Iris Recognition Algorithm Using Modified Log-Gabor Filters

Peng Yao[1], Jun Li[2], Xueyi Ye[1], Zhenquan Zhuang[1], Bin Li[1]

[1]Department of Electronic Science & Technology
University of Scientist & Technology of China
yaopeng@ustc.edu.cn

[2]School of Electrical & Electronic Engineering
Nanyang Technological University, Singapore
leejun@pmail.ntu.edu.sg

Abstract

In this paper, we presented an iris recognition algorithm based on modified Log-Gabor filters. The algorithm is similar as the method proposed by Daugman in general procedure while modified Log-Gabor filters are adopted to extract the iris phase information instead of complex Gabor filters used in Daugman's method. The advantage of Log-Gabor filters over complex Gabor filters is the former are strictly bandpass filters and the latter are not. The property of strictly bandpass makes the Log-Gabor filters more suitable to extract the iris phase features regardless of the background brightness. The comparison experiments between complex Gabor filters based methods and the proposed method are also presented in this paper.

1. Introduction

Automatic biometric recognition system has received great attentions in recently decades. Biometrics refer to recognize a person based on his distinctive anatomical(face, fingerprint, iris, retina and hand geometry *etc.*) or behavioral(signature, gait *etc.*) characteristics. Unlike the traditional methods such as "password" or "ID card", biometric identifiers can verify that you are who you claim you are. In addition, it cannot be shared, misplaced. These advantages cause lots of potential applications in commercial, forensic and civilian scenes.

Iris, as one of biometric traits, has been proved its uniqueness and stability over decades by American ophthalmologists Flom and Safir in their many years of clinical observation [7]. Daugman furthermore analyzed the iris texture and presented in his paper [4, 5] that the complexity of iris phase information spans about more than 200 freedom, which is enable cognition with very high confidence. due to these attractive properties iris recognition is still a popular topic in both academic and industrial fields.

Much works has been reported by researchers till now. In 1987 Flom and Safir first proposed the concept of automated iris recognition [7]. Daugman extracted local texture phase feature of iris by complex 2D Gabor filters [4, 5]. The difference between a pair of iris representations was measured by computing their Hamming distance. Wildes *et al.* used Laplacian pyramid to represent the iris feature and applied the normalized correlation for matching[13, 12]. Boles and Boashash characterized the texture of the iris by a zero-crossing representation of one-dimensional (1-D) wavelet transform at various resolution levels [1]. Ma *et al.* described an efficient algorithm for iris recognition by characterizing key local variations [9]. The matching method was similar to Hamming distance. Sun *et al.* used the directional information of iris image's gradient vector field (GVF) to represent iris pattern [11].

In all these algorithms, the method using complex 2D Gabor filters is the most famous one and has successfully been applied in practical systems. In this method, complex 2D Gabor filters $g(x, y)$ [2, 3] are explored to extract the phase information of the iris texture. The mathematical expression of $g(x, y)$ is shown in Eq. 1.

$$g(x, y) = g^e(x, y) + jg^o(x, y) \tag{1}$$

where $g^e(x, y)$ and $g^o(x, y)$ indicate the real and imaginary parts of the complex 2D Gabor filters respectively. They have the following forms:

$$g^e(x, y) = \frac{1}{2\pi\sigma_x\sigma_y} exp[-\frac{1}{2}(\frac{x_1^2}{\sigma_x^2} + \frac{y_1^2}{\sigma_y^2})] \cos(2\pi F x_1) \tag{2}$$

$$g^o(x, y) = \frac{1}{2\pi\sigma_x\sigma_y} exp[-\frac{1}{2}(\frac{x_1^2}{\sigma_x^2} + \frac{y_1^2}{\sigma_y^2})] \sin(2\pi F x_1) \tag{3}$$

where $x_1 = x\cos(\theta) + y\sin(\theta)$, $y_1 = -x\sin(\theta) + y\cos(\theta)$, F is the frequency of the sinusoidal plane wave, θ is the orientation of the Gabor filter, σ_x and σ_y are the standard deviations of the Gaussian envelope along the *x* and *y* axes, respectively.

