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An Efficient Iris Feature Encoding and Pattern Matching for Personal Identification

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Abstract— *Recognize people identity becomes an essential problem, Iris based biometric system provides accurate personal identification. Feature encoding and pattern matching are major task in the iris recognition. In our proposed system gives how to set a model to extract the feature of different irises and match them is especially important for it determines the results of the whole system directly. Gabor wavelets are able to provide optimum conjoint representation of a signal in space and spatial frequency. A Gabor filter is constructed by modulating a sine/cosine wave with a Gaussian. Feature Encoding was implemented by convolving the normalised iris pattern with 1-D Gabor filters. For Matching hamming distance will be calculated and accurate recognition was achieved.*

Keywords— Feature Encoding, Gabor Filters, 1-D Gabor Filters, Hamming Distance, Pattern Matching

I. Introduction

Iris Segmentation and Edge Detection Provides abundant texture information. Feature selection and extraction is to find out important features to perform matching. The visible features of an iris are ciliary processes, contraction furrows, crypts, rings, cornea, and freckles and so on. To set a model to extract the feature of different irises and match them is especially important for it determines the results of the whole system directly. A feature vector is formed which consists of the ordered sequence of features extracted from the various representation of the images. 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 image to create biometric templates.

II. Materials and Methods

A. Gabor Filters

Gabor wavelets are able to provide optimum conjoint representation of a signal in space and spatial frequency.

A Gabor filter [1], [2] is constructed by modulating a sine/cosine wave with a Gaussian. A 2-D Gabor filter over an image domain (x, y) is represented as:

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$$G(x,y) = e^{-\pi[(x-x0)^2/\alpha^2 + (y-y0)^2/\beta 2]} e^{-2\pi i[u0(x-x0) - v0(y-y0)]} \quad (1)$$

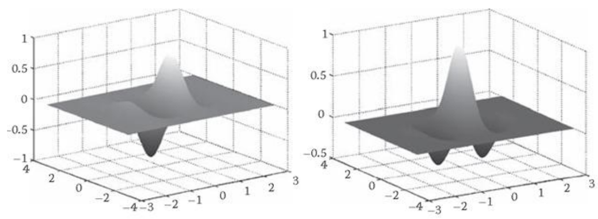

Figure 1: A quadrature pair of 2D Gabor Filters, (a) Depicts the real component or even symmetric filter characterised by a cosine modulated by a Gaussian and (b) Depicts the imaginary component or odd symmetric filter characterised by a sine modulated by a Gaussian.

Where equation 1

(x0, y0) Specify position in the image,

(α, β) Specify the effective width and length,

And (u0, v0) Specify modulation, which has spatial frequency $\omega 0 = \sqrt{u_0^2 + v_0^2}$

This is able to provide the optimum conjoint localisation in both space and frequency, since a sine wave is perfectly localised in frequency, but not localised in space. Modulation of sine with a Gaussian provides localisation in space, through with loss of localisation in frequency. Decomposition of a signal is accomplished using a quadrature pair of Gabor filters, with a real part specified by a sine modulated by a Gaussian. The real and imaginary filters are also known as the even symmetric and odd symmetric components respectively. The center frequency of the filter specified by the frequency of the sine/cosine wave, and the bandwidth of the filter is specified by the width of the Gaussian. Daugman makes use of a 2-D version of Gobar filters in order to encode iris pattern data.

Daugman demodulated the output of the Gabor filters in order to compress the data. This is done by quantising the phase information into four levels, for each possible quadrant in the complex plane. Taking only the phase will allow encoding of discriminating information in the iris, while discarding redundant information such as illumination, which is represented by the amplitude component. These four levels are represented using two bits of data, so each pixel in the normalised iris patterns to two bits of data in the iris template. A total of 9600 bits are calculated for the template, and an equal number of masking bits are generated in order to mask out corrupted regions within the iris. This creates a compact 1200-byte template, which allows for efficient storage and comparison of irises. The daugman system makes of polar co-ordinates for normalization, therefore in polar form the filters are given as:

$$h(r,\theta) = e^{-i\omega(\theta-\theta_0)} e^{-(r-r_0)^2/\alpha^2} e^{-i(\theta-\theta_0)^2/\beta^2} \quad (2)$$

(r_0, θ_0) Specify the centre frequency of the filter.

