UNIVERSITY IN NIŠ

FACULTY OF ELECTRONIC ENGINEERING

SEMINAR

Recognition of human Iris Patterns for Biometric Identification

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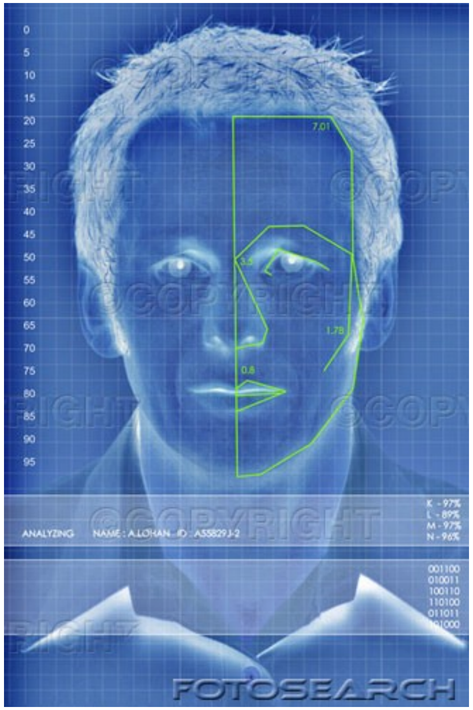
Abstract

- A **Biometric system** provides automatic identification of an individual, based on a unique possessed feature or characteristic.
- **Iris recognition** is regarded as the most reliable and accurate biometric system available.
- **Developing an iris recognition system** in order to verify both the uniqueness of the human iris and its performance as a biometric.

Biometric technology

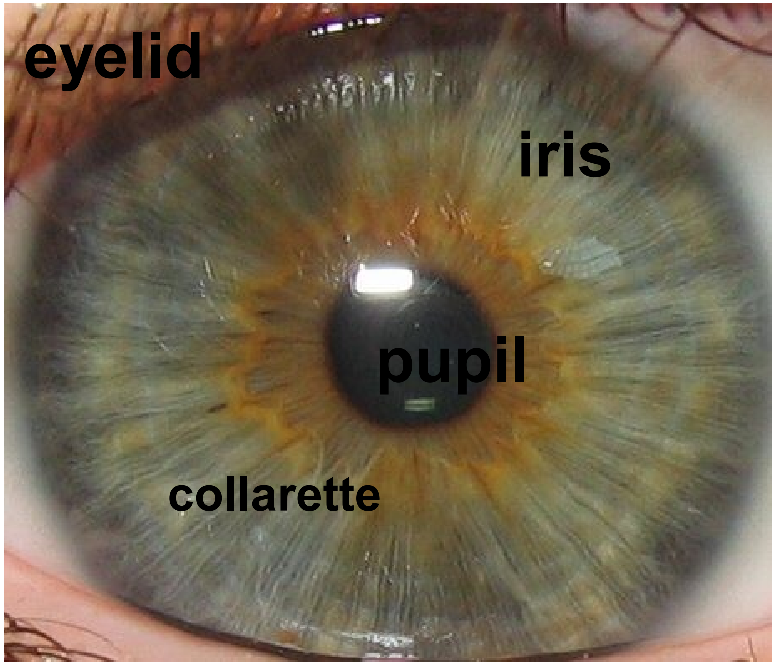
- <u>How does a biometric system work?</u>
  1) **Capturing** a sample of the feature
  2) **Transformation** into a biometric template
  3) **Comparison** with other templates.
- <u>Modes of operation:</u> - **enrolment**

  - **identification.**
- <u>A good biometric is:</u>
  - ➢ **highly unique**
  - ➢ **stable**
  - ➢ **easily captured**



The Human Iris

- **The iris** is a thin circular diaphragm, lying between the cornea and the lens.
- Function: **controlling the amount of light** entering through the pupil.
- Average diameter: **12 mm**.
- Consisting of a number of layers:
  - **epithelium** – dense pigmentation cells
  - **stromal** – blood vessels, muscles
  - **external** – ciliary & inner pupilary zone.
- The probability of two individuals having identical iris patterns is 1 : 10^{78}.

