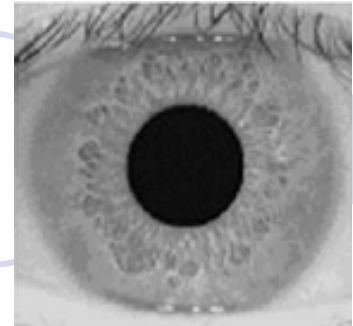


A decorative graphic consisting of five circles arranged in a pentagonal pattern. The top row has three circles: an empty circle on the left, and two solid light purple circles on the right. The bottom row has two solid light purple circles on the left and one empty circle on the right. The text "Iris Recognition" is centered over the top-right solid circle.

Iris Recognition

Introduction – The Iris



- Annular part between the pupil and the white sclera
- Provides many interlacing minute characteristics such as freckles, coronas, stripes, furrows, crypts and so on.
- Uniqueness result of difference in anatomical structures
- It is essentially stable over a person's life.
- Iris-based personal identification systems are noninvasive to their users

Iridian vs. Competition

Iris Recognition

- Accuracy
 - Never accepted an imposter ($EER=10^6$)
- Outlier population
 - $< 2\%$ can't use iris
- Uniqueness
 - Stable for life after age 1
 - Probability of identical irides = 1 in 10^{78}
 - DOF = 240-270

All the Others

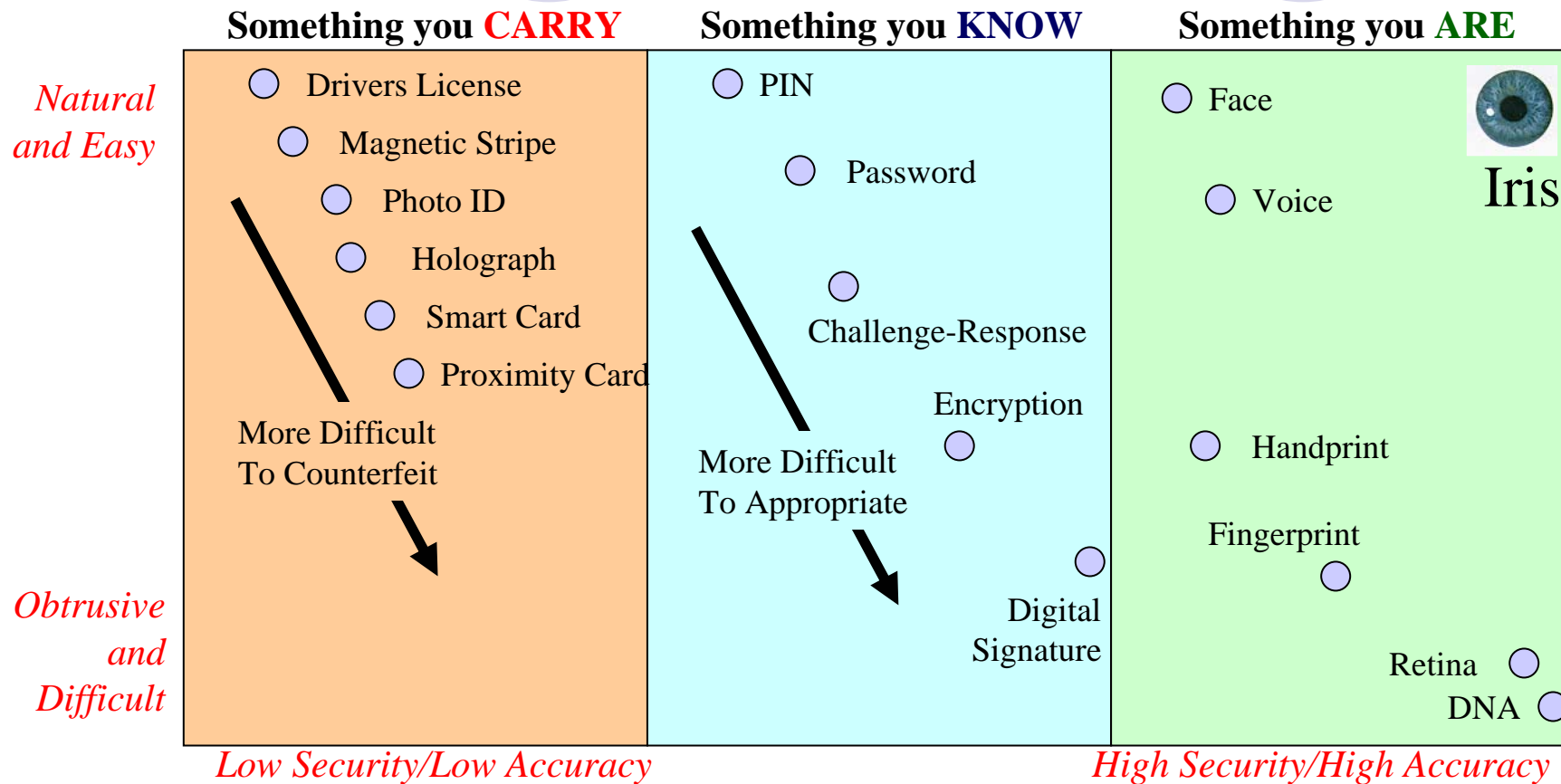
- Accuracy
 - Error rates up to 15%
- Outlier population
 - As high as 30%
- Uniqueness
 - Conditional changes
 - Conditional similarities
 - Up to 60 DOF



