Intrinsically Reliable Biometric Technique Using Wavelet Transform

Afshin shaabany, Fatemeh jamshidi

Sama Technical and Vocational Training College, Islamic Azad University, Shiraz Branch, Shiraz, Iran
afshinshy@yahoo.com

Abstract: intrinsically reliable biometric technique for human recognition Features extraction to a crucial step in recognition, and the trend nowadays is to reduce the size of the extracted features. Special efforts have been applied in order to obtain low templates size and fast verification algorithms. In this paper, an effective eyelids removing method, based on masking it, has been applied. Moreover, an efficient recognition encoding algorithm has been employed. Different combination of wavelet coefficients which quantized with multiple quantization levels are used and the best wavelet coefficients and quantization levels are determined. Experimental results show that this algorithm is efficient and gives favorable results of False Accept $Ratio = 0.001\%$ and False Reject $Ratio = 1.011\%$ with a template size of only 364 bits.

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1. Introduction

The term "Biometrics" refers to a science involving the statistical analysis of biological characteristics. This measurable characteristic, biometric, can be physical, such as eye, face, retina vessel, fingerprint, hand and voice or behavioral, like signature and typing rhythm. Biometrics, as a form of unique person recognition, is one of the subjects of research that is growing rapidly [1].

The advantages of unique recognition using biometric features are numerous, such as fraud prevention and secure access control. Biometrics systems offer great benefits with respect to other authentication techniques. In particular, they are often more user friendly and can guarantee the physical presence of the user [1]. Iris recognition is one of the most reliable biometric technologies in terms of recognition and verification performance. The iris is the colored portion of the eye that surrounds the pupil as depicted in Figure 1. It controls light levels inside the eye similar to the aperture on a camera. The round opening in the center of the iris is called the pupil. The iris is embedded with tiny muscles that dilate and constrict the pupil size. It is full of richly textured patterns that offer numerous individual attributes which are distinct even between the identical twins and between the left and right eyes of a person. Compared with other biometric features such as face and fingerprints, iris patterns are highly stable with time and unique, as the probability for the existence of two irises that are same is estimated to be as low as, one in 1072 [1, 2].

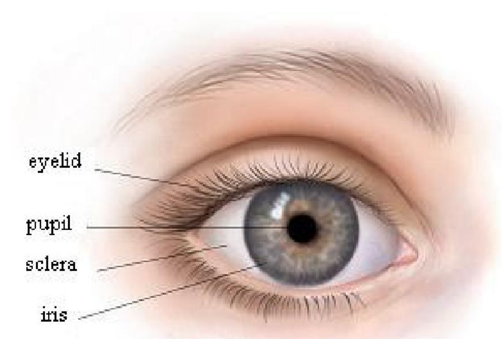


Figure 1. Image of the eye.

In this paper, the iris is efficiently normalized such that only useful data are encoded. Image enhancement techniques are applied. Moreover, the best combination of wavelet coefficients is found and used for successful recognition and the best number of bits used for encoding the feature vector has been deduced while maintaining low template size. Iris recognition using analysis of the iris texture has attracted a lot of attention and researchers have presented a variety of approaches in the literature. Generally, an iris recognition system is composed of many stages

1. Preprocessing and acquisition
2. Segmentation
3. Normalization
4. Code generation and feature extraction
5. Identification

Firstly, an image of the person's eye is captured by the system and preprocessed. Secondly, the image is localized to determine the iris boundaries. Thirdly, the iris boundary coordinates are converted to the stretched polar coordinates to normalize the scale of the iris in the image. Fourthly, features representing the iris patterns are extracted based on texture analysis. Finally, the person is identified by comparing their features with an iris feature database.

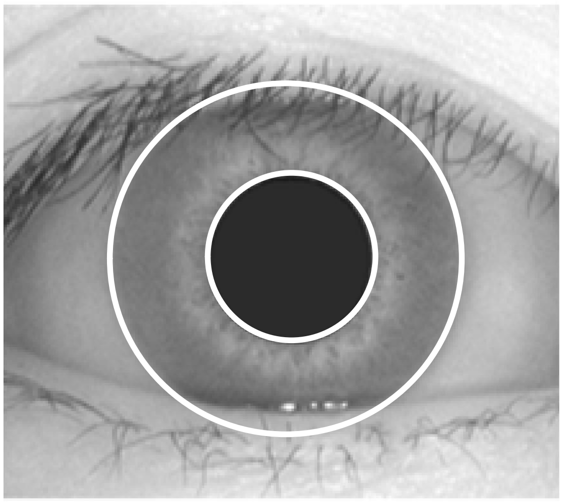


Figure 2. Segmented eye image

For the purpose of recognition, the part of the eye image carrying useful information is only the iris that lies between the sclera and the pupil [2]. Therefore, prior to performing iris matching, it is very important to localize the iris in the acquired image. The iris region, shown in Figure 2, is bounded by two circles, one for the boundary with the sclera and the other, interior to the first, with the pupil.

