

Prodigious Utilization of Genetic Algorithm in Tuning Gabor filter parameters in the Application of Iris Recognition

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Abstract—Gabor filters find an important place in image processing field but the use is restricted because of its computational complexity. Many methods are used in practice for security systems. Most common being the face recognition, voice recognition and biometric methods. Biometric systems are finding a lot of acceptances in the market. Mostly the finger print recognition and the iris recognition. Accurate automatic personal identification is critical in a variety of applications in our electronically interconnected society. Biometrics, which refers to identification based on physical or behavioral characteristics, is being increasingly adopted to provide positive identification with a high degree of confidence. Among all the biometric techniques, IRIS based authentication systems have received the most attention because of the uniqueness of iris. Due to its reliability and nearly perfect recognition rates, iris recognition is used in high security areas. In this paper, a systematic approach is introduced to design the parameters of the Gabor filter banks for iris recognition. In this paper we also introduce how the Genetic Algorithm (GA) can be used to tune the parameters of the Gabor filter banks. The paper also explains how Daugman’s method can be used from a different point of view. We have also tried to show how Gabor filters can be replaced by a different set of filters, i.e., the Derivative of Gaussian (DoG) and the Laplacian of Gaussian (LoG) without sacrificing the recognition rate.

Index Terms—Daugman’s method, Derivative Of Gaussian (DOG), Genetic Algorithm, Gabor Filter, Iris Recognition, Laplacian Of Gaussian (LOG).

I. INTRODUCTION

A. Automatic Identification

With the advent of electronic banking, e-commerce, and smartcards and an increased emphasis on the privacy and security of information stored in various databases, *automatic* personal identification has become a very important topic. Accurate automatic personal identification is now needed in a wide range of civilian applications involving the use of passports, cellular telephones, automatic teller machines, and driver licenses. Therefore, traditional knowledge-based and token-based approaches are unable to satisfy the security requirements of our electronically interconnected information society (see Figure 1.1). As an example, a large part of the annual \$450 million MasterCard credit card fraud [14] is due to identity fraud. A perfect identity authentication system will

necessarily have a biometric component. In this paper, the only focus is on the biometrics component of an automatic identification system in general, and an Iris based biometric identification system in particular.

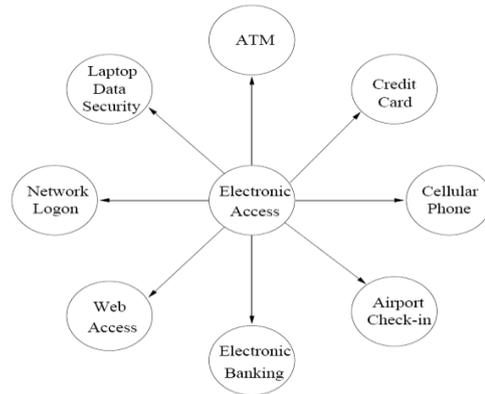


Fig1.1: Various electronic access applications in widespread use that require automatic authentication

B. Human Iris:

The iris is a protected internal organ of the eye, located behind the cornea and the aqueous humor, but in front of the lens. A visible property of the iris is the random morphogenesis of their minutiae. The phenotypic expression even of two irises with the same genetic genotype has uncorrelated minutiae. The iris texture has no genetic penetrance in the expression and is chaotic. 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. The iris grows from the ciliary body and its colour is given by the amount of pigment and by the density of the iris tissue that means from blue to black.

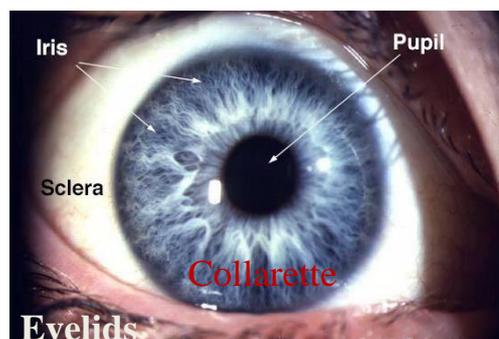


Fig1.2: Human Iris Image

The most important function of the iris is controlling the size of the pupil. Illumination, which enters the pupil and falls