Testing & Evaluation

- American Academy of Ophthalmology – “Eye Safe”
- Communications Electronics Security Group (NPL)
 - 2.7 million attempts 0% false accept rate
 - 0% false reject rate (3 attempts)
- ASIO T4 – recommended for “Secure Access”
- EPL Evaluation (CC) TOE complete – EPL 2
- Germany/Singapore/USA testing underway

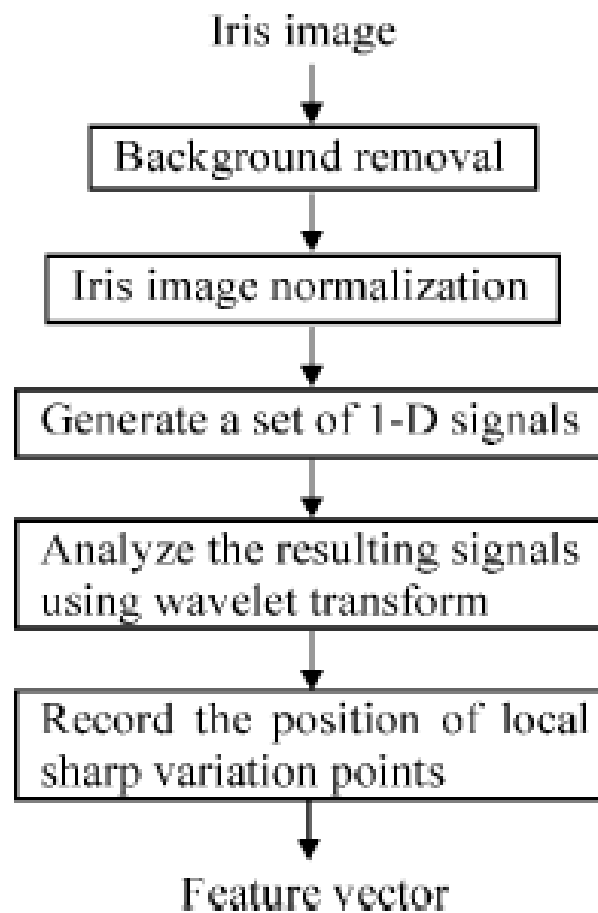
Why Iris Recognition will Emerge as the Standard



Efficient Iris Recognition by Characterizing Key Local Variations

Li Ma, Tieniu Tan, *Fellow, IEEE*,
Yunhong Wang, *Member, IEEE*, and
Dexin Zhang

Diagram of approach



Preprocessing - Localization

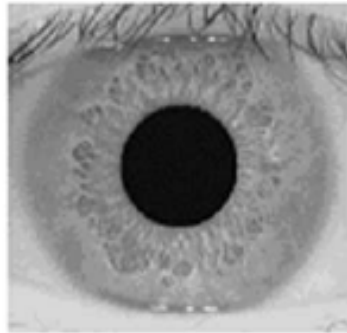
- Project the image in vertical and horizontal directions
 - Pupil generally darker than surroundings
 - Minima of the two projection profiles gives centre of pupil (X_p Y_p).
- For more accuracy
 - Binarize a 120X120 region around (X_p Y_p)
 - Centroid of resulting region is new centre
 - Repeat for more accurate result
- Exact parameters of the two circles found using edge detection and Hough transform.

Preprocessing- Normalization

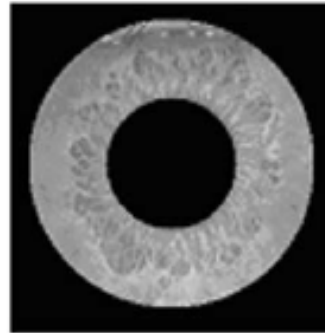
- Irises may be captured in different sizes.
- Size may also change due to illumination variations.
- Annular Iris is un-wrapped counter clockwise to a rectangular texture block with a fixed size
- Helps in reducing distortion of iris caused by pupil movement
- Also simplifies subsequent processing.

