

Tutorial 8

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COMP435p
Biometrics Authentication

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- Problem 1: Answer The Questions
- Problem 2: Daugman's Method
- Problem 3: Separating IrisCodes
- Problem 4: Fourier Transforms of Irises
- Problem 5: Another pattern of Iris



Outline

1 Problems

- Problem 1: Answer The Questions
- Problem 2: Daugman's Method
- Problem 3: Separating IrisCodes
- Problem 4: Fourier Transforms of Irises
- Problem 5: Another pattern of Iris

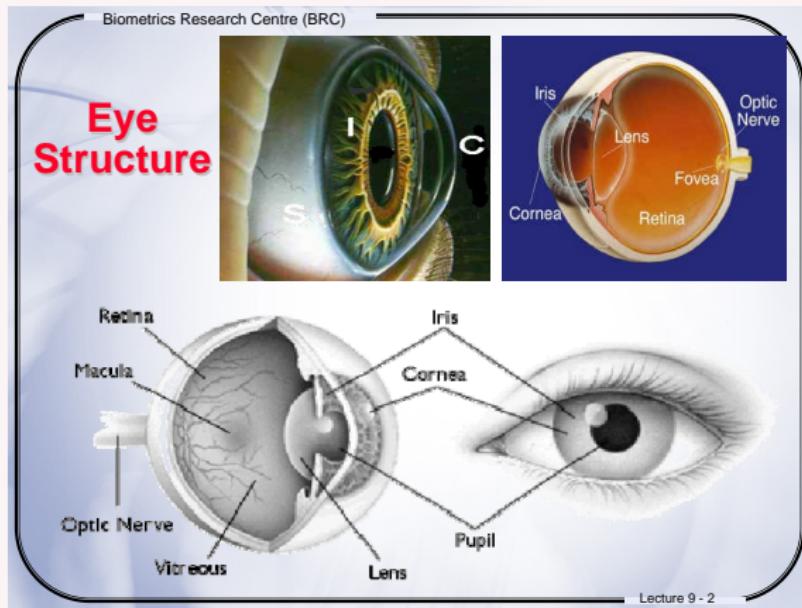


Problem 1.1 Compare Retina and Iris

Please compare two different kinds of biometrics technologies: Retina and Iris. (P9:2-3)



Problem 1.1 Compare Retina and Iris





Problem 1.1 Compare Retina and Iris

Eye Signature: Retina & Iris

The diagram illustrates the internal structure of the eye with numbered labels:

- 1 Eyelid
- 2 Iris
- 3 Pupil
- 4 Cornea
- 5 Sclera
- 6 Lens
- 7 Macula
- 8 Vitreous Humor
- 9 Fovea
- 10 Optic Nerve
- 11 Choroid
- 12 Retina
- 14 Extraocular Muscles
- 15 Visual Pathways of the Brain

Anatomy of the Eye

This detailed diagram shows the internal components of the eye:

- Anterior chamber (Space between the cornea and iris)
- Iris
- Cornea
- Lens
- Pupil
- Posterior chamber (Space behind the iris)
- Optic Nerve
- Retina
- Macula
- Retinal blood vessels
- Vitreous body
- Ciliary body and ciliary muscle
- Conjunctiva

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Iris: An annular region between the pupil and the white sclera.

Retina: Blood vessels at the back of the eye.

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Problem 1.1 Compare Retina and Iris

- Differences

- Location: inner round region for Retina, outer annular region for Iris.
- Sensor: fundus camera is very expensive and large; general cameras or industrial camera would be fine for the Iris recognition.
- Features: geometries for Retina and texture for Iris.
- Extraction method: Syntactic based features for Retina and Statistical based features for Iris.
- Performance: Iris is much better than Retina.





Problem 1.2 Two Kinds of Features

There are two kinds of features, Physical feature (Vessels and Optic Disk) and Pathological feature (Red lesion and Bright lesion), in Retina. Please understand how to extract them (P9:7-11).

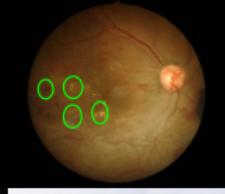


Problem 1.2 Two Kinds of Features

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Major Retinal Features

- Physical features
 - ◆ Vessels: Blood transfer;
 - ◆ Optic Disk: The nerves of eye connected to brain;
 - The deformation of vessels can be a sign of some diseases such as hypertension and diabetes. The optic disk is used to describe the position of the deformation.
- Pathological features
 - ◆ Red Lesion
 - ◆ Bright Lesion
 - Red lesion and bright lesion on the retina are signs of some diseases, such as hypertension and diabetes



A healthy retina and an unhealthy retina.