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on the retina of the eye, is controlled by muscles in the iris. They regulate the size of the pupil and this is what permits the iris to control the amount of light entering the pupil. The change in the size results from involuntary reflexes and is not under conscious control. The tissue of the iris is soft and loosely woven and it is called STROMA. The visible one is the anterior layer, which bears the gaily-colored relief and it is very lightly pigmented due to genetically determined density of melanin pigment granules. The invisible one is the posterior layer, which is very darkly pigmented, contrary to the anterior layer. The surface of this layer is finely radiantly and concentrically furrowed with dark brown colour. Muscles and the vascularized stroma are found between these layers from back to front. The surface of the anterior layer is Pigment frill, the boundary between the pupil and the human iris. It is a visible section of the posterior layer and looks like a curling edge of the pupil. The whole anterior layer consists of the pupillary area and the ciliary area and their boundary is called collarets. The ciliary area is divided into the inner area, which is relatively smooth and bears radial furrows, the middle area, heavily furrowed in all directions and with pigment piles on the ridges, and the outer marginal area bearing numerous periphery crypts.

C. Iris Codes

We turn now from the very traditional ways of identifying people to the modern and innovative. Recognizing people by the patterns in the irises of their eyes is far and away the technique with the best error rates of automated systems when measured under lab conditions. Every human iris is measurably unique. The iris pattern contains a large amount of randomness, and appears to have many times the number of degrees of freedom of a fingerprint. It is formed between the third and eighth month of gestation, and (like the fingerprint pattern) is phenotypic in that there appears to be limited genetic influence; the mechanisms that form it appear to be chaotic. So the patterns are different even for identical twins (and for the two eyes of a single individual), and they appear to be stable throughout life. A signal processing technique (Gabor filters) has been found which extracts the information from an image of the iris into a 256-byte *iris code*. This involves a circular wavelet transform taken at a number of concentric rings between the pupil and the outside of the iris (Figure 1.5), and has the beautiful property that two codes computed from the same iris will typically match in 90% of their bits. This is much simpler than in fingerprint scanners where orienting and classifying the minutiae is a hard task. The speed and accuracy of iris coding has led to a number of commercial iris recognition products. Iris codes provide the lowest false accept rates of any known verification system—zero, in tests conducted by the U.S. Department of Energy. The equal error rate has been shown to be better than one in a million, and if one is prepared to tolerate a false reject rate of one in ten thousand, then the theoretical false accept rate would be less than one in a trillion.

The main practical problem facing deployment of iris scanning in the field is getting the picture without being too intrusive. The iris is small (less than half an inch) and an image including several hundred pixels of iris is needed. A cooperative subject can place his eye within a few inches of a

video camera, and the best standard equipment will work up to a distance of two or three feet. Cooperation can be assumed with entry control to computer rooms, but it is less acceptable in general retail applications, as some people find being so close to a camera uncomfortable. Possible attacks on iris recognition systems include—in unattended operation at least—a simple photograph of the target's iris. This may not be a problem in entry control to supervised premises, but if everyone starts to use iris codes to authenticate bank card transactions, then your code will become known to many organizations. As iris codes can be compared rapidly (just exclusive-or them together and count the number of zero bits), they may start to assume the properties of names, rather than being passwords (as in current systems). So it might be possible to use your iris code to link together your dealings with different organizations.

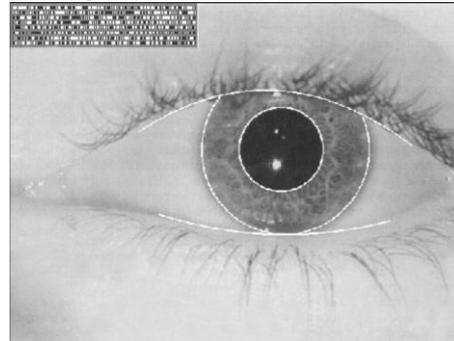


Fig1.3: An iris with iris code (courtesy John Daugman)

A possible solution to the impersonation problem is to design terminals that measure *hippus*—a natural fluctuation in the diameter of the pupil which happens at about 0.5Hz. But even this isn't infallible. One might try, for example, to print the target's iris patterns on contact lenses (though existing vanity contact lens printing techniques are so coarse-grained that they are detectable).