Preprocessing - Enhancement

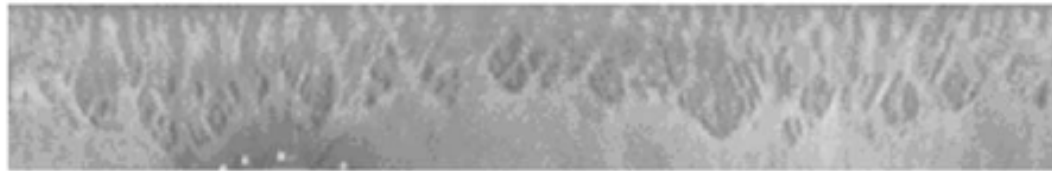
- Normalized image has low contrast and may have non-uniform brightness.
- An estimate of intensity variations is found using bicubic interpolation using 16X16 blocks.
- This estimate is then subtracted from the normalized image.
- More enhancement is done using Histogram Equalization in each 32X32 region.



(a)



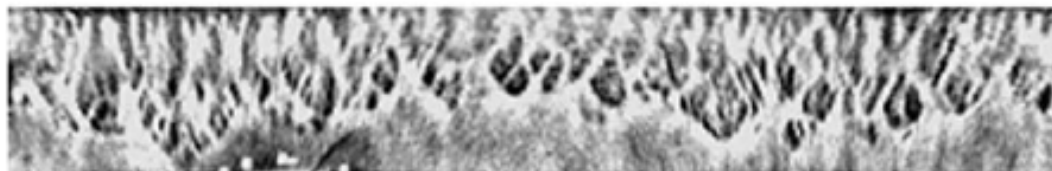
(b)



(c)



(d)



(e)

(a) Original image

(b) Localized image

(c) Normalized
image

(d) Estimated local
average intensity

(e) Enhanced image

Feature Extraction

- The 2-d normalized image is decomposed into 1-D signals S_i .

$$S_i = \frac{1}{M} \sum_{j=1}^M I_{(i-1)*M+j} \quad i = 1, 2, \dots, N$$

$$I = \begin{pmatrix} I_1 \\ \vdots \\ I_x \\ \vdots \\ I_K \end{pmatrix} = (I_1^T, \dots, I_x^T, \dots, I_K^T)^T$$

I is normalized image ($K \times L$)

I_x denotes gray values of x th row

M is total no. of rows used to form S_i

N is total no. of 1-D signals

Feature Extraction

- A set of such signals contains most of the local features.
- Such representation reduces computational costs.
- Iris regions close to sclera contain few texture characteristics
- So features are extracted from the top 78% of the image
- $K \times 78\% = N \times M$
- Recognition rate regulated by changing M.

Feature Vector

- For precise location of local sharp variations, dyadic wavelet transform is used.
- Dyadic wavelet transform of S at scale 2^j is

$$WT_{2^j} S(x) = \frac{1}{2^j} \int S(X) \psi \left(\frac{x - X}{2^j} \right) dX$$

- The function $\psi(x)$ is a quadratic spline which has a compact support and one vanishing moment
- Local extremum points of the wavelet transform correspond to sharp variation points of the original signal

Feature Vector



- There is an underlying relationship between information at consecutive scales
- The signals at finer scales are easily contaminated by noise.
- Hence only scales are used
- For each intensity signal S_i , the position sequences at two scales are concatenated to form the corresponding features.

Feature Vector

$$f_i = \{d_1, d_2, \dots, d_i, \dots, d_m; d_{m+1}, d_{m+2}, \dots, d_{m+n}; p_1, p_2\}$$

- Here,

d_i = position of sharp local variation point in S_i

m = no. of components from first scale

n = no. of components from the second scale

p_i = property of first local sharp variation point at two scales :
minima (+1) and maxima (-1).

- Features from different 1-D intensity signals are concatenated to constitute an ordered feature vector

$$f = \{f_1, f_2, \dots, f_i, \dots, f_N\}$$

Matching

- The original feature vector is expanded into a binary feature vector
- The similarity between a pair of expanded feature vectors is calculated using the exclusive OR operation
- The similarity function is defined in the following:

$$D = \frac{1}{N} \sum_{i=1}^N \frac{1}{2L} \sum_{j=1}^2 \left(Ef_{(i,j)}^1 \oplus Ef_{(i,j)}^2 \right)$$

where Ef^1 and Ef^2 denote two different expanded binary feature vectors, \oplus is the exclusive OR operator