During the phase extraction, the iris image is divided into m by n blocks. Consequently, the local phase information

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in each block is encoded into 2-bit codes according to the following equations 4:

$$\begin{aligned} h_{Re} = 0 \quad &\text{if} \quad \iint_{x,y} I(x,y) \bullet g^e(x,y)dxdy \geq 0 \\ h_{Re} = 1 \quad &\text{if} \quad \iint_{x,y} I(x,y) \bullet g^e(x,y)dxdy < 0 \\ h_{Im} = 0 \quad &\text{if} \quad \iint_{x,y} I(x,y) \bullet g^o(x,y)dxdy \geq 0 \\ h_{Im} = 1 \quad &\text{if} \quad \iint_{x,y} I(x,y) \bullet g^o(x,y)dxdy < 0 \end{aligned} \tag{4}$$

Where $\bullet$ denotes convolution operator and $I(x, y)$ denotes the normalized iris image.

Thus the phase information in each block is discribed by 2-bit codes and totally $2mn$ bits to discribe the whole iris. The difference between two iris images was measured by their hamming distance according to the following equation 5:

$$HD = \frac{\Sigma[(codeA \otimes codeB) \cap (maskA \cap maskB)]}{\Sigma(maskA \cap maskB)} \tag{5}$$

where $\otimes$ denotes the Boolean Exclusive-OR operator (XOR), $maskA$ and $maskB$ denote two iris matching masks, respectively, "0" for the non-iris regions, and "1" for the iris regions; $\cap$ denotes the AND operator. The decision whether two irises are from the same person is made by the predefined threshold.

In above method, the key issue of complex 2D Gabor filters based methods is to extract the local phase information in an iris image. While the real parts of the complex 2D Gabor filters (equation 2) are not strictly bandpass filters [5], therefore the performance of the whole system will be decreased by background brightness. In general, the background brightness is non-uniform illumination distributed due to complex lighting condition and therefore the DC component is hard to eliminate from its Gabor filters response.

In this paper, we proposed a new algorithm, which is based on Log-Gabor filters. One of advantages of Log-Gabor filters is that they are strictly bandpass filters. So no DC components will pass the filters. Therefore the background brightness will not affect the extraction of the pure phase information of iris texture.

The rest of this paper is arranged as follows: the section 2 represented the new algorithm based on modified Log-Gabor filters; Experimental results are shown in section 3 and section 4 concludes this paper.

2. Iris recognition method by modified 2D Log-Gabor filters

2.1. 2D Log-Gabor filters

Log-Gabor filters were proposed by Field in 1987 [6]. 2D Log-Gabor filters are constructed in the polar coordinate system of frequency domain as shown in Eq. 6 and only can be numerically constructed in the spatial domain via the inverse Fourier transform:

$$G(w,\theta) = exp\{\frac{-\log(w/w_0)^2}{2\log(k/w_0)^2}\}exp\{\frac{-(\theta-\theta_0)^2}{2T(\Delta\theta)^2}\} \tag{6}$$

where w_0 represents the center frequency of the filter; k determines the bandwidth of the filter in the radial direction; θ_0 represents the orientation angle of the filter; T is a scaling factor and $\Delta\theta$ is the orientation spacing between the filters.

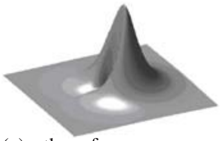
As Eq. 6 shows, Log-Gabor filters have Gaussian transfer functions when viewed on the *logarithmic linear* frequency scale. Compared with Gabor filters, Log-Gabor filters have three important characteristics. Firstly, Log-Gabor filters, by definition, always have no DC component. Secondly, the transfer function of the Log-Gabor filters has an extended tail at the high frequency end. Field's studies [6] indicate that natural images have amplitude spectra that fall off at approximately $1/f$. To encode images having such spectral characteristics one should use filters having the similar spectra. Field suggests that Log-Gabor filters, having extended tails, should be able to encode natural images more efficiently than ordinary Gabor filters, which would over-represent the low frequency components and under-represent the high frequency components in any encoding. Lastly, the Log-Gabor filters are more consistent with measurement of the mammalian visual systems, which indicate we have cell response that are symmetric on the log frequency scale [6, 8].