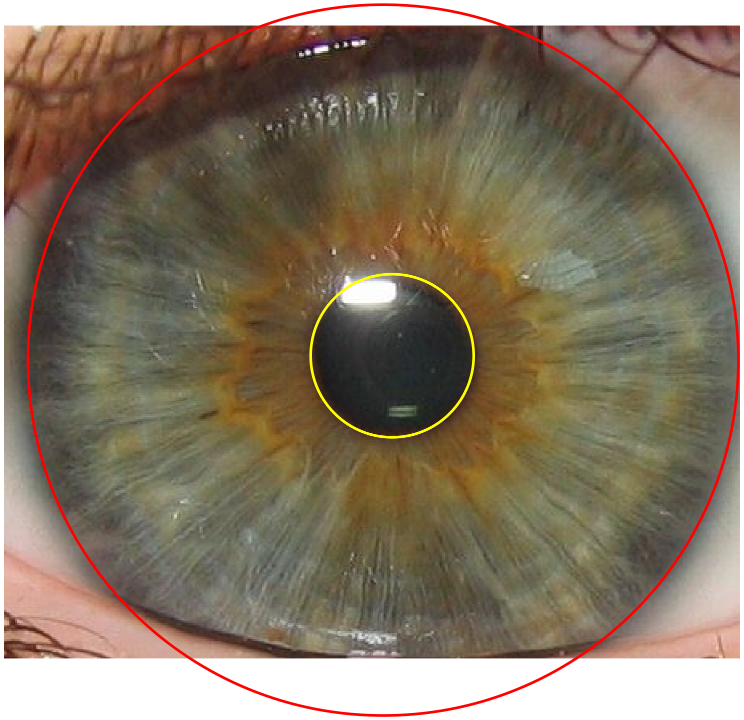


Iris Recognition

- Characteristics of the iris make it very attractive for use as a biometric.
- **The unique iris pattern** from a digitised image of the eye is encoded **into a biometric template**, and then stored in a database.
- A Biometric template contains an **objective mathematical representation** of the unique information stored in the iris and allows **comparisons between templates**.
- **John Daugman** patented and implemented a first working, automated iris recognition system.

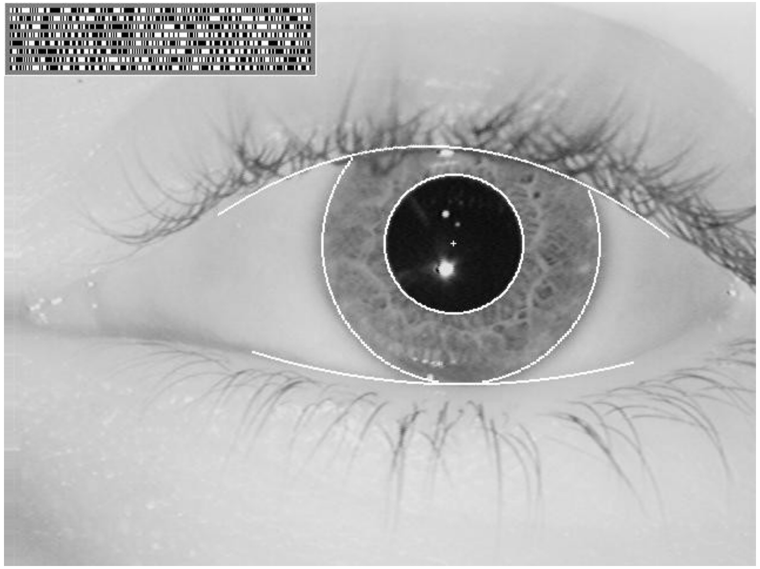
Segmentation

- The **first stage** of iris recognition is to isolate the actual iris region in a digital eye image.
- **The iris region** can be approximated by two circles.
- Occluding issue: **eyelids and eyelashes**.
- Corrupting issue: **Specular Reflection (SR)**
- A successful segmentation depends on the imaging quality of eye images. It is a stage critical to the success of a system.
- For achieving better results, a **close IR light** is used for illumination.