Translation, Scale and Rotation

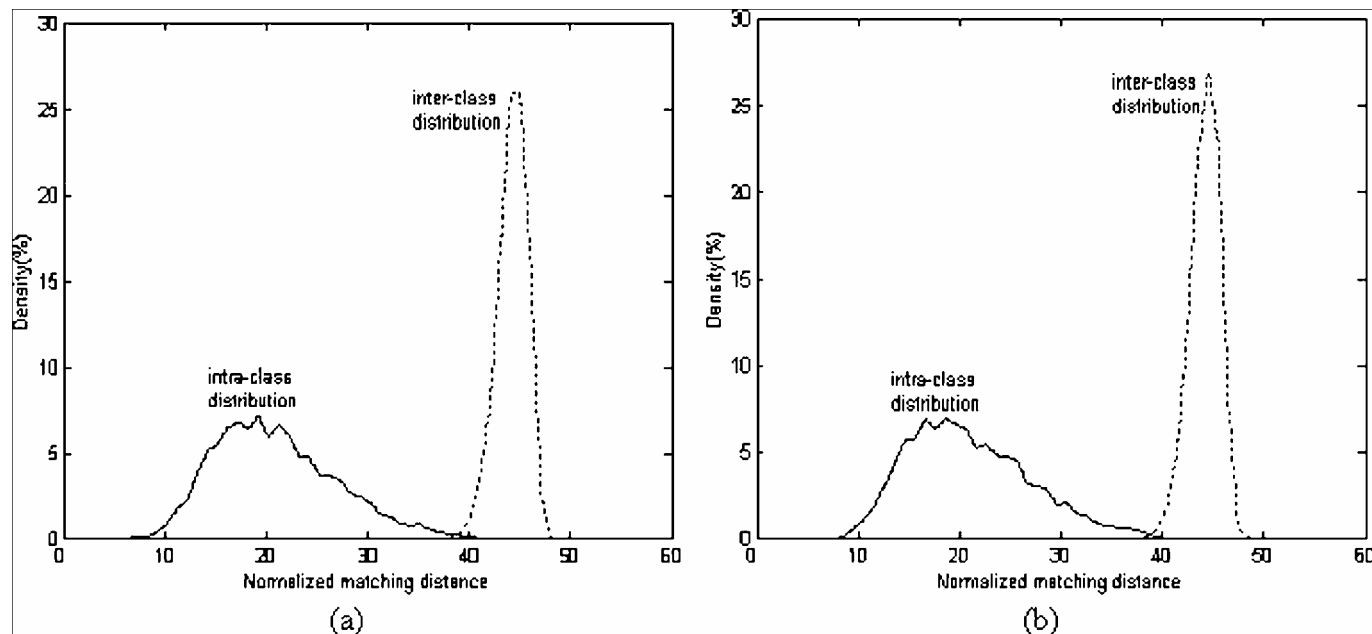
- Translation invariance is inherent because the original image is localized before feature extraction.
- To achieve approximate scale invariance, normalize irises of different size to the same size.
- Rotation in the original image corresponds to translation in the normalized image.
- The binary sequence at each scale can be regarded as a periodic signal, hence we obtain translation invariant matching by circular shift
- After several circular shifts, the minimum matching score is taken as the final matching score.

Experiments – Image Acquisition

- A large number of iris images were collected using a homemade sensor to form a database named *CASIA Iris Database*.
- The database includes 2255 iris images from 306 different eyes (hence, 306 different classes) of 213 subjects.
- The images are acquired during different sessions and the time interval between two collections is at least one month