III. IRIS CODE CONSTRUCTION AND ENTROPY MEASURES

A. The Iris Code

The 2-D Gabor filters used for iris recognition are defined the doubly dimensions polar co-ordinate system $(r\ ,\theta)$ as shown in figure 2, 2-D Gabor Filter Equation is as follows.

$$G(r,\theta) = e^{-i\omega(\theta-\theta_0)} e^{-(r-r_0)^2/\alpha^2} e^{-i(\theta-\theta_0)^2/\beta^2} \quad (3)$$

The real parts of the 2D Gabor filters are slightly adjusted through truncation to give them zero volume, and hence no DC response, so that computed iris code bits do not depend upon the strength of illumination (The imaginary parts of the filters have no DC response because of odd symmetry).

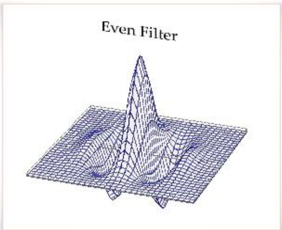

Figure 2: Gabor Filter at 0 Degree Orientation

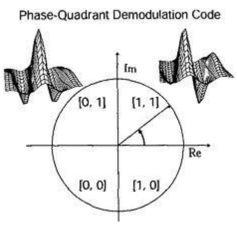

Figure 3: Phase-Quadrant Iris Demodulation Code

The parameters α and β co-vary in inverse proportion ω to generate a self- similar, multi-scale wavelet family of 2D frequency-selective quadrate filters with constant logarithmic bandwidth, whose locations, specified by θ_0 and r_0, range across the zones of analysis of the iris. Each bit, h, in an iris code is regarded as a co-ordinate of one of the four vertices of a logical unit square in the complex plane It is composed by evaluating the sign of the iris image, I(P, ϕ), on to a particular complex 2D Gabor filter.

B. Commensurability of Iris Codes

A very important aspect of iris coding approach is to achieve commensurability among the iris codes. This is done by mapping all irises into a representation having universal format and constant length, regardless of the apparent amount of iris detail. If there were no commensurability among the codes, showing partial agreement and partial disagreement in their lists of features, in this case, there is no straight ahead mathematically solution for how one would be able to make objective decisions and compute confidence levels. Therefore commensurability is necessary to facilitate and objectify the code comparison process, and the computation of confidence levels for each decision. It also speeds up the whole process of iris recognition as well as increasing the reliability.

IV. IRIS ENCODING

For Encoding, we have used log-Gabor filter because it covers more spectrum and eliminates DC component of the images. Feature encoding was implemented by convolving the normalized iris pattern with 1-D Log Gabor Wavelets. The 2-D normalized pattern is broken up into a number of 1-D signals, and then these 1-D signals are convolved with 1-D Gabor Wavelets [3]-[6].

The rows of the 2-D normalized pattern are taken as the 1-D signal. Each row corresponds to circular ring on the iris region. The angular direction is taken rather than the radial one, which corresponds to columns of the normalized pattern, since maximum independence occurs in the angular direction.

The intensity values at known noise areas in the normalized pattern are set to the average intensity of surrounding pixels to prevent intense of noise in the output of the filtering. The output of filtering is then phase quantized to four levels using the daugman method, with each filter producing two bits of data for each phases. The output of phase quantisation is chosen to be grey code, so that when going from one quadrant to another, only one bit changes. This will minimize the number of bits disagreeing, if say two intra-class patterns are sightly misaligned and thus will provide more accurate recognition. Therefore, the encoding process produced a bitwise template containing a number of bits of information, and a corresponding noise mask which corresponds to corrupt areas within the iris pattern, and marks bits in the template as corrupt.