1) Eyelash and Noise Detection:

Kong and Zhang [19] present a method for eyelash detection, where eyelashes are treated as belonging to two types, separable eyelashes, which are isolated in the image, and multiple eyelashes, which are bunched together and overlap in the eye image. Separable eyelashes are detected using 1D Gabor filters, since the convolution of a separable eyelash with the Gaussian smoothing function results in a low output value. Thus, if a resultant point is smaller than a threshold, it is noted that this point belongs to an eyelash. Multiple eyelashes are detected using the variance of intensity. If the variance of intensity values in a small window is lower than a threshold, the centre of the window is considered as a point in an eyelash. The Kong and Zhang model also makes use of connective criterion, so that each point in an eyelash should connect to another point in an eyelash or to an eyelid. Specular reflections along the eye image are detected using thresholding, since the intensity values at these regions will be higher than at any other regions in the image.

D. Iris Recognition Process:

The flow chart of an iris recognition system is shown in Fig. 3.1. In general, the iris images can be acquired with a near-infrared camera. However, the miniature size of the human iris has made it a challenging task to develop a user

friendly iris pattern imaging system. In many systems, human intervention is needed to acquire satisfactory iris images. Once an iris image is acquired, the next step is to locate the iris region present between the black pupil and white sclera. Sometimes the boundaries of eyelids will also have to be computed to remove image regions that are not relevant to the iris recognition process.

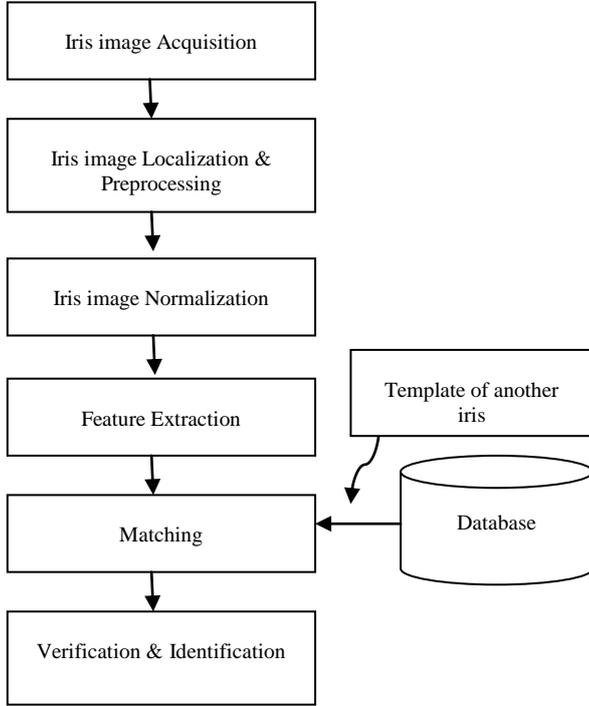


Fig 1: Flowchart of the Iris recognition process

Then, the iris pattern is normalized so that a rectangular iris image is obtained. Since matching the normalized iris images directly is very time consuming, iris feature extraction methods were developed to remove redundancies and to preserve useful information for iris recognition. Finally, a pattern classifier is used to recognize one's identity using the extracted features.

II. GABOR FILTER

A. The Equation

In spatial domain,

$$g(x, y) = e^{-\pi[\frac{x'^2}{\alpha^2} + \frac{y'^2}{\beta^2}]} e^{-2\pi j[u_0 x' + v_0 y']},$$

where

$$x' = (x - x_0) \text{ and } y' = (y - y_0)$$

(x_0, y_0) is the filter position,

α and β are the size parameters related to the effective width and height of the filter, u_0 and v_0 represent the horizontal and vertical spatial frequencies, and

$\theta = \tan^{-1}(v_0/u_0)$ is the orientation of the filter.