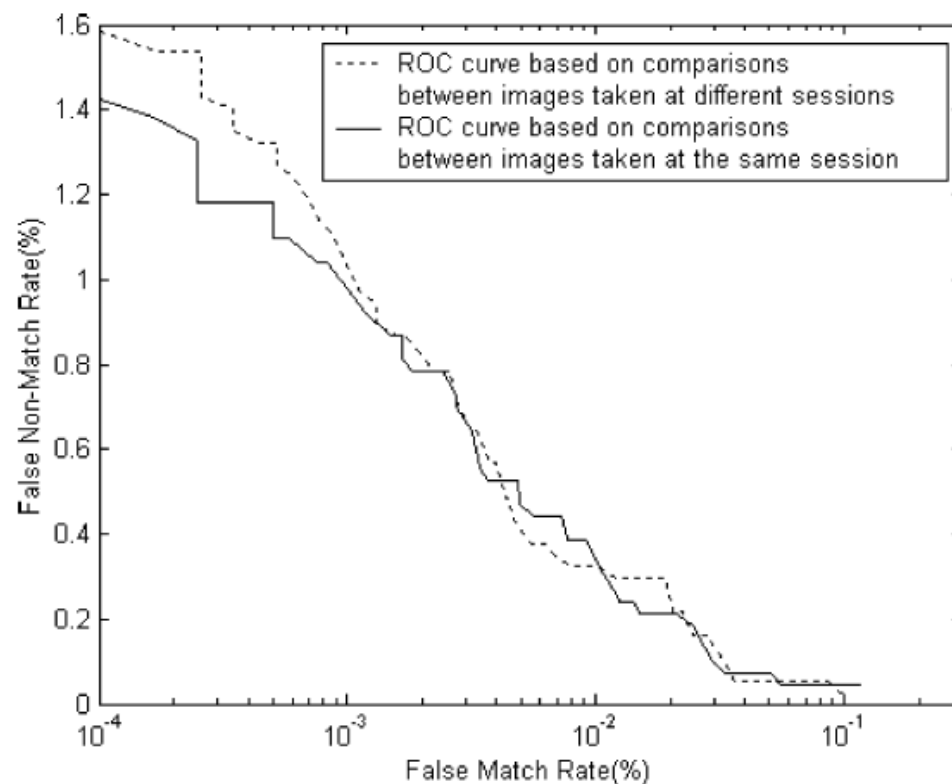
Performance Evaluation

- Experimental results were produced based on comparisons between images taken at the same session and those at different sessions



- (a) The results from comparing images taken at the same session.
(b) The results from comparing images taken at different sessions.

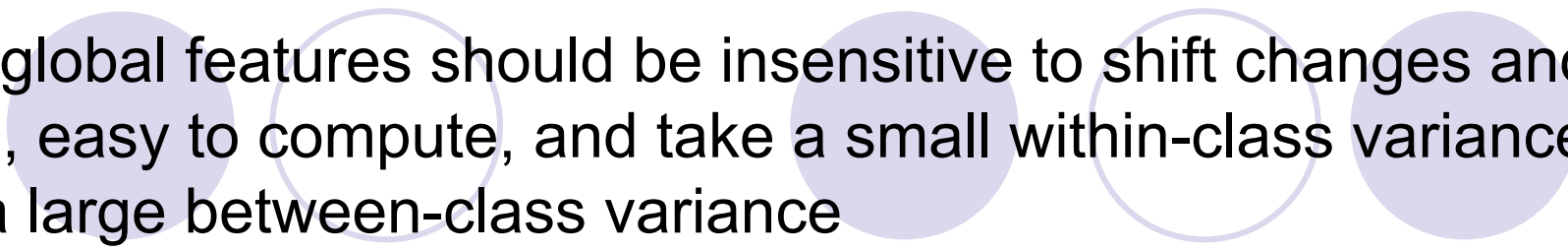
ROC



- The performance of our algorithm is very high
- The EER is only 0.09% for different session comparisons.

A NOVEL IRIS RECOGNITION METHOD BASED ON FEATURE FUSION

- Global and local iris feature are extracted to improve the robustness of iris recognition for the various image quality.
- The global feature are obtained from the 2D log Gabor wavelet filter and the local features are fused to complete the iris recognition.
- The weighting Euclidean distance and the *Hamming* distance are applied to match and classify, in addition to the threshold values .

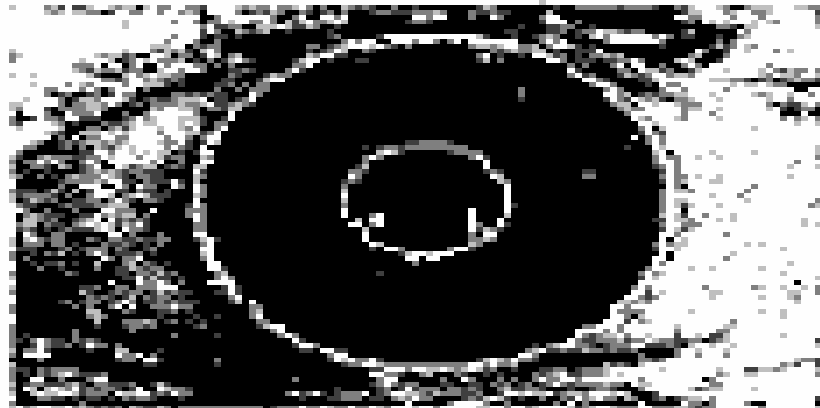
- 
- The global features should be insensitive to shift changes and noise, easy to compute, and take a small within-class variance and a large between-class variance
 - local features should be variant in the within-class and can not affect the between-class.

Iris image preprocessing

- The preprocessing stage of iris recognition is to isolate the iris region in a digital eye image.
- The iris region, can be approximated by two circles, one for the iris and sclera boundary and another for the iris and pupil boundary.