Lecture 9 - 7



Problem 1.2 Two Kinds of Features

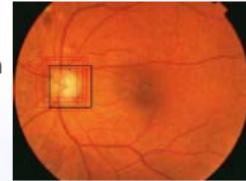
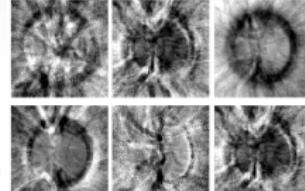
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How to extract Optic Disk?

PCA-based Method

- 1) Some optic disks of the images are manually cut to obtain the training data.
- 2) The eigen vectors of the covariance matrix of the training data can be calculated, which may be named as eigen optic discs.
- 3) A square window is moved iteratively on the retinal image. The sub-image inside the square window is projected onto the optic disc space and the reconstruction error is calculated. The sub-image with the minimum reconstruction error will be classified as the optic disk.

The first 6 Eigen vectors



Lecture 9 - 8



Problem 1.2 Two Kinds of Features

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How to extract Vessels?

Matched Filter

-- Because the cross-section of vessel is approximate to Gaussian, a filter with shape of Gaussian can be used to match the vessel,

$$g(x,y) = -\exp(-x^2/\sigma^2) - m, \text{ for } |x| \leq 3\sigma, |y| \leq L/2$$

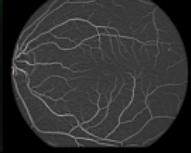
where σ represents the scale of the filter; $m = -\left(\int_{-3\sigma}^{3\sigma} \exp(-x^2/\sigma^2) dx\right)/6\sigma$ is used to normalize the mean value of the filter to 0 so that the smooth background can be removed



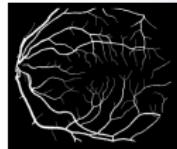
The matched filters in 3 scales and 8 directions



A Retinal Image



Matched filter response



Hand-labeled ground truth



Extraction result by matched filter

Lecture 9 - 9



Problem 1.2 Two Kinds of Features

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How to extract Bright Lesions?

Morphological Method

- 1) A morphological closing is used to erase all vessels;
- 2) The local variation is calculated to find the bright lesion boundary, the local variation is defined as: $e_2(x) = \frac{1}{N-1} \cdot \sum_{\xi \in W(x)} (e_1(\xi) - \mu_{e_1}(x))^2$. where W is the local window, and μ is the mean.
- 3) The local variation is thresholded.

A retinal image

Closing

Local variation

Thresholding the local variation to obtain bright lesion candidates

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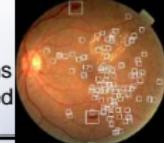
Problem 1.2 Two Kinds of Features

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How to extract Red Lesions?

SVM based Method

- 1) Some red lesions of the images are manually cut to obtain the red lesion feature.
- 2) The eigen vectors of the covariance matrix of the training data are calculated to reduce the feature dimension.

The first 10 Eigen vectors (Eigen redLesions)
- 3) SVM evidence is calculated and the optimal separating hyperplane is defined as $f(x) = \text{sgn} \left(\sum_{i=1}^l y_i \alpha_i K(x_i, x) + b \right)$ 



Problem 1.2 Two Kinds of Features

- Physical features
 - PCA based matching method to extract the region for the optic disk
 - Gaussian filters based line extraction for the vessels
- Pathological features
 - Morphological method for the bright lesions
 - SVM based method for the red lesions





Problem 1.3 Example of Verification System

*P9:20 show a representative example of identification system.
Please give another example of verification system.*



Problem 1.3 Example of Verification System

Biometrics Research Centre (BRC)

Iris Process Overview

Eye Sensor → Segmentation → Feature Extraction

Binomial Distribution of IrisCode Hamming Distances

Principle : Failure of a test of statistical Independence

Binary decision: Accept/ reject

Hits or false alarm (FA); very low standard deviation high probability of FA; high degree of freedom results in low FA

Hits or false alarm (FA); very low standard deviation high probability of FA; high degree of freedom results in low FA