Hough transform

- A standard **computer vision algorithm** used to determine the parameters of simple geometric objects (lines, circles, etc.) presented in an image.
- **Circular Hough transform** is employed to deduce the radius and centre coordinates of the pupil and iris regions.
- An **edge map** is generated by calculating the first derivatives of intensity values and then thresholding the result.
- *Problems:*
  - threshold values are required to be chosen
  - computationally intensive

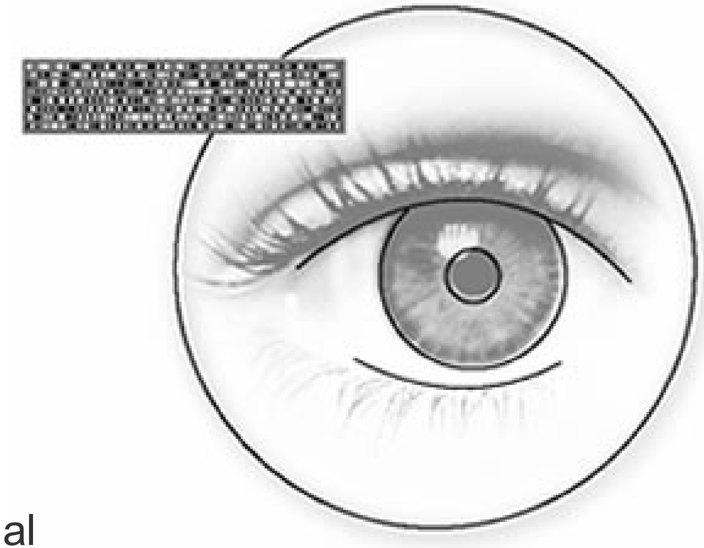


Other methods

- **Daugman's integro-differential operator:**

$$\max_{(r,x_p,y_0)} \left| G_\sigma(r) * \frac{\partial}{\partial r} \oint_{r,x_0,y_0} \frac{I(x,y)}{2\pi r} ds \right|$$

The operator searches for the circular path with maximum change in pixel values, by varying the r, x_0, y_0 position of the circular contour.



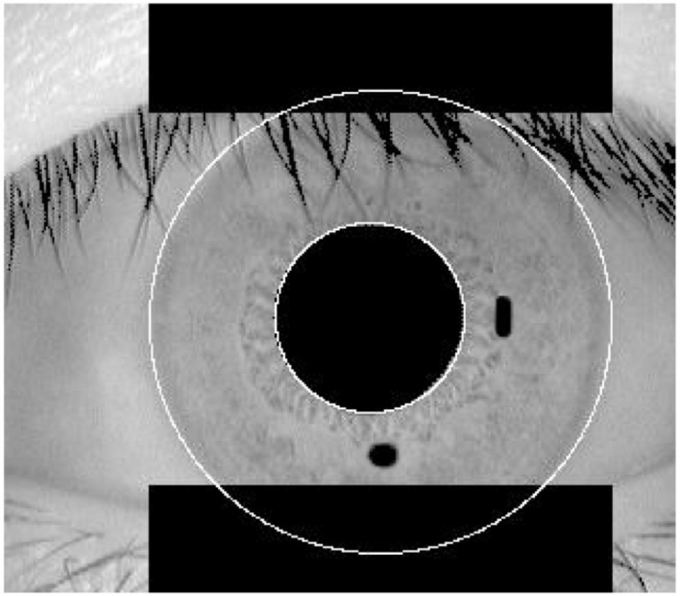
- **Active Contour Models:**

The contour contains a number or vertices, whose positions are changed by two oposing forces: internal (desired characteristics) and external (image).