Iris localization

- The iris localization is to detect the iris area between pupil and sclera from an eye image.
- The image is projected in the vertical and horizontal direction to approximately estimate the center coordinates of the pupil, which is considered as the reference point,
- The inner boundary and outer boundary can be known by Hough transform.



Iris Normalization

- The proposed method excludes the upper and lower $\pi/2$ cones and the outer less half of the iris region,
- The inner more halves of the left and right $\pi/2$ cones of the iris region consider as the region for feature extraction.
- The formula of the iris region from Cartesian coordinates to the normalized non-concentric polar representation is

$$I(x(r, \theta), y(r, \theta)) \rightarrow I(r, \theta)$$

with

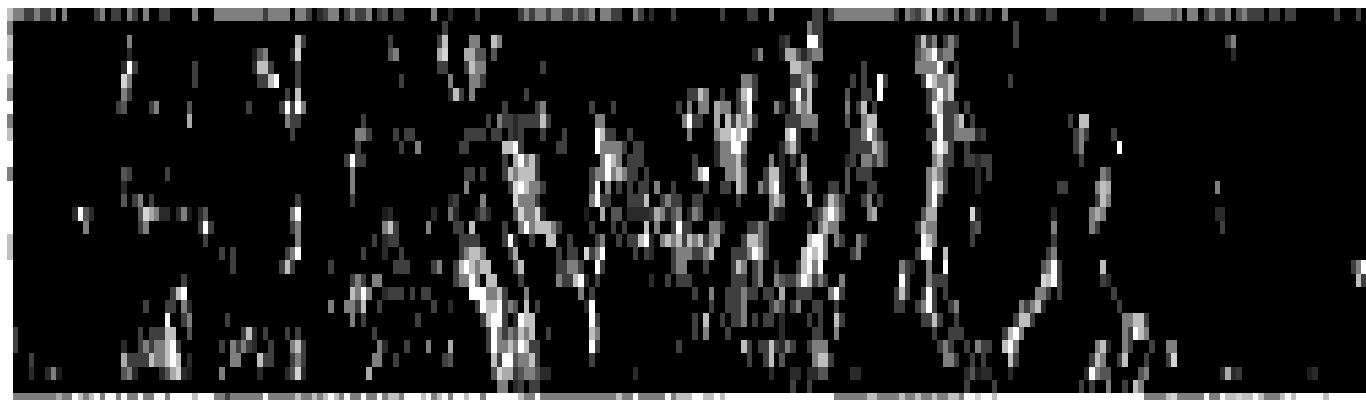
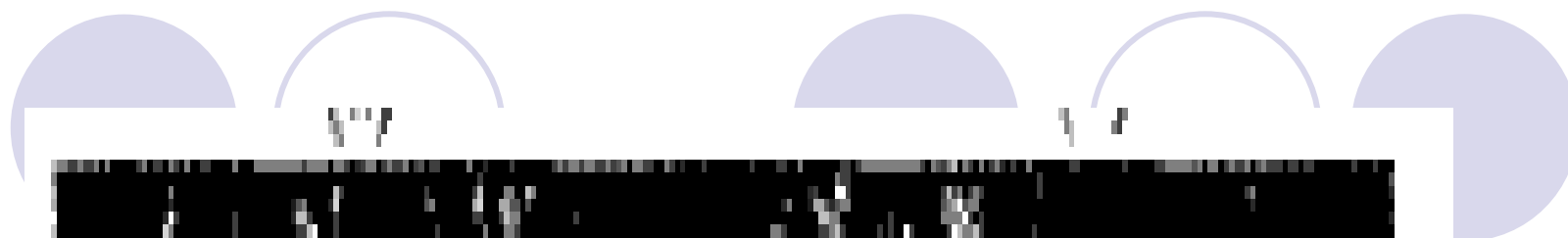
$$x(r, \theta) = (1 - r)x_p(\theta) + rx_i(\theta)$$

$$y(r, \theta) = (1 - r)y_p(\theta) + ry_i(\theta)$$

Where

$I(X, y)$ is the iris region image,
 (x, y) are the original Cartesian coordinates,
 (r, θ) are the corresponding normalized polar coordinates,
and
 X_p, y_p , and X_i, y_i are the coordinates of pupil and iris
boundary along θ direction.