To detect these two circles the Circular Hough transform has been used. The Hough transform is a standard computer vision algorithm that can be used to determine the geometrical parameters for a simple shape, present in an image, and this has been adopted here for circle detection [15]. The main advantage of the Hough transform technique is its tolerance for gaps in feature boundary descriptions and its robustness to noise [16]. Basically, the first derivatives of intensity values in an eye image are calculated and the result is used to generate an edge map. From the edge map, votes are cast in Hough space for the parameters of circles passing through each edge point. These parameters are the center coordinates x_c and y_c, and the radius r, which are able to define any circle according to the following equation:

$$x_c^2 + y_c^2 - r^2 = 0 \quad (1)$$

A maximum point in the Hough space will correspond to the radius and center coordinates of the best circle defined by the edge points [15].

The size of the iris varies from person to person, and even for the same person, due to variation in illumination, pupil size and distance of the eye from the camera. These factors can severely affect iris matching results. In order to get accurate results, it is necessary to eliminate these factors. To achieve this, the localized iris is transformed into polar coordinates by remapping each point within the iris region to a pair of polar coordinates (r, θ) where r is in the interval $[0, 1]$ with 1 corresponding to the outermost boundary and θ is the angle in the interval $[0, \theta]$ as shown in Figure 3 [17, 18].

For a typical eye image of dimension 320×280 pixel, the previous normalization method is performed to produce 50 pixels along r and 600 pixels along θ which result in 600×50 unwrapped strip.

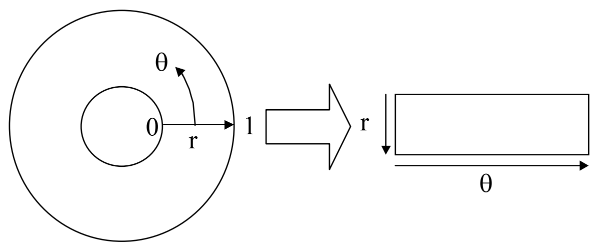


Figure 3. Rubber sheet model [17]

2. Purposed Method

Since in most cases the upper and lower parts of the iris area are occluded by eyelids, it was decided to use only the left and right parts of the iris with a partial area of the upper and lower region for the iris recognition. Therefore, the whole iris [0, 360°] is not transformed in the proposed system. Experiments were conducted by masking the iris from [150, 214°] and [330, 30°] for the right and left parts while for the upper and lower parts, Hence, the regions that contain the eyelids and eyelashes have been omitted while the remaining eyelashes are treated by thresholding, since analysis reveals that eyelashes are quite dark when compared with the rest of the eye image [15]. The corresponding rectangular block is show in Figure 4. Afterward, the block is concatenated together as shown in Figure 5.

1	4	2	5	3
	Removed region		Removed region	

Figure 4. The normalized masked iris image

1	2	3	4
			5

Figure 5. The concatenated block after removing the ignored parts.

The size of the rectangular block is reduced accordingly. By applying this approach, detection time of upper and lower eyelids and some cost of the polar transformation are saved. Saving ratio can be calculated from this equation:

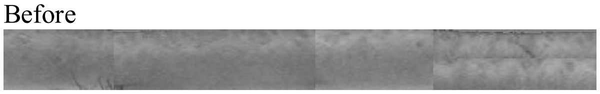
$$\text{Saving ratio}=\left(\frac{\text{ignored parts of the iris}}{\text{whole iris region}}\right)\times 100\% \qquad (2)$$

where $\text{ignored parts}=\frac{\left((150\text{-}30)+(330\text{-}214)\right)}{2}=128$,

$$\text{Saving ration}=\frac{128}{360}\times 100\%=35.55\%$$

Although the homogenous rubber sheet model accounts for pupil dilation and imaging distance it does not compensate for rotational inconsistencies. Rotational inconsistencies are treated in the matching stage. Due to the effect of imaging conditions and situations of light sources; the normalized iris image does not have an appropriate quality. These disturbances may affect the performance of feature extraction and matching processes [12]. Hence for getting a uniform distributed illumination and better contrast in iris image, the polar transformed image is enhanced through adjusting image intensity values by mapping the intensity values in the input grayscale image to new values such that 1% of the pixel data is saturated at low and high intensities of the original image. This increases the contrast in a low-contrast grayscale image by remapping the data values to fill the entire intensity range [0, 260]. Then, histogram equalization has been used. Results of images before and after enhancement are shown in Figure 6.