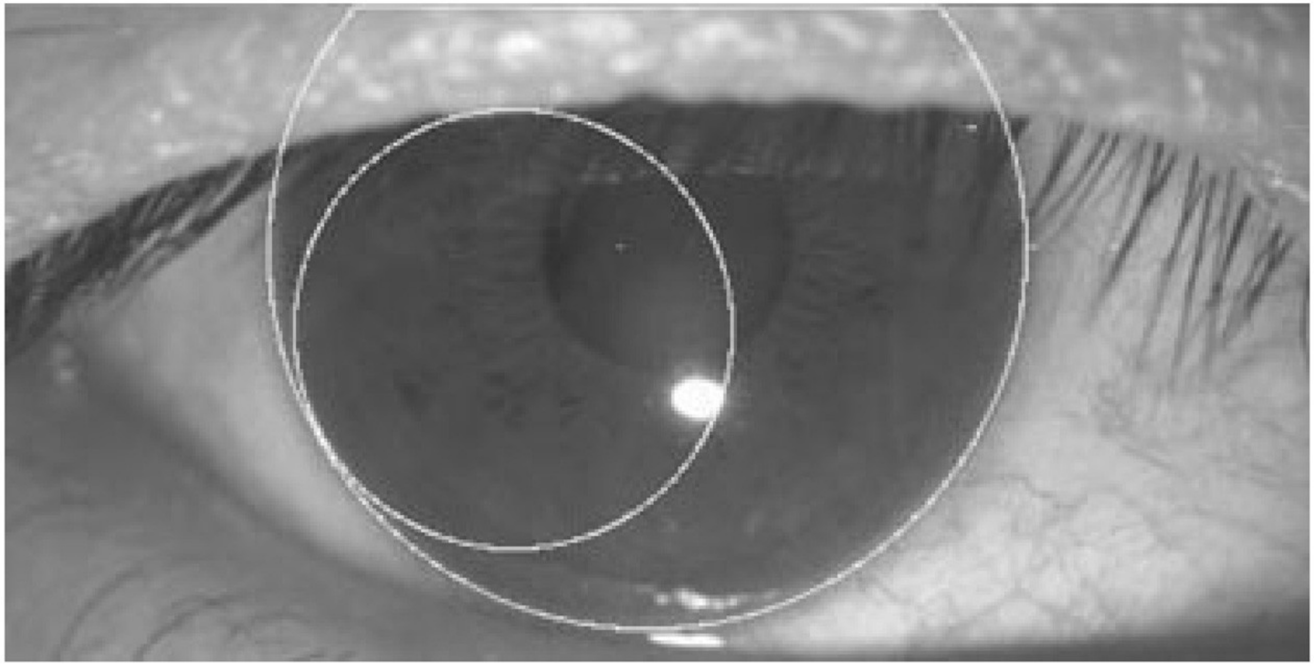
$$v_i(t+1) = v_i(t) + F_i(t) + G_i(t)$$

Eyelash and Noise Detection

- <u>**Eyelashes**</u>:
  - **separable**
  - **multiple**
- **Reflektujući odraz (SR)**:
  - detected using thresholding.
- **Problems**:
  - isolation of occluding eyelid regions.
  - areas with light eyelashes (tips).