V. MATCHING OF IRIS PATTERNS

For matching, the hamming distance was chosen as a metric for recognition, since bit-wise comparisons between biometric iris templates were required. The Hamming distance also incorporates noise masking, so that only significant bits are used between to iris templates. The hamming distance will be calculated using only the bits generated from the true iris region [7], [8].

Although, in theory, two iris templates generated from the same iris should have a Hamming distance of 0, in practice this will not occur because normalization is not perfect due to noise that goes undetected. So some variation will be present when comparing two intra-class iris templates. In order to account for rotational inconsistencies, when calculating the hamming distance of two templates, one template is shifted left and right bit-wise and a number of hamming distance values are calculated from each shifts. This bit-wise shifting in the horizontal direction corresponds to rotation of the original iris region by an angle given by the angular resolution used. If an angular resolution of 360 is used, each shift will corresponds to a rotation of 1 degree in the iris region. This method corrects misalignments in the normalized iris pattern caused by rotational differences during imaging.

From the calculated Hamming distance values, only the lowest is taken, since this corresponds to the best match between the two templates. The actual number of shifts required to normalise rotational inconsistencies will be determined by the maximum angle difference between two images of the same eye. For our set of eye images, a rotational inconsistency was a maximum of 24 degrees hence, shift of -8 to +8 bits. The template that is generated in the feature encoding process will need a corresponding matching metric system, which gives a measure of similarity between two iris templates. This metric system should give one range of values when comparing templates generated from the same eye, known as intra-class comparisons, and another range of values when comparing templates created from different irises, known as inter-class comparisons. These two cases should give distinct and separate values, so that a decision can be made high confidence as to whether two templates are from the same iris, or from two different irises.

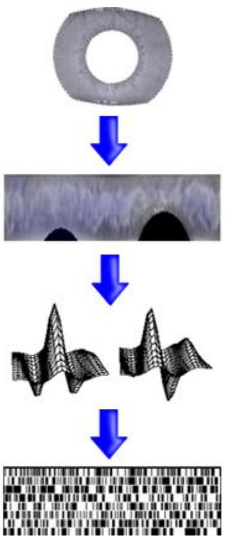

Figure 4: An Illustration of encoding Process

A. Hamming Distance(HD)

The Hamming Distance (HD) gives a measure of how many bits are same between two bit patterns [7], [8]. Using the hamming distance of two bit patterns, a decision can be made as to whether the two patterns were generated from different irises or from the same one.

In comparing the bit patterns X and Y, the HD, is defined as the sum of disagreeing bits (Sum of the exclusive-OR between X and Y) over N, The total number of bits in the bit pattern.

TABLE I
TRUTH TABLE OF XOR

Truth Table of XOR		
X	**Y**	**Result**
0	0	0
0	1	1
1	0	1
1	1	0

$$d^{HAD}(i,j) = \sum_{k=0}^{n-1} [y_{i,k} \neq y_{j,k}] \quad (4)$$

In the equation d^{HAD} is the Hamming distance between the objects *i* and *j*, *k* is the index of the respective variable reading *y* out of the total number of variables *n*. The Hamming distance it gives the number of mismatches between the variables paired by *k*. Each iris region will produce a bit-pattern which is independent to that produced by another iris, on the other hand, two iris codes produced from the same iris will be highly correlated. If two bits patterns are completely independent, such as iris templates generated from different irises, the hamming distance between the two patterns should be equal to 0.5. This occurs because independence implies the two bit patterns will be totally random, so there is 50 percent chance of setting any bit to 1, and vice versa. Therefore, half of the bits will agree and half will disagree between the two patterns.

If two patterns are derived from the same iris, The HD between them will be close to 0.0. Since they are highly correlated and the bits should agree between the two iris codes. The hamming distance is the matching metric employed by daugman, and calculation of the hamming distance is taken only with bits that are generated from the actual iris region. Matching process requires a threshold value of HD to decide whether the iris of and authenticated user or an imposer. Deciding this threshold value requires comparison between inter-class and intra-class distribution.