Count

9,060,000 different iris samples

mean = 0.499, std.dev. = 0.0317
min = 0.334, max = 0.664

Hamming Distance

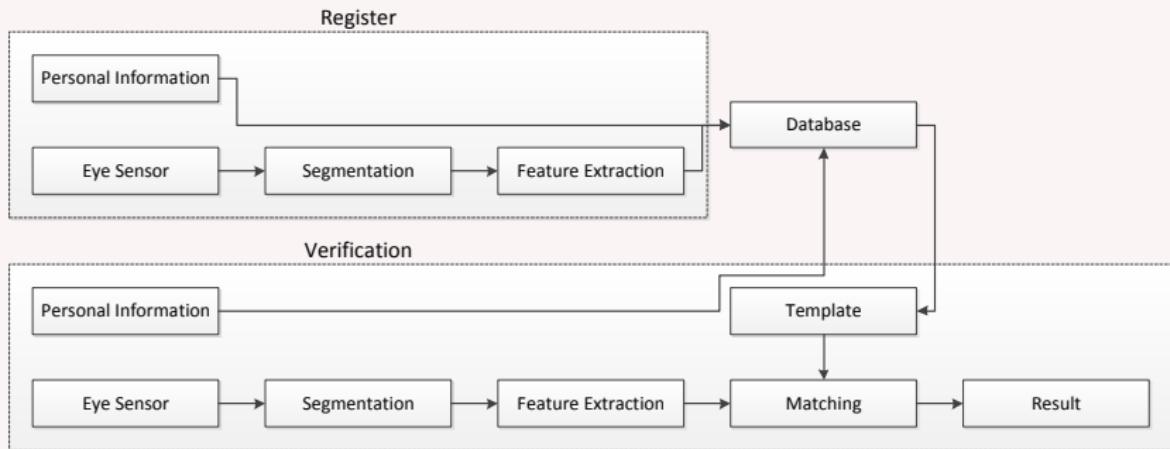
Legend: mera takes a outer boundaries entrance organ form, color and general texture, the iris texture stochastic or possibly

Lecture 9 - 20

The diagram illustrates the Iris Process Overview. It starts with an 'Eye Sensor' leading to 'Segmentation' and then 'Feature Extraction'. Below this, a histogram shows the 'Binomial Distribution of IrisCode Hamming Distances' with a mean of 0.499 and a standard deviation of 0.0317. A legend on the right describes various iris characteristics: 'outer boundaries', 'entrance organ', 'form, color and general texture', and 'stochastic or possibly'. At the bottom, a note states 'Hits or false alarm (FA); very low standard deviation high probability of FA; high degree of freedom results in low FA'.



Problem 1.3 Example of Verification System



Personal information: name, ID, smart card, etc. □



Problem 1.4 Iris Recognition System

Please understand the iris recognition system. (P9: 24-38)



Problem 1.4 Iris Recognition System

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Evaluation & Selection of Iris Image

The image shows four panels of a human eye, each with a blue rectangular frame around the iris area. The first panel is labeled 'Clear Image' and shows a sharp, clear iris. The second panel is labeled 'Unfocused Image' and shows a blurry iris. The third panel is labeled 'Movement Blur' and shows a distorted iris due to motion. The fourth panel is labeled 'Covered Image' and shows a dark iris where the pupil is completely covered by a white rectangular mask.

Clear Image Unfocused Image Movement Blur Covered Image

It is necessary to evaluate the quality of iris image.

- Daugman: Estimate High Frequency Energy of Fourier Transform of Iris Image
- Zhang: Detect the Degree of Changing between Pupil and Edge of Iris

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Problem 1.4 Iris Recognition System

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Evaluation & Selection of Iris Image

The Characteristic Analysis of Iris Image

Clear Image Unfocused Image Movement Blur Covered Image

The Flowchart of Quality Evaluation

```
graph LR
    Eye[Eye Image] --> CoarseLocation[粗定位  
Location]
    CoarseLocation --> FourierTransform[计算傅立叶变换  
Transform]
    FourierTransform --> Descriptors[计算质量描述子  
Calculation]
    Descriptors --> SVM[基于SVM的决策  
Decision]
    SVM --> Result[判断结果  
Result]
```

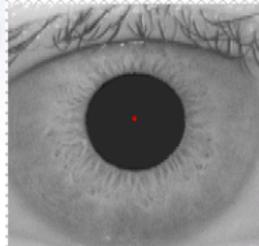
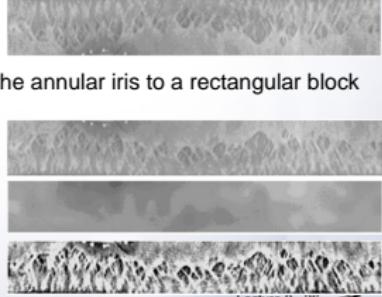
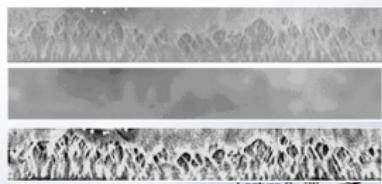
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Problem 1.4 Iris Recognition System