The image of polar normalization and after local histogram
equalization shown below

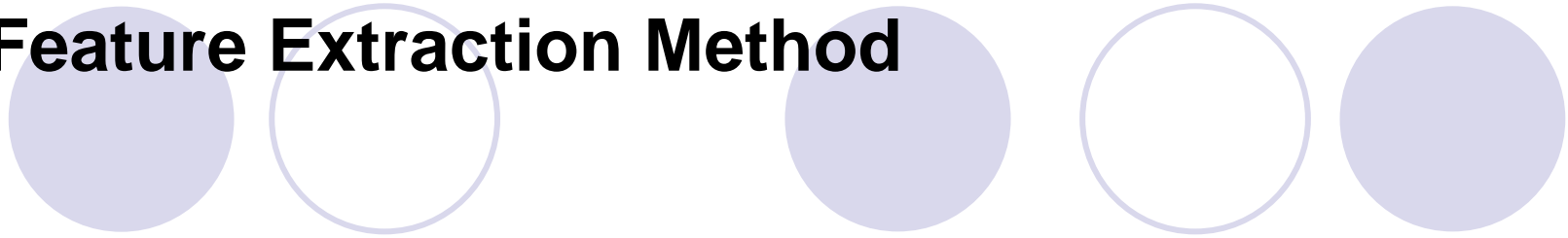


W



W

Iris Feature Extraction Method



- The features are extracted from the log Gabor wavelet filter at the different levels
- The statistics of textures features is used to represent the global iris features as it decreases the computation demand
- The local feature can represent iris local texture effectively.

The global feature extraction

- The wavelet transform is used to obtain frequency information based on a pixel in a image.
- Log Gabor wavelet is used which allow arbitrarily large bandwidth filters and zero DC component in the even-symmetric filters
- Gabor function has a transfer function

$$G(f) = \exp\left(\frac{-(\log(f / f_0))^2}{2(\log(\sigma / f_0))^2}\right)$$

Where f_0 -- center frequency, and σ -- bandwidth of filter

Let $I(x, y)$ denote image and W_n^e and W_n^o denote the even-symmetric and odd-symmetric wavelet at a scale then the responses of each quadrature pair of filter as forming a response vector

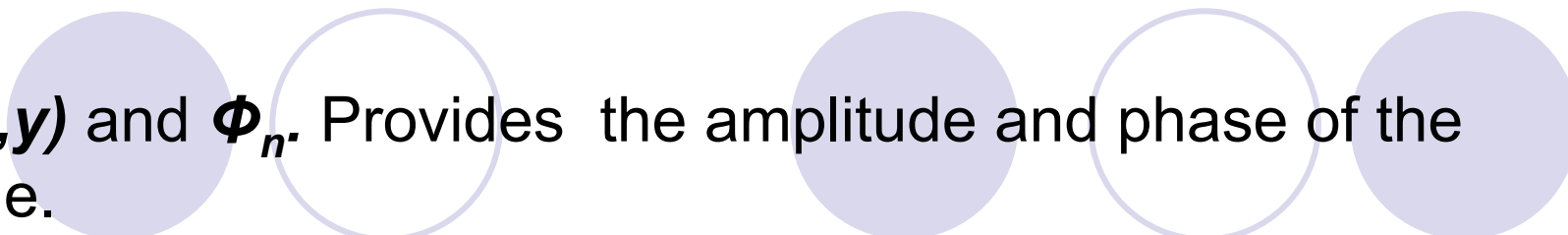
$$[e_n(x, y), o_n(x, y)] = [I(x, y) * W_n^e + I(x, y) * W_n^o]$$

The amplitude of the transform at a given wavelet scale is given as

$$A_n(x, y) = \sqrt{e_n^2(x, y) + o_n^2(x, y)}$$

the phase is given by

$$\phi_n = \tan^{-1}(o_n(x, y) / e_n(x, y))$$



$A_n(x,y)$ and ϕ_n . Provides the amplitude and phase of the image.

- The statistical values of amplitude are arrayed as the global feature to classify with weighting Euclidean distance.
- The system proposed includes the **32** global features including the mean and average absolute deviation of each out image with four orientation and four frequency levels.



The local features extraction

- The global feature need local feature to perfect the recognition.
- Due to the texture at the high frequency, levels is strongly affected by noise.
- Extraction of the local iris feature is done at the intermediate levels.

The local window is divided into $m \times n$ smaller sub-images with $p \times q$ pixels window now image is convoluted with log Gabor wavelet filter and encoded the amplitude into binary. The resulting code is called the local code.