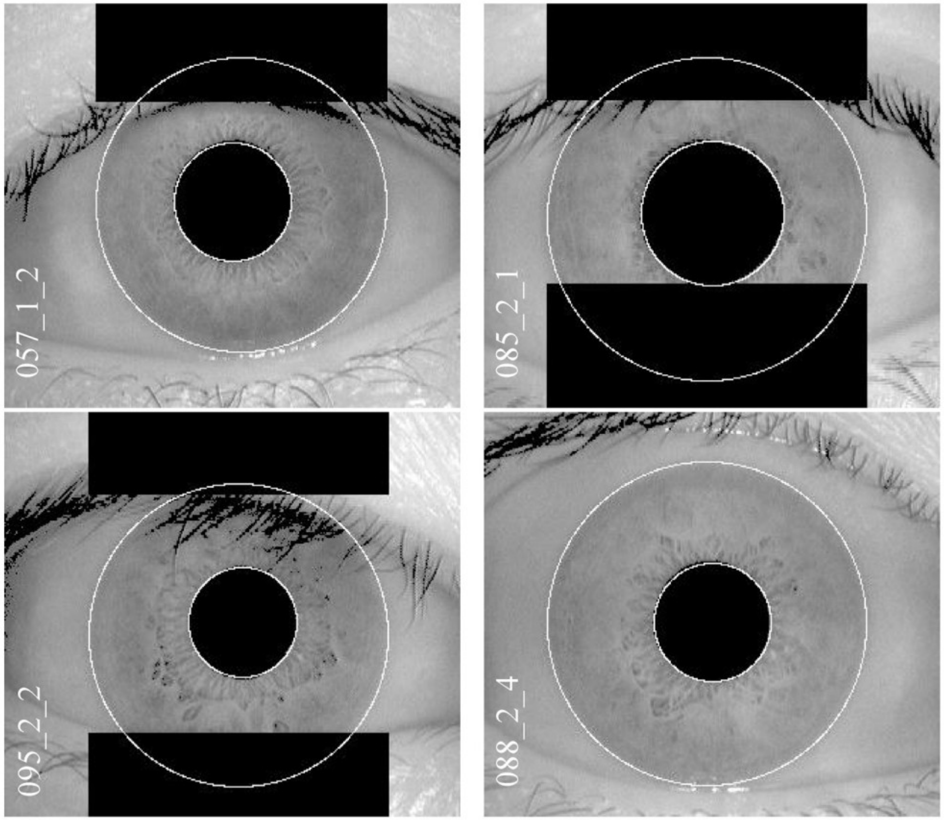


Eyelash and Noise Detection



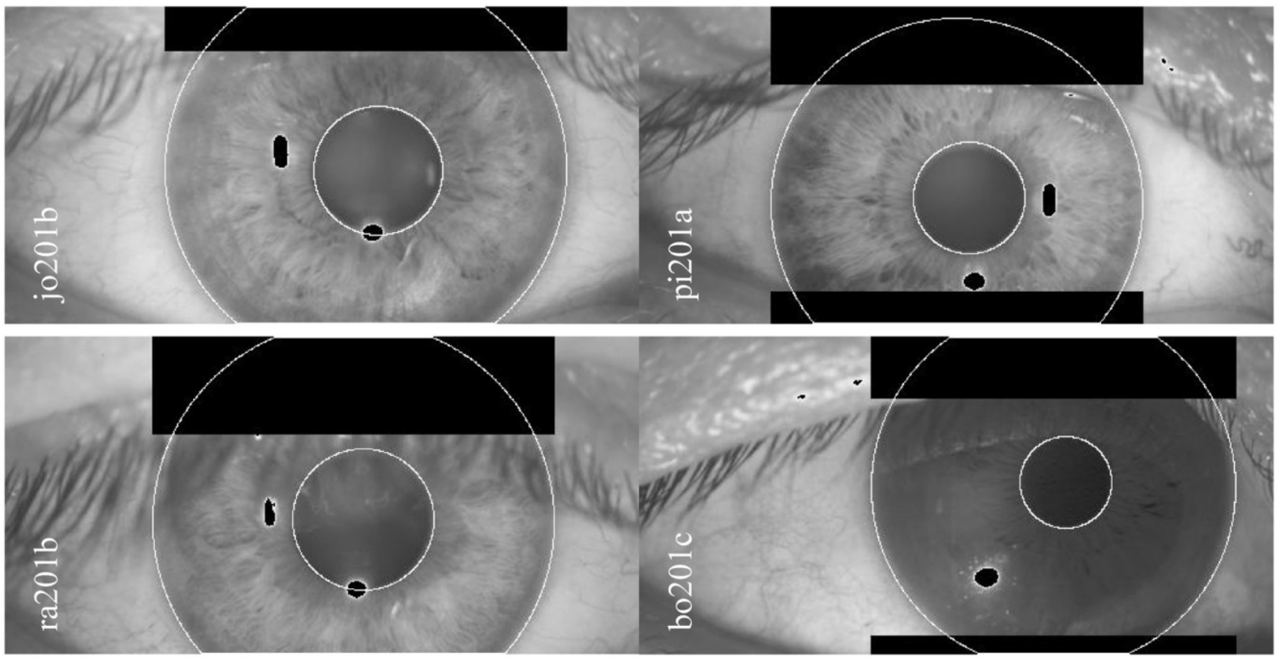
An example of segmentation failure
(LEI)

Implementation



CASIA database

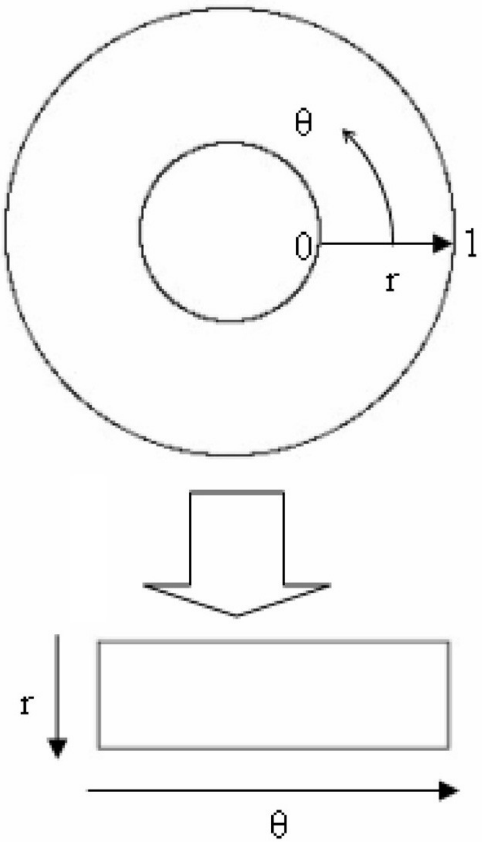
Implementation



LEI database

Normalisation

- Transformation of the iris region to **fixed dimensions** in order to allow comparisons.
- Dimensional **inconsistencies** occur mainly due to streching of the iris caused by pupil dilation.
- *Other*: - varying imaging distance,
  - camera rotation,
  - head tilt, etc.
- The pupil region is not always concentric within the iris region!
- When the pupil radius changes, the iris linearly streches like a rubber band.