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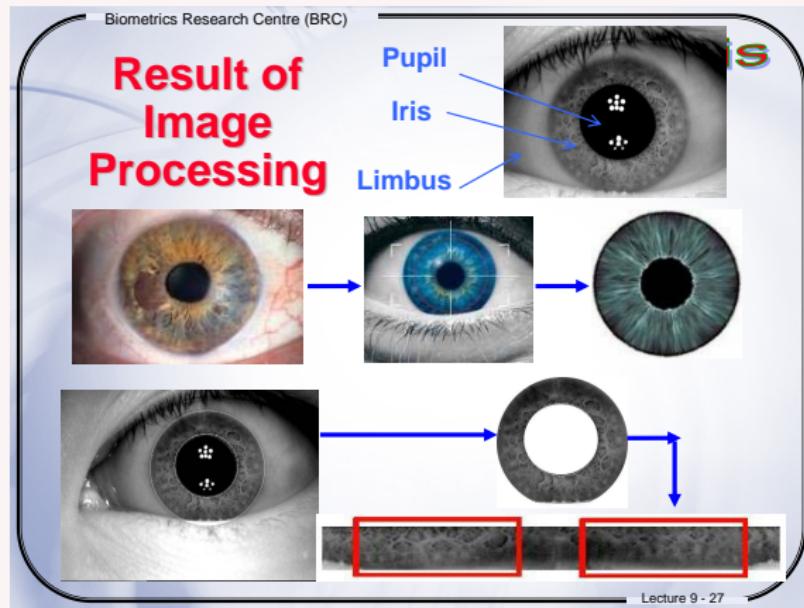
Iris Image Processing

- Localization
 - ◆ Find centroid by x and y transforms
 - ◆ Binarize the image and estimate the radius of pupil
 - ◆ Approximate the radius of iris by some image processing techniques
- Normalization
- Enhancement
 - ◆ Mean of 16 x 16 Block
 - ◆ Bicubic Interpolation
 - ◆ Subtract from original image

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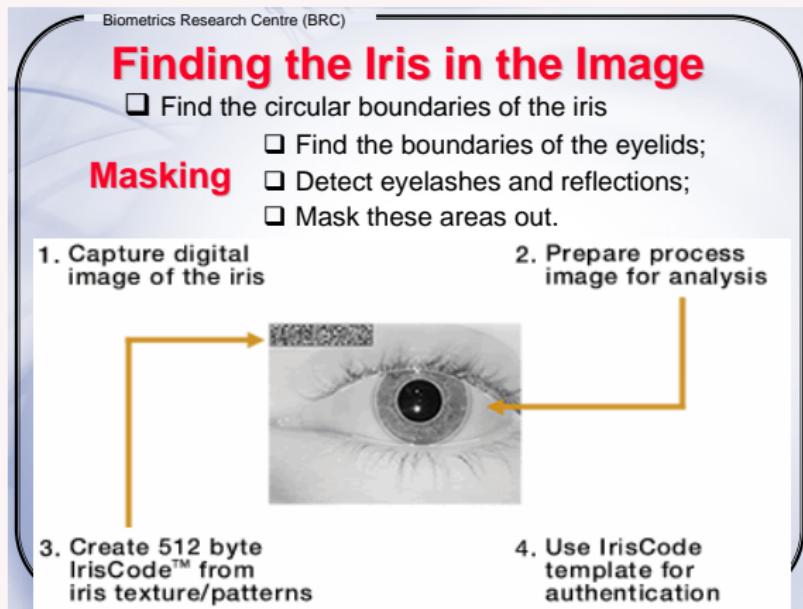


Problem 1.4 Iris Recognition System





Problem 1.4 Iris Recognition System





Problem 1.4 Iris Recognition System

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Iris Structures

Stream Iris Structure

Flower Iris Structure

Jewe Iris Structure

Shaker Iris Structure

Lecture 9 - 29

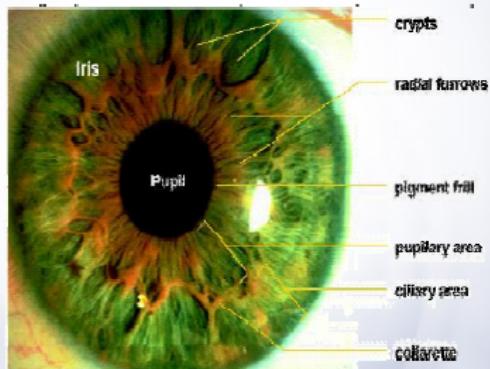


Problem 1.4 Iris Recognition System

Biometrics Research Centre (BRC)

Iris Feature

- ❑ A primary characteristic is the trabecula meshwork, a tissue that gives the appearance of dividing the iris in a radial fashion.
- ❑ Other visible characteristics include rings, furrows, freckles, and the corona.