One filter is used to encode the templates, so only two bits are moved during a shift. The lowest Hamming Distance, in this case zero, is then used since this corresponds to the best match between the two templates. The iris code is represented by 256 bytes, or 2048 bits, but the iris only has 250 degrees of freedom (not 2048). The reason for this is that the furrow and ciliary processes tends to propagate across a significant radial distance in the iris, and thus making the iris code less independent. Also, Inherent correlations are introduced by the band pass property of the 2-D Gabor filters, specifically by the finite bandwidth determined by parameters.

The number of independent degrees-of-freedom that remains in an iris code after these two sources of correlation has been removed, can be estimated by examining the distribution of hamming distances computed across a population of unrelated iris codes. Comparing each pair of iris codes A and B bit-by-bit, their normalized Hamming distance HD is defined as the fraction of disagreeing bits between them.

$$HD = \frac{1}{2048} \sum_{j=1}^{2048} A_j (XOR) B_j \quad (5)$$

Where the Boolean operator (XOR) equals 1, the two bits A_j and B_j are different. Each of the bits in an iris code has an equal chance of being 1 or 0, this means that there is a 50 percent chance that any pair of bits in an iris code, this means that if the iris code consisted of only independent bits, the hamming distances would be a binominal distribution with p=0, 5 and N=2048(Hence a peak around 1024). Adding the 2D Gabor filters, the new distributed Hamming distances would have a distributions of p= 0, 5 and N=506, where all of the iris code are without any correlations. This measured distribution of Hamming distances, generated from 2064 comparisons between unrelated pairs of iris codes.

Here the mean is $\mu = 0{,}497$ and the standard derivation is σ =0,038. This distribution of hamming distances is equivalent to a binominal process with N=173 Bernoulli trials per run and p=0,5 which as it turns out corresponds to about 173 independent binary degrees of freedom remaining in a 2048-bit iris code(This number varies in each measure, and is often closer to 250 as mentioned before). This means that the probability of two irises having the same iris code by chance in these distributions, is in the order $10^{52}= (2^{173})$.

Hamming distributions contains unrelated iris codes, but there still remains the problem of determining at what hamming distance a sampled iris code should be considered an authentic, or an imposer. There are lot of the same iris. The following figure models the hamming distance measured for 9.1 million eyes to the left the Hamming distance of 7070 different pairs of same-eye images at different times, under different conditions, and usually with different cameras.

Here, the Hamming distance is 0, because there is absolutely no overlapping between the two distributions. Since the camera conditions almost never will be the same for two different images of neither the same eye nor different eyes. That means there always will be a chance for failing the test, either by saying that a sample is authentic. One will always have to find a balance between these two states of error, because the reducing one will make the other grow. A way of calibrating this is calculating its decidability index, d':

$$d' = \frac{|\mu 1 - \mu 2|}{\sqrt{(\sigma 1^2 + \sigma 2^2)/2}} \qquad (6)$$

d' Measures how well separated the two distributions are. It is based on the means, μ_1 and μ_2 their standard derivatives, σ_1 and σ_2 .The higher the value of d', the more separated are the distribution of the distributions of the imposers and the authentic.

B. Uniqueness of 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 statistical independence resulting in a match. Uniqueness was determined by comparing templates generated from different eyes to each other, and examining the distribution of hamming distance values produced. This distribution is known as the inter-class distribution.

C. Recognition of Individuals

The main objective of an iris recognition system able to achieve a distinct separation on intra-class and inter-class hamming distance distributions. A separation or threshold value of hamming distance can be chosen which allows a decision to be made when comparing two templates. If the hamming distance between two templates is less than the threshold, the templates were generated from the same iris and a match is found. Otherwise if the hamming distance is greater than the threshold the two templates are considered to have been generated from different irises.

The distance between the minimum hamming distance value for inter-class comparisons and maximum hamming distance value for intra-class comparisons could be used as a metric to measure separation. However, this is not a very accurate measure since outliers will corrupt the value calculated, and the measure is dependent on the number of iris templates compared. A better metric is decidability, which takes into account the mean and standard deviation of the intra-class and inter-class distributions.