The six parameters, $\{x_0, y_0, \alpha, \beta, u_0, v_0\}$, specify the characteristics of a Gabor filter in spatial domain. The cut-off frequencies are determined by first transforming Gabor filter into frequency domain.

$$G(u, v) = e^{-\pi[(u-u_0)^2 \alpha^2 + (v-v_0)^2 \beta^2]} \times e^{-2\pi j[x_0(u-u_0) + y_0(v-v_0)]},$$

Then, by selecting a threshold, say k ($k \in [0, 1]$), of the amplitude response of the filter, we have the horizontal cutoff frequency

$$u_c = u_0 + \sqrt{\frac{\ln k}{\mu \alpha^2}}$$

and the vertical cut-off frequency

$$v_c = v_0 + \sqrt{\frac{\ln k}{\mu \beta^2}}$$

If the sampling rate is at least twice the cut-off frequency, then the sampling results would be less sensitive to the filter positions.

To simplify the design problem of filter banks, Filters parameters with different orientations are used. We can design the 0-level filter parameters and then the parameters in the other levels can be obtained by changing the scale of the 0-level parameters. From the spectrum analysis result of 756 normalized iris images from the CASIA database. It is clear that the spectra of the normalized iris images differ from each other mainly in the horizontal band. Although there are also some strong vertical frequency components, they all distribute within a very narrow vertical bands which might be contributed by the eyelids. Therefore, in this work, we will set $v_0 = 0$ and try to design α, β and u_0 with the GA.

B. Genetic Algorithm

A genetic algorithm (GA) is a search technique used in computing to find exact or approximate solutions to optimization and search problems. Evolutionary algorithms are computational models that solve a given problem by maintaining a changing population of individuals, each with its own level of "fitness". The change in the population is achieved by the selection, reproduction and mutation procedures within the method. The operation of these three procedures is dependent upon the fitness of the individuals concerned. Genetic algorithms are characterized by the fact that all the information for any individual in the population is encoded using some linear encoding system. This (usually binary) encoding is intended to be analogous to natural DNA consisting of a string of four kinds of chromosomes. The standard encoding technique for applying genetic algorithms to non-linear optimization problems (where the parameters are continuous and real), is a concatenation of all the binary approximations to each number. Genetic algorithms are implemented as a computer simulation in which a population of abstract representations (called chromosomes or the genotype of the genome) of candidate solutions (called individuals, creatures, or phenotypes) to an optimization problem evolves toward better solutions. The evolution usually starts from a population of randomly generated individuals and happens in generations. In each generation, the fitness of every individual in the population is evaluated, multiple individuals are stochastically selected from the current population (based on their fitness), and modified (recombined and possibly randomly mutated) to form a new population. The new population is then used in the next iteration of the algorithm. Commonly, the algorithm terminates when either a maximum number of generations has been produced, or a satisfactory fitness level has been reached

for the population. If the algorithm has terminated due to a maximum number of generations, a satisfactory solution may or may not have been reached.

C. Implementation of Genetic Algorithm

Genetic Algorithm, to start with we need initial population for the problem, of all the 108 classes of the CASIA iris images; we randomly choose M classes of iris images as the training data set. Then the data of the first training set are restored and another training set is selected randomly. With this training data set or initial population, compute the histograms of both the intra- and the inter-class distances given a set of filter parameters. Additionally, *authentic* distribution for iris recognition means the similarity between different images of the same eye depends very strongly upon the image acquisition conditions; sometimes also called as *Intra class comparisons*. Imposter means when different irises are compared independent of imaging factors also called as *Inter Class comparison*. Furthermore, the means and the variances of the inter- and intra-class distances can be evaluated. Denote the mean and the variance of the intra-class (inter-class) distance by $m_a(m_i)$ and $s_a^2(s_i^2)$, respectively. The subscript 'a' and 'i' are the acronyms of authentic and imposter, respectively. The overall decidability of the task of recognizing persons by their iris patterns is revealed by calculating fitness function for same versus for different irises (intra and inter class). The fitness function to design the filter parameters with GA is defined to be the measured decidability given by:

$$d = \frac{|m_a - m_i|}{\sqrt{(s_a^2 + s_i^2)/2}}$$

In order to reduce the computation time, the search range of the parameters are confined to $u_0 \in [0, 0.5]$, $\alpha \in [1, 32]$ and $\beta \in [1, 8]$. The first constraint is obvious since the Nyquist sampling theorem provides an upper bound of u_0 to be 0.5. The other search ranges of the parameters were determined empirically, e.g., when α is greater than 32, then the convolved image is too blurry which cause a severe reduction of the inter-class distance. Also, when β is greater than 8, the height of the level 3 filter will be greater than that of the iris image which is not desired. The Real Coded Genetic Algorithms provide efficient search in the parameter space. Gabor filter is designed using the GA process under the 2-D wavelet configuration, where the real part has been adjusted to have zero mean. Interestingly enough, the real part and the imaginary part of our best Gabor filter are very similar to the LoG and the DoG filters that are frequently used to detect ridge edges and step edges, respectively. The edge detection interpretation is also useful to understand the classification process of the iris pattern. In the matching process, each bit of the input Iris Code is XORed with the corresponding bit of the enrolled Iris Code. Let us consider a specific bit of the Iris Code computed with the real part of a Gabor filter. If the enrolled value of this bit is '1', the XOR process can be regarded as a simple classifier discriminating persons whose iris pattern does not have a positive ridge edge at a specific location. In general, if the filter parameters are properly designed, the percentage of the population with/without a

ridge edge been detected at that specific location of their iris is about 50%. Therefore, the performance of IA using a single-bit Iris Code is no better than chance. To improve the recognition rate, the length of the Iris Code should be increased. This is equivalent to use the *boosting* technique to improve the accuracy of the classification algorithm. In view of the classifier boosting, the XOR of each bit in the Iris Code can be regarded as the decision of a component classifier. The final decision is a simple vote among the component classifiers. To summarize, each bit of the Iris Code indicates whether a positive ridge/step edge of certain scale can be detected at a specific location of the iris. To verify if two Iris Codes come from the same iris, the consistency of edge types and locations is examined one by one. If the degree of inconsistency is less than a threshold value, then we decide that these two Iris Codes are from the same iris; otherwise, we decide that they are from different irises. To confirm our observation about how Daugman's method works, we propose to use the LoG and DoG as an alternative to the Gabor filters for edge detection. For simplicity, we define the LoG and the DoG as follows:

$$\begin{aligned} LoG(x, y) &= \frac{d^2}{dx^2} e^{-\pi \left[\frac{(x-x_0)^2}{2\alpha^2} + \frac{(y-y_0)^2}{2\beta^2} \right]} \\ DoG(x, y) &= \frac{d^2}{dx} e^{-\pi \left[\frac{(x-x_0)^2}{2\alpha^2} + \frac{(y-y_0)^2}{2\beta^2} \right]} \end{aligned}$$

where, (α, β) denote the effective width and height of filter, and (x_0, y_0) denote the filter position. With the LoG and DoG filters, the size parameters α and β can also be designed with the GA. We will compare the performance of the designed filter banks in the next section.

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III. EXPERIMENTAL RESULTS

A. Overview:

In this paper, the performance of the iris recognition system as a whole is examined. Tests are carried out to find the best separation, threshold, so that the false match and false accept rate is minimized, and to confirm that iris recognition can perform accurately as a biometric for recognition of individuals. As well as confirming that the system provides accurate recognition, experiments were also conducted in order to confirm the uniqueness of human iris patterns by reducing the number of degrees of freedom present in the iris template representation.

B. Data Sets: Chinese Academy of Sciences

The Chinese Academy of Sciences - Institute of Automation (CASIA) eye image database [1] contains 756 grayscale eye images with 108 unique eyes or classes and 7 different images of each unique eye. Images from each class are taken from two sessions with one month interval between sessions. The eye images are mainly from persons of Asian descent, whose eyes are characterized by irises that are

densely pigmented, and with dark eyelashes. Due to specialized imaging conditions using near infra-red light, features in the iris region are highly visible and there is good contrast between pupil, iris and sclera regions. The CASIA iris database [5] is used to test the proposed filter bank design method. This database includes 756 iris images taken from 108 different eyes. For each eye, seven images were captured during two different sessions.