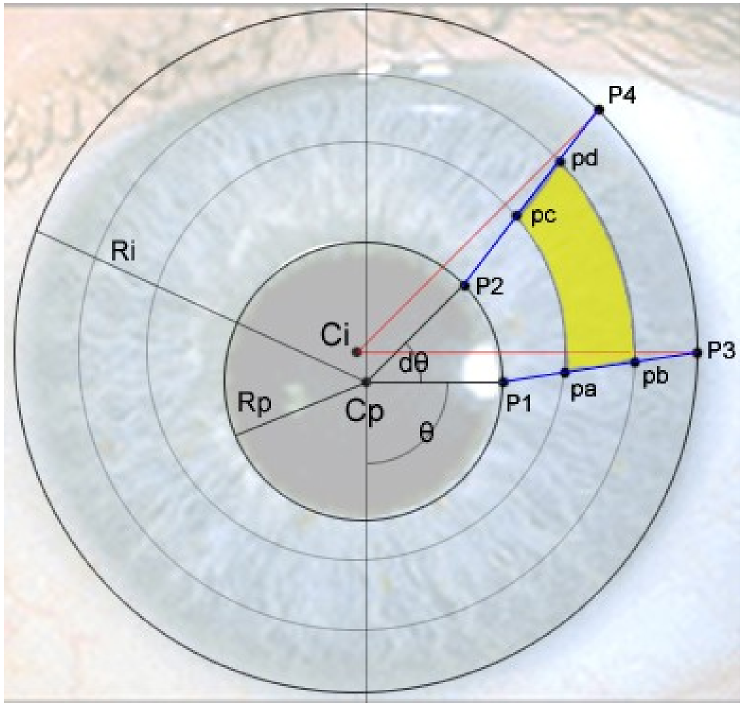


Iris unwrapping algorithm

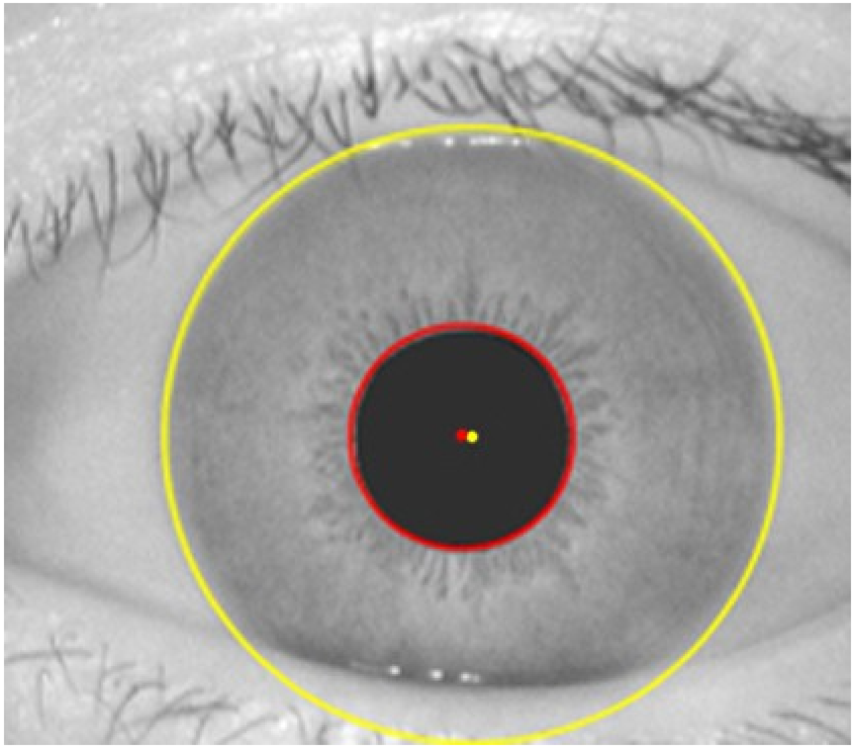
- C_p i C_i – detected centers of the pupil and iris.
- R_p i R_i – their radii, respectively .
- By extending a wedge of angle *dθ* from both points with the radii, the intersection points with the pupil and iris circles form a skewed wedge polygon ($P_1P_2P_3P_4$).
- The skewed wedge is subdivided radially into N blocks and the image pixel values in each are averaged to form a **pixel (*j*,*k*)** in the unwrapped iris image, where:

