WAVELET MAXIMA AND MOMENT INVARIANTS BASED IRIS FEATURE EXTRACTION

Makram Nabti , Ahmed Bouridane

Institute for Electronics, Communications and Information Technology (ECIT),
School of Electronics, Electrical Engineering and Computer Science,
Queen's University Belfast, Northern Ireland, UK, BT7 1NN.

ABSTRACT

Iris recognition is one of the most reliable personal identification methods and is becoming the most promising technique for high security. In this paper, we propose an efficient method for personal iris identification by investigating iris textures that have a high level of stability and distinctiveness. To improve the efficiency and accuracy of the proposed system, we present a new approach to making a feature vector compact and efficient by using wavelet transform (wavelet maxima components), and moment invariants. The proposed scheme is invariant to translation, rotation, and scale changes. Experimental results have shown that the proposed system could be used for personal identification in an efficient and effective manner.

Index Terms— multiscale edge detection, iris feature extraction, wavelet maxima, moment invariants.

1. INTRODUCTION

The reliability and acceptance of a biometric system depends on the effectiveness of the system. Systems based on physiological-based techniques as: iris, face, fingerprint and palm print etc. are *more* accurate and acceptable in the market, but the authentication system based on iris recognition is reputed to be the most accurate among all biometric 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 [2].

It has been discovered that every iris is unique and no two people even two identical twins have uncorrelated iris patterns [1], and is stable throughout the human life, so these factors intake human iris an ideal tool for identification.

Most works on personal identification and verification using iris patterns have been done in the 1990s. Daugman [1] developed a feature extraction technique based on information from a set of 2-D Gabor filter. He generated a 256 byte code by quantizing the local phase angle according to the outputs of the real and imaginary parts of the filtered image. On the other hand, Wildes' system made use of a Laplacian pyramid constructed with four different resolution levels to generate the iris code [3]. It also exploited a normalized correlation based on goodness-of-match values and a Fisher's linear discriminant for pattern matching. Boles [4] implemented a system operating on the set of 1-D signals composed of normalized iris signatures at a few intermediate resolution levels where the iris representation of these signals is obtained through the zerocrossing of the dyadic wavelet transform.

The main difficulty of human iris recognition is that it is hard to find perceptible feature points in the image and to keep their representability high in an efficient way. In addition, the identification or verification process suitable for iris patterns is required to get high accuracy.

In this paper, we propose an optimized and robust method for improving the performance of human identification system based on the iris patterns. A wavelet modulus maximum has been used as a pre-processing step for multiscale edge detection in order to improve iris localization with wavelet maxima components for feature extraction. In addition, moments invariant have been used to represent the feature vector in a compact manner and Hamming distance for pattern matching. Through various experiments, we show that the proposed method can be used for personal identification systems in an efficient way.

The contents of this paper are as follows. In the following section, iris localization step using wavelet modulus maxima is described while the processes of mapping and normalization are presented in Section 3. Section 4 gives the details of the proposed method for extracting the features and their recognition while the matching method is described in Section 5. Experimental results and their analysis are given in Section 6. Section 7 concludes the paper.

2. IRIS LOCALIZATION

Iris localization is the process to isolate the actual iris region in a digital eye image by detecting the inner and outer boundaries of the iris. The localization step is crucial to the success of an iris recognition system, since data that is falsely represented as iris pattern data will corrupt the biometric templates generated thus resulting in poor recognition rates.

2.1. Proposed method using wavelet modulus maxima

A multiscale edge detection approach can provide a significantly more information on edges at varying scales[6] with a smaller number of texture points producing local maxima thus enabling us to find the real geometrical edges of the image. In this paper, we propose a novel approach for iris localization using a multiscale edge detection approach based on wavelet transform modulus maxima. First we detect the multiscale edge map using the information extracted from the wavelet coefficients. This allows us to obtain finer edges for pupil and iris circles. A Hough transform is then used to localize the iris and the pupil. The eyelids are isolated using the horizontal multiscale edges with a linear Hough transform while the eyelashes are isolated using a thresholding technique.

The method of multiscale edge detection described in [5, 6] is used to find the edges (figure1). The wavelet used based on a nonsubsampled wavelet decomposition and essentially implements a discretized gradient of the image at different scales. At each level of wavelet decomposition the modulus $M_j f$ of the gradients can be computed by:

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

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

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

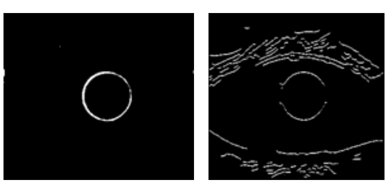

Figure 1. Edge detection, (a).pupil edge detection,(b). Edges for eyelids detection

The sharp variation points of the image f(x, y) smoothed by $S_j f$ $(f(x, y) * S_j f)$ are the points (x, y), where the modulus $M_j f$ has a local maxima in the direction of the gradient given by $A_j f$. W_j^H and W_j^V can be viewed as the two components (horizontal and vertical respectively at each scale j) of the gradient vector of the analyzed image f(x, y) smoothed by a lowpass filter. A Hough transform is then used to localize iris and pupil circles. The eyelids are isolated using the horizontal multiscale edges (figure1-b) with a linear Hough transform while the eyelashes are isolated using a thresholding technique (figure 2).