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Problem 1.4 Iris Recognition System

Biometrics Research Centre (BRC)

Overview: Daugman's Approach

1. search for the boundary of iris
2. divide into 8 sectors without regards of iris and pupil size
3. create 512 Byte Iriscode
4. compare to IrisCode in DB

- ◆ J. Daugman, "High confidence visual recognition of persons by a test of statistical independence", *IEEE Transactions on Pattern Analysis and Machine Intelligence*, vol. 15, no. 11, pp. 1148-1161, 1993.
- ◆ J. Daugman, "Biometric personal identification system based on iris analysis," U.S. Patent No 5,291,560, 1994.

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Problem 1.4 Iris Recognition System

Biometrics Research Centre (BRC)

Gabor Wavelets

Figure 3.29. A graphical representation of a bank of 24 ($n_o = 8$ and $n_f = 3$) Gabor filters where $\sigma_x = \sigma_y = 4$.

- ❑ Gabor Wavelets filter out structures at different scales and orientations
- ❑ For each scale and orientation there is a pair of odd and even wavelets
- ❑ A scalar product is carried out between the wavelet and the image (just as in the Discrete Fourier Transform)
- ❑ The result is a complex number

Lecture 9 - 32



Problem 1.4 Iris Recognition System

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Phase Demodulation

- ❑ The complex number is converted to 2 bits
- ❑ The modulus is thrown away because it is sensitive to illumination intensity
- ❑ The phase is converted to 2 bits depending on which quadrant it is in

Phase-Quadrant Demodulation Code

Figure 2: The phase demodulation process used to encode iris patterns. Local regions of an iris are projected (Eqn 2) onto quadrature 2D Gabor wavelets, generating complex-valued coefficients whose real and imaginary parts specify the coordinates of a phasor in the complex plane. The angle of each phasor is quantized to one of the four quadrants, setting two bits of phase information. This process is repeated all across the iris with many wavelet sizes, frequencies, and orientations, to extract 2,048 bits.

LECTURE 9 - 33



Problem 1.4 Iris Recognition System

Biometrics Research Centre (BRC)

- This process is carried out at a number of points throughout the image.
- The result is 2,048 bits which describe each iris uniquely
- Two codes from different irises can be compared by finding the number of bits different between them – this is called the Hamming distance
- This is equivalent to computing an XOR between the two codes. This can be done very quickly
- To allow for rotation of the iris images the codes can be shifted with respect to each other and the minimum Hamming distance found

IrisCodes

Pictorial Examples of four IrisCodes



```
0100101010111010101011101010101101000010  
100101010101010101010101010101011101010  
001010101000100100000010101011101011110  
10101011010011010101010111011101010010101  
11010101011110101010111010101010101010101  
010101010101110111101111010101000010110
```

Lecture 9 - 34



Problem 1.4 Iris Recognition System



Problem 1.4 Iris Recognition System

Binomial Distribution

- ❑ If two codes come from different irises the different bits will be random
- ❑ The number of different bits will obey a binomial distribution with mean 0.5

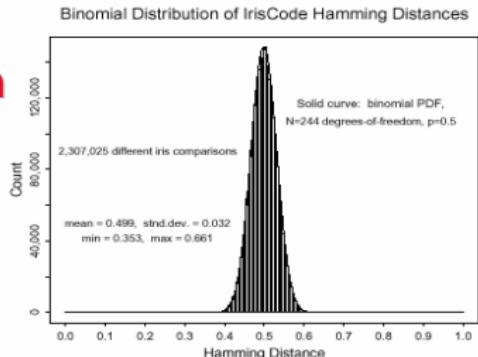


Figure 4: Distribution of Hamming Distances from all 2.3 million possible comparisons between different pairs of irises in the database. The histogram forms a perfect binomial distribution with $p = 0.5$ and $N = 244$ degrees-of-freedom, as shown by the solid curve (Eqn 4). The data implies that it is extremely improbable for two different irises to disagree in less than about a third of their phase information.



