4,H5,V5) are obtained thus making a feature vector size of 70 (7x10) for every iris image.

5 Matching

It is important to present the obtained vector in a binary code because it is easier to determine the difference between two binary code-words than between two number vectors. In fact, Boolean vectors are always easier to compare and to manipulate.

We have applied Hamming Distance matching algorithm for the recognition of two samples. It is basically an Exclusive OR (XOR) function between two bit patterns. Hamming Distance is a measure, which delineates the differences, of iris codes. Every

bit of the presented iris code is compared to every bit of referenced iris code so that if the two bits are the same e.g. two 1's or two 0's, the system assigns a value '0' to that comparison and if the two bits are different, the system assigns a value '1' to that comparison. The equation for iris matching is as follows:

$$HD = \frac{1}{N} \sum P_i \oplus R_i \quad (7)$$

where N is dimension of feature vector, P_i is the i^{th} component of the presented feature vector while R_i is the i^{th} component of referenced feature vector. The Match Ratio between two iris templates is computed by:

$$Ratio = \left(\frac{T_z}{T_b} \right) * 100 \quad (8)$$

where T_z is total number of zeros calculated by the Hamming distance vector and T_b is the total number of bits in iris template.

6 Results and Analysis

The proposed algorithm have been assessed using the CASIA iris image database, which consists of 80 persons, 108 set eye images and 756 eye images. From the results shown in Table 2, we can find that Daugman's method and the proposed method have the best performance, followed by Li Ma and Tan method.

Table 2. Accuracy and speed Comparison

Methods	Daugman	Tan	Proposed
Correct recognition rate (%)	99.90	99.23	99.50
Speed (ms)	310	110	85

Daugman analyzed the iris texture by computing and quantizing the similarity between the quadrature wavelets and each local region, which requires that the size of the local region must be small enough to achieve high accuracy. In [6] special class of wavelet to represent local texture information of the iris has been adopted. Our proposed method achieves higher accuracy based on a texture analysis method using wavelet maxima modulus for edge detection to localize the iris region and wavelet maxima components for feature extraction.

The result of this feature extraction is a set of moments (7 elements) at different wavelet maxima decomposition levels for each iris image those features called in the proposed method as wavelet maxima moments. These features significantly represent iris images; they are compact and can be easily used to compute similar distances. Finally, wavelet maxima moments are invariant to all affine transforms namely translation, scaling and rotation.

From the point of view complexity, as shown in Table 2, our proposed method clearly outperforms the other two. In particular, it can be said that, although Daugman's method achieves a very slightly better recognition rate (+0.4%) our

proposed method is about 3.65 times faster. Compared against Tan's method, our proposed solution achieves a better recognition rate (+0.5%) and is about 1.3 times faster. It is worth noting that the speed results were obtained on a PC running Windows OS with a 1.8 MHz clock speed. Implementations were carried out under MATLAB tools.

7 Conclusion

In this paper, we propose some optimized and robust methods for improving the accuracy of human identification system based on the iris patterns from the practical viewpoint. To achieve this some efficient methods based on a multiscale edge detection approach using wavelet maxima modulus and wavelet maxima moments have been presented. Our extracted features are invariant to all affine transforms namely translation, scaling and rotation. Through various experiments, we show that the proposed methods can be used for personal identification systems in an efficient way.

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