2.2. Modified 2D Log-Gabor filters

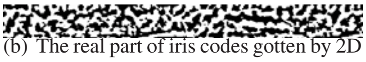
Because of above characteristics, Log-Gabor filters are more fit to extract iris phase features than the complex 2D Gabor filters.

However in order to extract an accurate phase features, cares must be taken in the following case: 2D Log-Gabor filters can be analyzed as band-pass filters in the radial coordinate and low-pass filters in the angular coordinate. To preserve the complexity of iris phase information, the bandwidth of 2D Log-Gabor filters in angular coordinate should be large enough. Otherwise, the resultant iris codes using small bandwidth in angular coordinate would become regular stripes as shown in Fig 2. As such many Hamming distances of inter-class matching would be evidently less than 0.5 and the performance of iris recognition would significantly decrease. However the 2π periodicity of the bandwidth of 2D Log-Gabor filters in angular coordinate bounds the large bandwidth selection. Furthermore when the bandwidth approaches to 2π, the frequency response of Log-Gabor filters in angular coordinate would become bent as Fig. 1 shows. Such bent frequency response impairs the phase sensitivity of Log-Gabor filters.

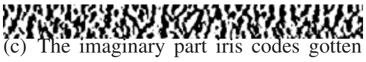
To eliminate the above shortcomings, we change the frequency expression of 2D Log-Gabor filters and construct it



(a) the frequency response of 2D Log-Gabor filters with large angular bandwidth



(b) The real part of iris codes gotten by 2D Log-Gabor with large angular bandwidth



(c) The imaginary part iris codes gotten by 2D Log-Gabor with large angular bandwidth

Figure 1. An example of iris codes obtained by 2D Log-Gabor with large angular bandwidth

Figure 2. The iriscodes gotten by the imaginary part of spatial domain of 2D Log-Gabor when the bandwidth in angular coordinate is too small

in the Cartesian coordinate system of frequency domain:

$$G(u,v) = exp\{\frac{-\log(u_1/u_0)^2}{2\log(k/u_0)^2}\}exp\{\frac{-v_1^2}{2\sigma_v^2}\} \quad (7)$$

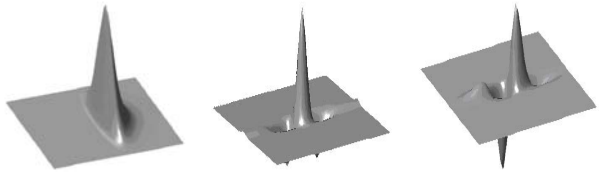
where $u_1 = u\cos(\theta)+v\sin(\theta)$, $v_1 = -u\sin(\theta)+v\cos(\theta)$, θ is the orientation of the 2D Log-Gabor filter, u_0 is the center frequency, k determines the bandwidth of the filter in the u_1 direction, and σ_v determines the bandwidth of the filter in the direction v_1.

The modified 2D Log-Gabor filters have no periodicity limitation of Log-Gabor filters in polar systems so it can obtain very large bandwidth in any direction. The modified 2D Log-Gabor filters have no expressions in the spatial domain. Fig. 3 shows their impulse response in spatial domain and frequency response.

2.3. Feature extraction using Log-Gabor filters

Before the features extracted from iris images, the iris image should be preprocessed so that the features are invariant to translation, scale and rotation. While the most contribution of this paper is to present a new algorithm to encoding the iris local phase information, which is different from the complex 2D Gabor filters. So the preprocessing stage(localization, normalization and enhancement of the iris image) is omitted for the brief purpose. More details of preprocessing, please refer to [14].

The feature extraction in this work is quite similar as the one stated in Eq. 4 while the modified Log-Gabor filters in Eq. 7 is adopted to replace the complex 2D Gabor filters. Hence a $2mn$ bits iris code is formed to represent a distinct iris. The iris codes extracted using the modified Log-Gabor filters will be compared with the Hamming distance between two individuals.