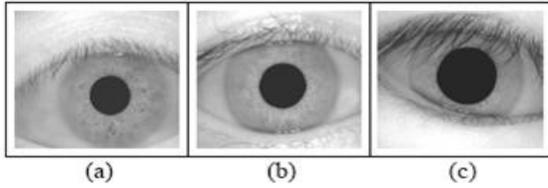


Fig 3.1: Three images from the CASIA database

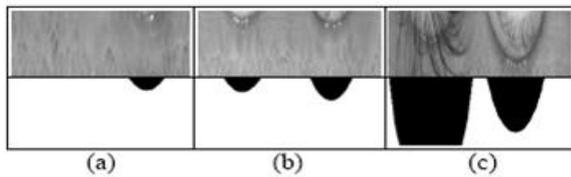


Fig 3.2: Normalized iris images and its masks

Figure 3.1 shows three typical images contained in the CASIA database. Their normalized iris images are shown in Fig. 3.2 where a mask image is computed for each normalized image. It should be noted that most of the images in the CASIA database are captured from the Asian people whose normal upper eyelid position is low. The eyelids and eyelashes might cover some portions of the iris pattern. (Fig 3.2)

C. Uniqueness of Iris Patterns:

The first test was to confirm the uniqueness of iris patterns. Testing the uniqueness of iris patterns is important, since recognition relies on iris patterns from different eyes being entirely independent, with failure of a test of statistical independence resulting in a match. Uniqueness was determined by comparing templates generated from different eyes to each other.

D. Process:

The Genetic Algorithm process is configured to have a population size of 50, a generation size of 200, a crossover probability of 0.7, and a mutation probability of 0.2. We randomly select 30 iris patterns from the CASIA database as the first training set $T1$. Then, the data of the first training set are restored and we randomly select another 30 iris patterns as the second training set $T2$. The fitness function is

$$d = \frac{|m_a - m_i|}{\sqrt{(s_a^2 + s_i^2)/2}}$$

Table1 shows the designed parameters of four Gabor filter banks where the measured decidability d is computed with $T1$ or $T2$. In order to obtain their overall performance, we tested the four Gabor filter banks with all the iris patterns in the CASIA database and the means m and standard deviations σ and the measured decidability are shown in Table 2. For

comparison, we have also added the test results of two manually selected parameters into Table 2. The experimental results show that started with randomly generated parameters, the GA method can successfully design Gabor filter banks for iris recognition.

E. The Results

The results for the system are as shown in the Figures 3.3 and 3.4 the tables depicts the parameters for the design and implementation.