Problem 1.4 Iris Recognition System

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- If two codes come from the same iris the differences will no longer be random
- The Hamming distance will be less than expected than if the differences were random
- If the Hamming distance is < 0.33 the chances of the two codes coming from different irises is 1 in 2.9 million
- So far it has been tried out on 2.3 million people without a single error

Identification

probability

Hamming distance

same

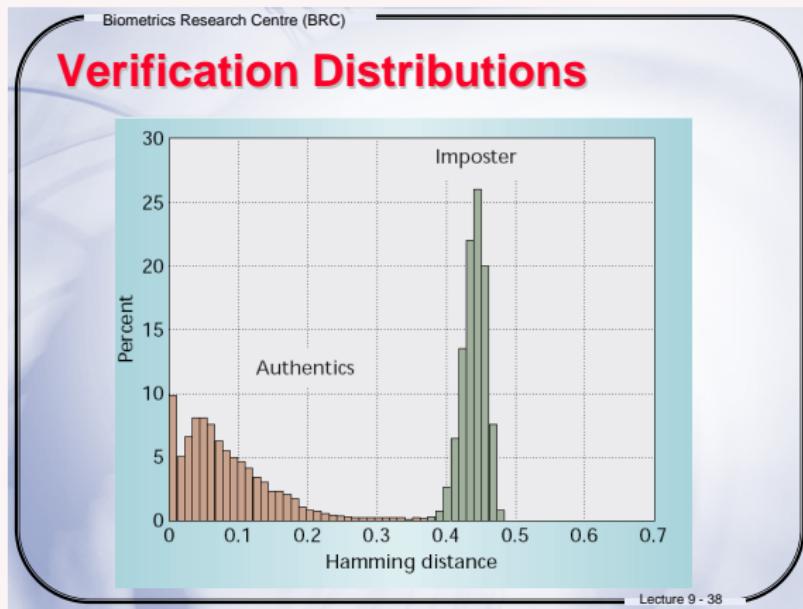
different

10^{-53} 10^{-29} 10^{-14} 10^{-5}

Lecture 9 - 37



Problem 1.4 Iris Recognition System





Problem 1.4 Iris Recognition System

- procedures
 - Evaluation of images
 - Processing of images
 - Locating the Iris
 - Feature extraction (Daugman's approach)
 - Dividing the Iris to eight sectors
 - Gabor wavelets filters to extract features
 - Coding by the output of the phase demodulation result
 - Encoding to IrisCodes
 - Matching by Hamming distances
 - The distribution of the Codes
 - Identifying by threshold
 - Or verifying





Problem 1.5 Texture Feature

What is texture feature (P6:18)? Why we can use texture feature in iris recognition (P9:30)?



Problem 1.5 Texture Feature

Feature Extraction in StatPR

- What features can we extract?



- But, sometimes it is difficult

As an example: Texture feature –

Surfaces characterized by more or less regular aggregates of similar patterns.



Irregular Texture Pattern in iris image



Figure 6 - 18

→ One solution: Frequency filters

Biometric Authentication

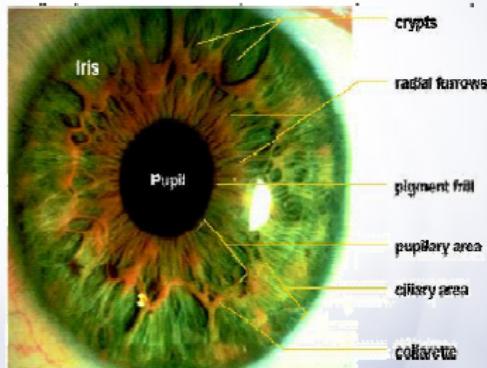


Problem 1.5 Texture Feature

Biometrics Research Centre (BRC)

Iris Feature

- ❑ A primary characteristic is the trabecula meshwork, a tissue that gives the appearance of dividing the iris in a radial fashion.
- ❑ Other visible characteristics include rings, furrows, freckles, and the corona.



Lecture 9 - 30



Problem 1.5 Texture Feature

- Texture features
 - Repeating similar patterns
- Texture features in Iris
 - Trabecula meshwork is a kind of texture in a radial distribution.





Outline

1 Problems

- Problem 1: Answer The Questions
- **Problem 2: Daugman's Method**
- Problem 3: Separating IrisCodes
- Problem 4: Fourier Transforms of Irises
- Problem 5: Another pattern of Iris



Problem 2: Daugman's Method

There are four steps in the Daugman's approach (P9:31-35). The third step generates IrisCode with 512 bytes. If 2 bits represent a feature, please compute the total number of features.



Problem 2: Daugman's Method

Biometrics Research Centre (BRC)

Overview: Daugman's Approach

1. search for the boundary of iris
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Problem 2: Daugman's Method

Biometrics Research Centre (BRC)

Gabor Wavelets

Figure 3.29. A graphical representation of a bank of 24 ($n_o = 8$ and $n_f = 3$) Gabor filters where $\sigma_x = \sigma_y = 4$.