  j – current **angle** number

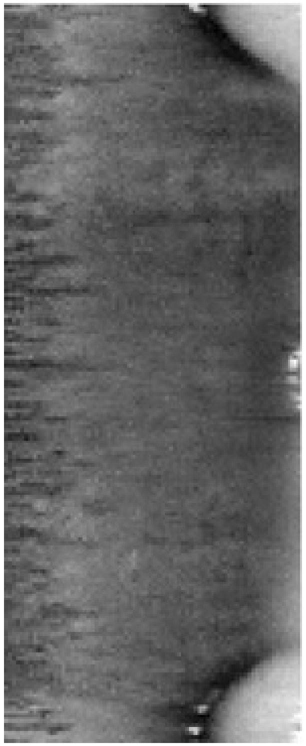
  r – current **radius** number



Masking of Extraneous Regions



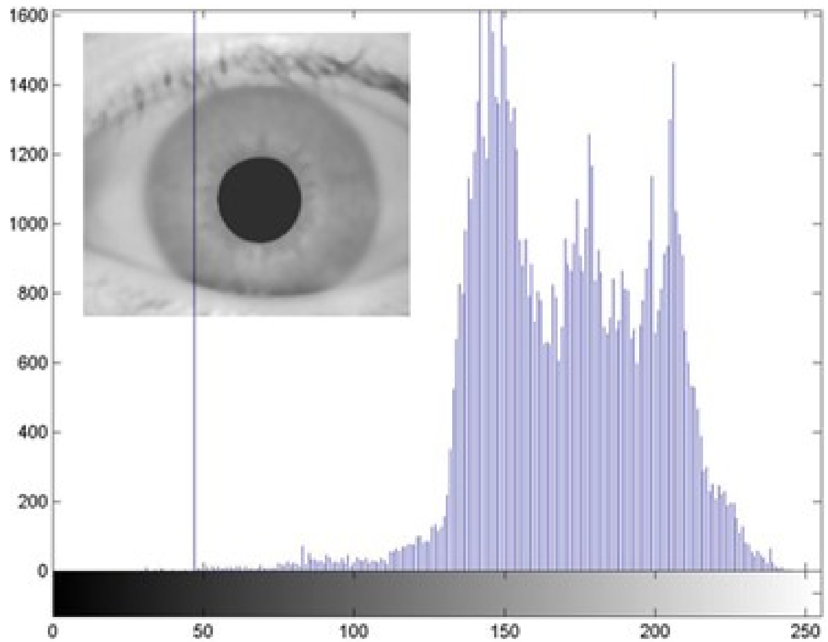
Detected iris and pupil circles



180 angle and 73 radius divisions

120 angle and 8 radius divisions

Contrast adjustment



Poor contrasted image

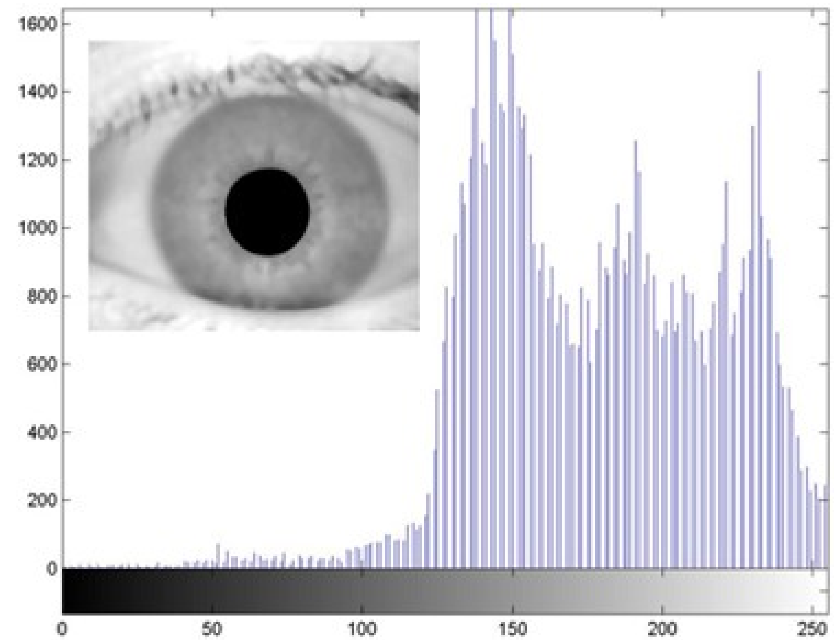
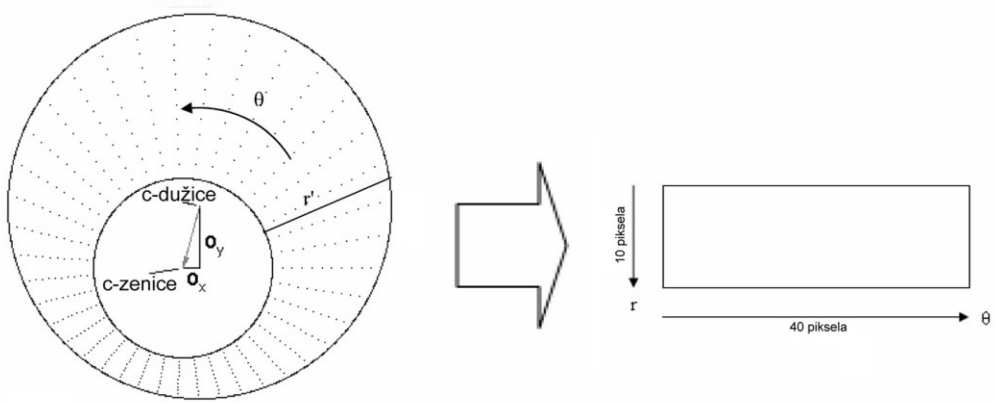


Image transformed by streching the luminance histogram

Unwrapping and Normalisation Models

1) **Daugman's Rubber Sheet Model**: remaps each point within the iris region to a pair of polar coordinates (r, θ), where r is on the interval [0,1], and θ is angle [0,2π].

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



Rotational inconsistencies are accounted for in the matching phase!

2) **Image Registration**: geometrically wraps a newly acquired image $I_a(x,y)$ into alignment with a selected database image $I_d(x,y)$.

3) **Virtual Circles**: iris images are first scaled to have a constant diameter so that when comparing two images, one is considered as the reference image.

Feature Encoding and Matching