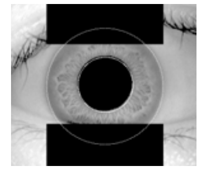

Figure 2. Iris localization, Black regions denote detected eyelid and eyelash regions.

3. IRIS NORMALIZATION

After determining the limits of the iris in the previous phase, the iris can 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, image capture distances, head incline, and other factors. For this reason, it is necessary to normalize the iris region and for this purpose all the points within the boundary of the iris are remapped (Figures 3,4) from Cartesian coordinate system to a polar coordinates (r, θ) system as follows:

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

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

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 3).

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

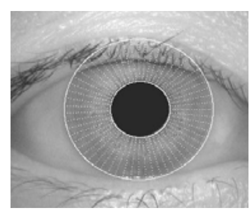

Figure 3. Normalized iris portion with radial resolution of 15 pixels, and angular resolution of 60 pixels.

Figure 4. Normalized iris image

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 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 for feature extraction

Wavelet decomposition provides a very good approximation of images and natural setting for the multi-level analysis. Since wavelet transform maxima provide useful information about textures and edges analysis [6], 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. Algorithm

As described in [5] to obtain the wavelet decomposition a pair of discrete filters H, G has been used as follows:

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

Table 1: Response of filters H, G

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:

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

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

- 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.
- λ_s, as explained in [5] 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.

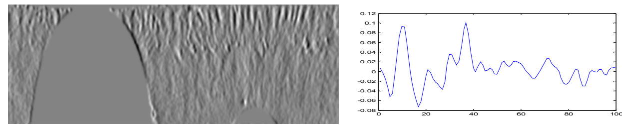

Figure 5. Wavelet maxima vertical components at scale 2 with intensities along specified column.

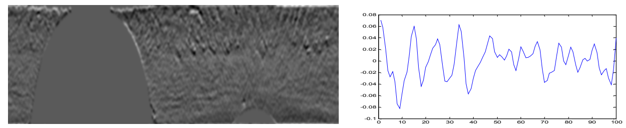

Figure 6. Wavelet maxima horizontal components at scale 2 with intensities along specified column.

4.3. Feature vector representation using moment invariants

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 [7].
Certain functions of moments are invariant to geometric transformation 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 [7].

A set of seven 2-D moment invariants that are insensitive to rotation, translation and scaling [7] have been computed for each horizontal and vertical wavelet maxima component from scale 1 to scale 3 . Therefore, six wavelet maxima components (i.e., H1,V1,H2,V2,H3,V3) are obtained thus making a feature vector size of 42 (7x6) for every iris image.

5. MATCHING

It is important to present the obtained vector in a binary code because it is easier to find 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:

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

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:

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

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. An average of correct recognition of 99.5% has been achieved. Table 2 depicts the efficiency of each part of the proposed iris recognition system.

	Edge detection	Mapping	Recognition
Efficiency (%)	99.6	100	99.5

Table 2: Efficiencies of each part of the IR system

To determine the appropriate level of wavelet maxima decomposition, initial experiments with a few test images have shown that the wavelet maxima at levels large than 3 have almost no discrimination power, therefore to save computation, a wavelet decomposition level of 3 has been adopted as it is sufficient in our application with a mapped image is of size 100x400 pixels.

Feature Extraction	Gabor Transform	Wavelet Maxima (Proposed Method)
Size of feature Vector	256 bytes	42 bits
Recognition rate	99.2%	99.5%

Table 3: Recognition rate comparison

This paper proposes an optimized and robust method for the improvement of recognition accuracy of human identification system based on the iris patterns. To demonstrate the findings, experiments have been carried out for the performance evaluation of the popular feature extraction method Gabor transform as shown in table3. The analysis has been done in terms of the dimension of a feature vector in order to make it more compact, maxima moments which are invariant to affine transformations (i.e., rotation, translation and scaling). The results obtained clearly show that the proposed method can be used for personal identification systems in an efficient way.

These features significantly represent images. They are compact and can be easily used to compute similar distances. This means that we have managed to successfully reduce the feature vector from 2048 bits as in Daugman's method [1] just to 42 bits in our approach while still achieving faster and improved recognition accuracy.

7. CONCLUSION

In this paper, an efficient method for personnel iris identification is presented. A new method using wavelet maxima and moment invariants has been proposed and used to improve feature vector discriminative power and compactness. This technique outperforms existing methods such as Gabor wavelet which is widely used for extracting features. The use of wavelet maxima has led to an optimization of the dimension of feature vector in order to reduce the processing time and space requiring only 42 bits. In addition, a very high recognition accuracy of 99.5%.

8. REFERENCES

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