- ❑ Gabor Wavelets filter out structures at different scales and orientations
- ❑ For each scale and orientation there is a pair of odd and even wavelets
- ❑ A scalar product is carried out between the wavelet and the image (just as in the Discrete Fourier Transform)
- ❑ The result is a complex number

Lecture 9 - 32



Problem 2: Daugman's Method

Biometrics Research Centre (BRC)

Phase Demodulation

- ❑ The complex number is converted to 2 bits
- ❑ The modulus is thrown away because it is sensitive to illumination intensity
- ❑ The phase is converted to 2 bits depending on which quadrant it is in

Phase-Quadrant Demodulation Code

Figure 2: The phase demodulation process used to encode iris patterns. Local regions of an iris are projected (Eqn 2) onto quadrature 2D Gabor wavelets, generating complex-valued coefficients whose real and imaginary parts specify the coordinates of a phasor in the complex plane. The angle of each phasor is quantized to one of the four quadrants, setting two bits of phase information. This process is repeated all across the iris with many wavelet sizes, frequencies, and orientations, to extract 2,048 bits.

LECTURE 9 - 33



Problem 2: Daugman's Method

Biometrics Research Centre (BRC)

- This process is carried out at a number of points throughout the image.
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- This is equivalent to computing an XOR between the two codes. This can be done very quickly
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IrisCodes

Pictorial Examples of four IrisCodes



```
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10010101010101010101010101011101010  
00101010100010010000001010101110101110  
101010110100110101010101110111010010101  
1101010101110101010111010101010101010101  
01010101011101110111101010101000010110
```

Lecture 9 - 34



Problem 2: Daugman's Method



Problem 2: Daugman's Method

- The IrisCode is 512 bytes
- then total bits is 512×8 bits
- and two bits represent one feature
- so the total number of features should be $\frac{512 \times 8}{2} = 2048$

□



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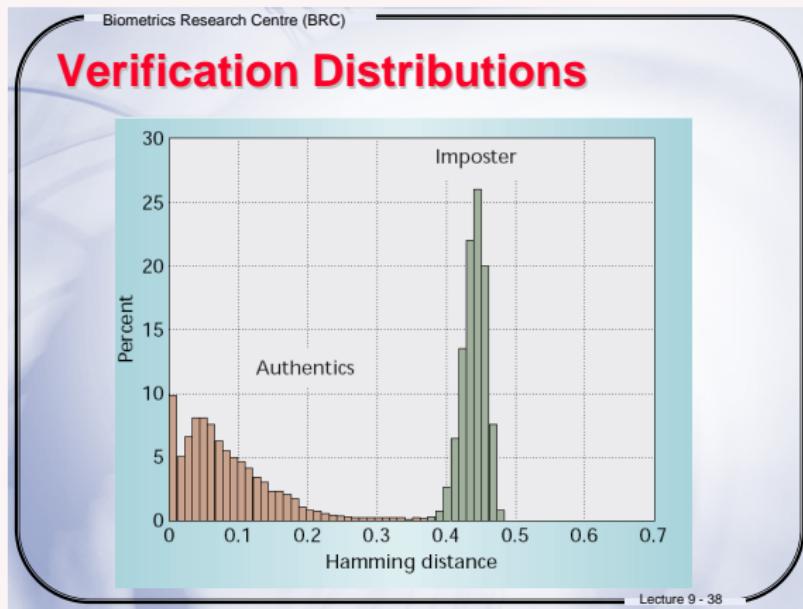


Problem 3: Separating IrisCodes

In P9:38, an example of iris verification distributions is given. Notice that Hamming distance is defined to measure the dissimilarity of two IrisCodes. Which value in the figure can separate two parts, authentics and imposters? If the dissimilarity between two IrisCodes is taken as 0.5, can you say they are identical? How about the comparison result when the dissimilarity is 0.2? What conclusion will you get from the hamming distance used to compute dissimilarity of IrisCodes?



Problem 3: Separating IrisCodes



The threshold should be 0.38. Hamming distance of 0.5 should not be from the same eye and 0.2 should.



Problem 3: Separating IrisCodes

- Hamming distance
 - The larger the hamming distance, the further two candidates separate away.
 - Imposters tend to be larger the hamming distance; the authentics tend to be smaller.