Before



After

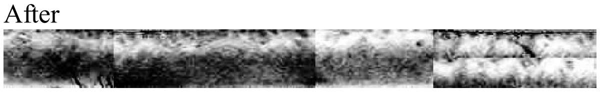


Figure 6. Image enhancement of the normalized iris

In order to provide accurate recognition of individuals, the most discriminating information present 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. Most iris recognition systems make use of a band pass decomposition of the iris image to create a biometric template. For the encoding process the outputs of any used filter should be independent, so that there are no correlations in the encoded template, otherwise the filters would be redundant [19]. The Wavelet transform is used to extract features from the enhanced iris images. Haar wavelet is used as the mother wavelet. The Wavelet transform breaks an image down into four sub-sampled images. The results consist of one image that has been high-pass filtered in the horizontal and vertical directions (*HH* or Diagonal coefficients), one that has been low-pass filtered in the vertical and high-pass filtered in the horizontal (*LH* or Horizontal coefficients), one that has been low-pass filtered in the horizontal and high-pass filtered in the vertical (*HL* or Vertical coefficients), and one that has been low-pass filtered in both directions (*LL* or details coefficient) [8]. Experiments were performed using different combinations of Haar wavelet coefficients and the results obtained from different combinations were compared to find the best. Since unwrapped image after masking has a dimension of 407×45 pixels, after 5 times decompositions, the size of the 5th level decomposition is 2×13 while for the 4th level is 3×26. Based on empirical experiments, the feature vector is arranged by combining features from *HL and LH* of level-4 *(vertical and horizontal coefficients [HL4 LH4])* with *HL*, *LH* and *HH* of level-5 *(vertical, horizontal and diagonal coefficients [HL5 LH5 HH5])*. In order to generate the binary data, features of *HL4* and *HH5* are encoded using two-level quantization while features of *LH4*, *HL5* and *LH5* are encoded using four-level quantization. After that these features are concatenated together as shown in Figure 7which illustrates the process used for obtaining the final feature vector.

LH4	HL4	LH5	HL5	HH5
156 bits	78 bits	52 bits	52 bits	26 bits
$2\times[3\times26]$	$[3\times26]$	$2\times[2\times13]$	$2\times[2\times13]$	$[2\times13]$

Figure 7. Organization of the feature vector which consists of 364 bits.

The last module of an iris recognition system is used for matching two iris templates. Its purpose is to measure how similar or different templates are and to decide whether or not they belong to the same individual or not. An appropriate match metric can be based on direct point-wise comparisons between the phase codes [18]. The test of matching is implemented by the Boolean XOR operator applied to the encode feature vector of any two iris patterns, as it detects disagreement between any corresponding pair of bits. This system quantifies this matter by computing the percentage of mismatched bits between a pair of iris representations, *i.e.*, the normalized Hamming distance.

Let X and Y be two iris representations to be compared and N be the total number

$$HD = \frac{1}{N}\sum_{j=1}^{N} X_j \oplus Y_j \quad (3)$$

In order to avoid rotation inconsistencies which occur due to head tilts, the iris template is shifted right and left by 6 bits. It may be easily shown that scrolling the template in Cartesian coordinates is equivalent to an iris rotation in polar coordinates. This algorithm performs matching of two templates several times while shifting one of them to different locations. The smallest *HD* value amongst all these values is selected, which gives the matching decision [18, 19].

With a pre-determined separation Hamming distance, a decision can be made as to whether two templates were created from the same iris (*a match*), or whether they were created from different irises. However, the intra-class and inter-class distributions may have some overlap, which would result in a number of incorrect matches or false accepts, and a number of mismatches or false rejects. Table 1 shows the FAR and FRR associated with different separation points.

Table 1. False accept and false reject rates for database with different separation points.

Threshold	FAR (%)	FRR (%)
0.20	0.01	56.34
0.24	0.01	38.60
0.26	0.02	11.35
0.28	0.025	3.67
0.29	0.01	1.011
0.30	1.71	1.86
0.32	5.83	0.20
0.36	36.47	0.02
0.38	48.88	0.01

3. Conclusion

In this article, we proposed an iris recognition algorithm using wavelet texture features based on a novel masking approach for eyelid removing. A masked area around the iris is used in the iris detection method. This area contains a complex and abundant texture information which are useful for feature extraction. The feature vector is quantized to a binary one, reducing the processing time and space, while maintaining the recognition rate. Experimental results using illustrate that relying on a smaller but more reliable region of the iris, although reduced the net amount of information, improve the recognition performance. And the feature vector consisting of concatenating *LH4*, *HL4*, *LH5*, *HL5*, and *HH5* gives the best results. On the other hand, Haar wavelet is particularly suitable for implementing high-accuracy iris verification/recognition systems, as feature vector is at the least with respect to other wavelets. In recognition mode, the CRR of the proposed algorithm was 99% with template size of 364 bits. Such vector size can be easily stored on smart cards and participate to reduce the matching and encoding time tremendously.

Corresponding Author:
Afshin Shaabany
Sama Technical and Vocational Training College, Islamic Azad University, Shiraz Branch, Shiraz, Iran
E-mail: afshinshy@yahoo.com

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