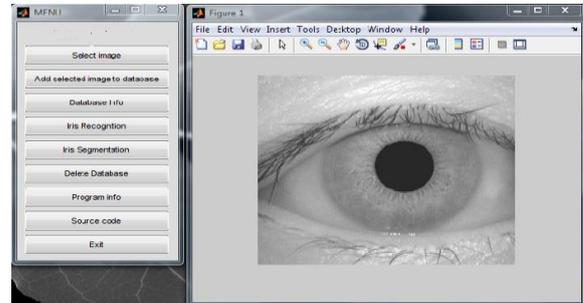


Fig 3.3: Selection of Iris from the CASIA database

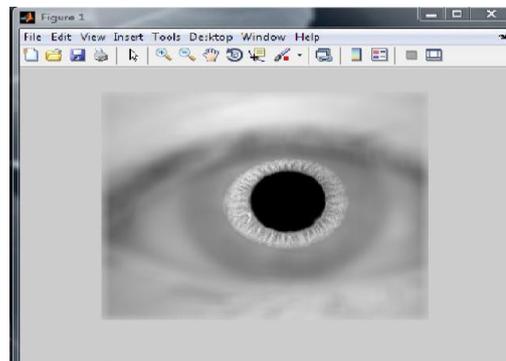


Fig 3.4: Image after application of Gabor filter



Fig 3.5: Iris section being extracted

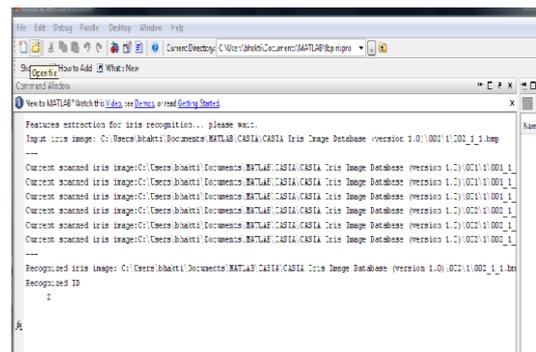


Fig 3.6: Result window depicting match of the iris selected

TABLE 1. PARAMETERS OF FOUR GABOR FILTER BANKS DESIGNED WITH GA

	α	β	u_0	d
Gabor filter with GA for T1	13.90625	7.78125	0.0817	7.19
Gabor filter with GA for T2	9.56250	7.46875	0.1797	6.77

TABLE 2. TEST RESULTS OF GABOR FILTERS

	Intra Class		Inter Class		d
	m	σ	m	σ	
Gabor filter with manually selected parameter	0.082	0.0451	0.426	0.0540	6.90
Gabor filter with GA for T1	0.083	0.0450	0.433	0.0468	7.62
Gabor filter with GA for T2	0.096	0.0461	0.423	0.0468	7.51

The LoG/DoG filters that we have designed with the GA process. By comparing although their sizes are different, one can still reveal the common characteristics of those two filter banks. Table 3 shows four sets of parameters. Table 4 shows the test result using the full CASIA database.

TABLE 3. PARAMETERS OF LOG/DOG FILTER BANKS DESIGNED WITH GA

	α	β	d
LoG filter with GA for T1	5.34375	7.59375	7.28
LoG filter with GA for T2	5.09375	7.03125	7.55

TABLE 4. PERFORMANCE OF THE GABOR FILTERS AND THE LOG/DOG FILTERS

	Intra Class		Inter Class		d
	m	σ	m	σ	
LoG filter with manually selected parameter	0.097	0.0492	0.436	0.0393	7.62
LoG filter with GA for T1	0.098	0.0490	0.436	0.0395	7.60
LoG filter with GA for T2	0.099	0.0504	0.438	0.0387	7.52

False accept rate (FAR): The probability that the system incorrectly declares a successful match between the input pattern and a non-matching pattern in the database. It measures the percent of invalid matches. These systems are critical since they are commonly used to forbid certain actions by disallowed people.

False reject rate (FRR): The probability that the system incorrectly declares failure of match between the input pattern and the matching template in the database. It measures the percent of valid inputs being rejected.

Equal error rate (ERR): The rate at which both accept and reject errors are equal. ROC or DET plotting is used because how FAR and FRR can be changed, is shown clearly. When quick comparison of two systems is required, the ERR is commonly used. Obtained from the ROC plot by taking the point where FAR and FRR have the same value. The lower the EER, the more accurate the system is considered to be.

The ROC curve is a false acceptance rate (FAR) versus false rejection rate (FRR) curve which shows the overall performance of an algorithm. We assume that the enrollment iris is acquired under supervision, thus the image quality is better than the test data. Therefore, we choose the iris image with the largest effective iris area as the enrollment image to compute the ROC curves. From the ROC curve, we can determine the equal error rate (EER) for each set of filter parameters which is shown in Table 5. The performance of iris recognition with either the Gabor filters or the LoG/DoG filters is almost the same, which means that our edge-detection interpretation of the Iris Code is reasonable. The best EER that can be achieved is approximately 0.034%, which is very accurate.

TABLE 5. THE EQUAL ERROR RATE OF THE PARAMETER UNITS

	EER using GF	EER using LD
2WGAT1	0.1637%	0.0715%
2WGAT2	0.0340%	0.0956%

IV. CONCLUSIONS

In this paper, I have presented a method to design Gabor filter banks for iris recognition with GA. The EER of iris recognition, with the optimal Gabor parameters is about 0.034% which is approximately equal to the performance of Daugman's method reported in [4]. By examining our optimal Gabor filters, we found that they are very similar to the LoG and DoG filters that are frequently used for edge detection.

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