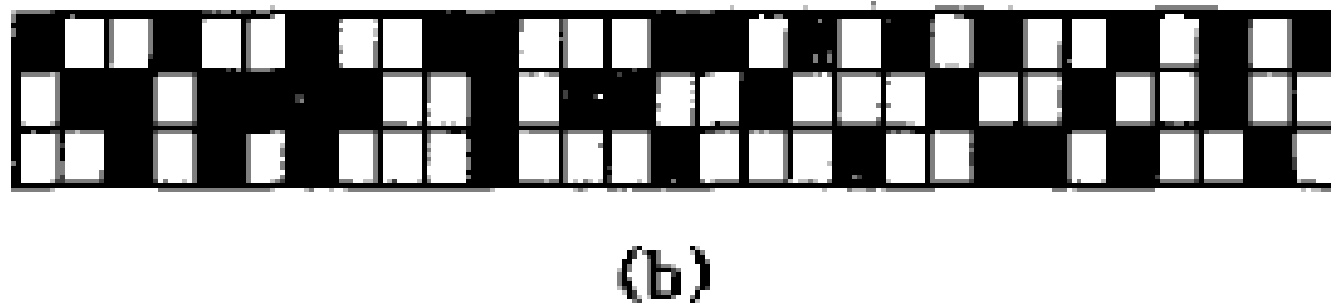



Figure 2. The binary local iris code
((a)the dived local window (b) the binary iris code)



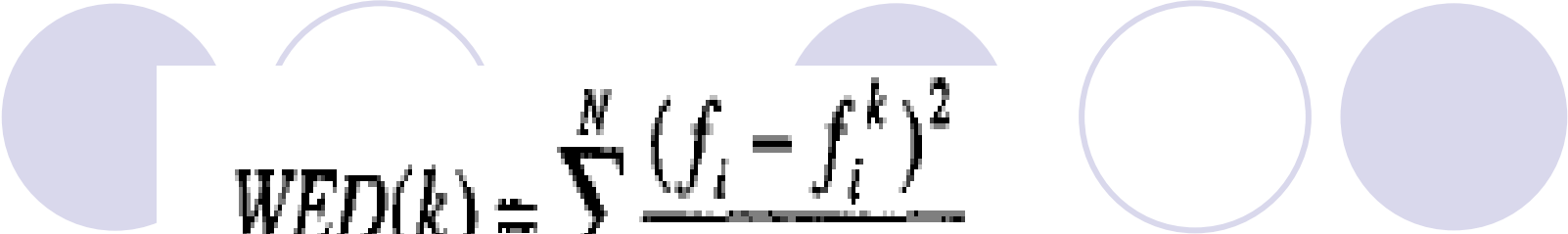
- If the real number sum of $D1$ is more than zero, the corresponding binary is low, whereas the corresponding binary is high.

- The imaginary number sum of $D1$ is more than zero, the corresponding binary is low, whereas the corresponding binary is high.

Iris Match and Recognition Fusion

- The classify method of the weighted Euclidean distance is used to compare two templates.

- The weighting Euclidean distance gives a measure of how similar a collection of values is between two templates. This metric is specified as-



$$WED(k) = \sum_{i=1}^N \frac{(f_i - f_i^k)^2}{(\delta_i^k)^2}$$

Where.

f_i -- i^{th} feature of the global feature of unknown iris.

f_i^k -- i^{th} feature of iris template k and

δ_i^k -- standard deviation of the i^{th} feature in iris template k .

When **WED** is a minimum at k . The unknown iris template is match with iris template k

- The local feature is extracted from the log Gabor filter
- To get relation each other sub images the code of local feature is quantized into bit.

HD is defined as the sum of disagreeing bits over ***N*** , the total number of bits in the bit pattern. X_i and Y_i is the bits of the iris and the stored template. The formula of the Hamming distance shows

$$HD = \frac{1}{N} \sum_{i=1}^N X_i (XOR) Y_i$$

The expression of classifier fusion

$$result = \begin{cases} 1 & WED < t_b \\ HD & t_b \leq WED < t_a \\ 0 & WED \geq t_a \end{cases}$$

As the value is between threshold t_a and t_b , local feature is considered to match for classify.

Experimental Result

The eye image database to test in this paper composes 10 persons with each eye. The eye image is captured at two stages with 3 months interval. At every stage, each eye is captured 4 images, so the test eye images database consists of 160 eye images with the 20 different iris classes. In this images database, a few images with noise, eyelids, eyelash, & illumination interfere are involved.

We record the former 4 iris images of each person as the stored known template and the later 4 images as the unknown input ins. Let the two thresholds are t_a and t_b 'to classify the iris

Table 1. Result of the local recognition

Threshold	FAR	FRR
0.35	0%	11%
0.40	8.1%	6.1%
0.45	14.1	1.9

Table 2. Result of the global and fusion recognition

Threshold	FAR	FRR
100	0%	10%
200	3.2%	0.7%
Fusion	0.3%	1.1%

Conclusions



- The key point of this method for iris recognition is the fusion of global feature and local feature.
- Speed of the recognition system increases significantly
- FAR reduces up to the significant extent ,
- Perform robustly with different image quality.

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