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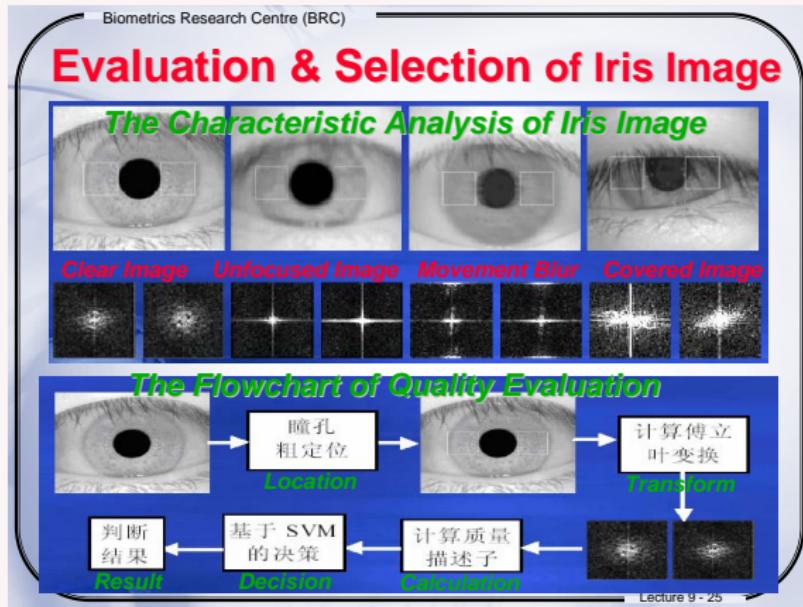


Problem 4: Fourier Transforms of Irises

P9:25 shows the corresponding Fourier transforms of iris images with different quality. Please give the property of Fourier transform of good quality iris images.



Problem 4: Fourier Transforms of Irises



The distribution should be even.





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- **Problem 5: Another pattern of Iris**



Problem 5: Another pattern of Iris

In Daugman's approach iris is regarded as a circular pattern (P9:31-34). In fact we can also take the iris as other pattern, as shown in P9:27. Please try to design the corresponding scheme.



Problem 5: Another pattern of Iris

Biometrics Research Centre (BRC)

Overview: Daugman's Approach

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Problem 5: Another pattern of Iris

Biometrics Research Centre (BRC)

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Problem 5: Another pattern of Iris

Biometrics Research Centre (BRC)

Phase Demodulation

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LECTURE 9 - 33



Problem 5: Another pattern of Iris

Biometrics Research Centre (BRC)

- This process is carried out at a number of points throughout the image.
- The result is 2,048 bits which describe each iris uniquely
- Two codes from different irises can be compared by finding the number of bits different between them – this is called the Hamming distance
- This is equivalent to computing an XOR between the two codes. This can be done very quickly
- To allow for rotation of the iris images the codes can be shifted with respect to each other and the minimum Hamming distance found

IrisCodes

Pictorial Examples of four IrisCodes

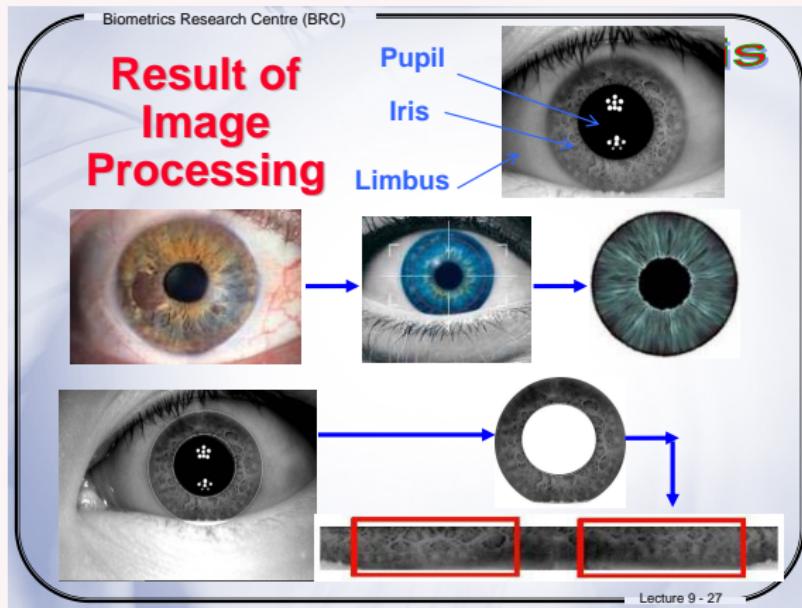


```
01001010111010101110101010110100010  
10010101010101010101010101011101010  
00101010100010010000001010101110101110  
101010110100110101010101110111010010101  
1101010101110101010111010101010101010101  
01010101011101110111101010101000010110
```

Lecture 9 - 34



Problem 5: Another pattern of Iris





Problem 5: Another pattern of Iris

• Scheme

- Generally the procedure should be the same
- Instead of eight annular sectors, we divide the Iris to eight bar-like sectors
- and other procedures should be the same
- To divide the iris to eight sectors, to use Gabor filters to encode the image to IrisCode, then to match the IrisCode by Hamming distances.

• Advantages

- Horizontal localization error could be adjusted along the horizontal direction.

• Disadvantages

- The spreading-out of the image will take in more noises or even fake patterns.

Q & A



Any questions?