Decidability d' is a distance measured in standard deviations and is a function of the magnitude of difference between the mean of the intra-class distribution μ_s and the mean of the inter-class distribution μ_D , and also the standard deviation of the intra-class and inter-class distributions $\sigma^2 s$ and $\sigma^2 D$ respectively. The higher decidability and greater separation provides more accurate recognition by Intra-class and inter-class distributions. However, the intra-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.

The Correct reject rate, also known as type I error, and measures the probability of an enrolled individual not being identified by the system. The false accept rate (FAR), also known as Type II error, measures the probability of an individual being wrongly identified as another individual.

The false accept and false reject rates can be calculated by the amount of overlap between two distributions, which is illustrated in Figure 5. The false accept rate is defined by the normalized area between 0 and the separation point, K, in the inter-class distributions P_{diff}. The false reject rate is defined as the normalized area between the threshold, K, and 1 in the intra-class distribution P_{same}.

Irises were encoded by convolving the normalized iris region with 1D Log-Gabor filters and phase quantizing the output in order to produce a bit-wise biometric template. Encoding depended upon the filter parameters and optimum filter parameters were chosen according to decidability factor.

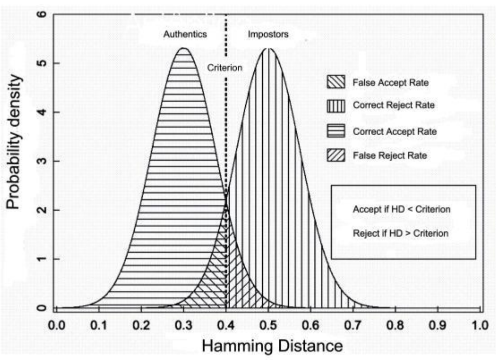

Figure 5: Intra-class and Inter-Class Hamming Distance Distributions with Overlap and Threshold at 0.35.

VI. Experimental Results

Table 2: Inter-class Hamming Distance

No Shift	8 Shift left and right
0.4015	0.3880
0.4007	0.3882
0.4017	0.3832
0.4023	0.3817
0.4090	0.3851
0.4016	0.3848
0.4102	0.3857
0.4122	0.3943
0.4157	0.4036
0.4122	0.3984
0.4078	0.3898
0.4111	0.3932
0.4203	0.3848
0.4087	0.3866
0.4017	0.3892

The inter-class hamming distance distributions fairly conform to the theory of statistical independence i.e. unique, since the mean of the distributed near to 0.5. After introducing shifting the mean inter-class hamming distance value decreased as expected.

Since information on filter parameters for encoding iris templates was lacking. The best filters parameters were found through statistical trial and error experimentations.

Filter parameters for which decidability factors were highest were taken, to maximize inter-class and intra-class filter distribution.

Table 3: Decidability (for σ/f=0.5)

λ_{min}	μ_s	σ_s	μ_d	σ_d	d'
18	0.2875	0.0968	0.3710	0.0065	1.01
19	0.2873	0.0967	0.3712	0.0068	1.22
20	0.2866	0.0966	0.3706	0.0063	1.22
21	0.2869	0.0966	0.3706	0.0065	1.21
22	0.2867	0.0967	0.3700	0.0073	1.21

The Maximum decidability factor is 1.2268 for $\sigma / f = 0.50$ and $\lambda = 20$.

VII. Conclusions

Successfully a new iris recognition system capable of comparing two digital eye-images is developed. The identification system is quite simple requiring few components and is effective enough to be integrated within security systems that require an identity check. The errors that occurred can be easily overcome by the use of stable equipment. Judging by the clear distinctiveness of the iris patterns we can expect iris recognition systems to become the leading technology in identity verification.

Segmented iris images were encoded in-to bit-wise biometric template by convolving the normalized iris region with 1-D Log Gabor filters and phase quantizing. The Hamming distance was chosen as a matching metric, to compare two-biometric templates. Optimum threshold was calculated experimentally by finding optimum filter parameters. A match occurred if the compared Hamming distance is less than calculated threshold of 0.36.

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