(a) the frequency response of modified 2D Log-Gabor filters (b) the real part of modified 2D Log-Gabor filters (c) the imaginary of modified 2D Log-Gabor filters

Figure 3. spatial profile and frequency response of modified 2D Log-Gabor filters

3. Experiments

In order to verify the performance of proposed method, our experiments are performed on the open iris database CASIA (1.0) [10], provided by the Institute of Automation, Chinese Academy of Science. CASIA (1.0) is composed of 756 images from 108 different irises. For each iris, 7 images were captured in 2 sessions. All possible comparisons are made between the iris images in the whole CASIA (1.0). Totally there are also $2,268$ intra-class comparisons and $283,122$ inter-class comparisons.

The second experiment is conducted on the same database CASIA(1.0) for the comparative propose as well. The only difference between the first experiment and the second one is that in the second experiment, the algorithm of encoding the iris phase information is based on the complex 2D Gabor filters while in the first one, it is based on the modified Log-Gabor filters.

Fig. 4 shows examples of iris codes using complex Gabor filters and modified Log-Gabor filters respectively.

In Fig. 4(c), the distribution of "0" and "1" in iriscodes

(a) normalized iris image

(b) iriscodes gotten by real part of complex 2D Gabor filters

(c) iriscodes gotten by imaginary part of complex 2D Gabor filters

(d) iriscodes gotten by the real part of modified 2D Log-Gabor filters

(e) iriscodes gotten by imaginary part of modified 2D Log-Gabor filters

Figure 4. example of iriscodes

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gotten by imaginary part of complex 2D Gabor wavelets is even. However, in Fig. 4(b), the proportion of "1" (black) is obviously more than the proportion of "0" (white) in section I of iriscodes gotten by real part of complex 2D Gabor filters and the "0" is more than the "1" in section II. The reason is that the background brightness of different sections in a iris image may be not always same because of non-uniform illumination or the physiological reason (Especially, the black blocks in the iris texture of yellow race mainly locate the inner cricoid regions near pupils. So the intensity of inner cricoid regions is less than the outer cricoid regions.). If this kind of iris image is filtered by even-symmetric Gabor filters(real part of complex Gabor filters),which are not strictly bandpass filters, the corresponding iris codes would have the phenomena that the code "1" is more than "0" in low intensity regions and the code "0" is more than "1" in high intensity regions (As the section I and II of Fig. 4 (b) show). The phenomena will cause that the entropy of iris codes decreases.

This limitation is overcome by the modified Log-Gabor filters from the observation of Fig. 4(d), where the "0" and "1" distribution is even in the whole encoded region.

The ROC curves are also plotted for both two experiments in Fig. 5 as comparison. From Fig. 5 the method using modified 2D Log-Gabor filters has the better recognition performance. For a recognition algorithm, the equal error rate (EER) is a good indicator of its recognition performance. It is the point where the false match and false non-match rate are equal. The smaller the EER is, the better the algorithm. The EER of the method using modified 2D Log-Gabor filters reaches 0.28%, less than the method using complex 2D Gabor filters, where EER is 0.36%.

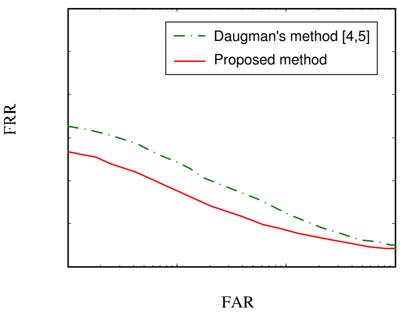

Figure 5. Comparison of ROCs

4. Conclusions

Though complex 2D Gabor filters have been successfully used in many applications, they are not perfectly suitable to encode the iris texture as the real parts of the filters are not strictly bandpass. In this paper, a new iris algorithm based on modified Log-Gabor filters, which can overcome the limitation of the complex 2D Gabor filters, is proposed. Applying modified Log-Gabor filters, no DC components will be included in the filters' response, therefore more robust system performance can be achieved. Experimental results show that the proposed method has better recognition performance than the method using complex 2D Gabor filters.

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