- *“One of the most interesting aspects of the world is that it can be considered to be made up of patterns. A pattern is essentially an arrangement. It is characterized by the order of the elements of which it is made, rather by the intrinsic nature of these elements”*

  Norbert Wiener

- **Extraction of the iris patterns** taking into account the correlation between adjacent pixels.
- Only the significant features of the iris must be extracted so that comparisons can be made.
- **Band pass decomposition** of the iris image is used to create a biometric template.

Feature Encoding and Matching

- **Matching metric** – a measure of similarity between two iris templates.
- The metric should give value ranges for:

  - **intra-class** comparisons

  - **inter-class** comparisons

- Feature Encoding Algorithms:
  - Wavelet Encoding
  - Gabor i Log-Gabor Filters
  - Zero-crossings of the 1D wavelet
  - Haar wavlet
  - Laplacian of Gaussian Filters

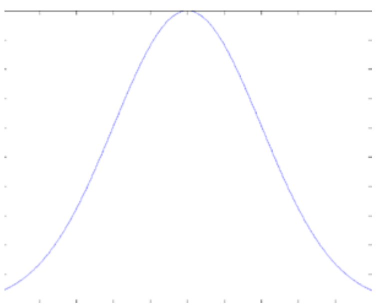
- A Gabor filter is constructed by **modulating a sine/cosine wave** with a **Gaussian evnelope**:

$$g(x,y)=s(x,y)w_r(x,y)$$

$$g(x,y)=e^{j(2\pi(u_0x+v_0y)+P)}e^{-\pi\left(a^2(x-x_0)_r^2+b^2(y-y_0)_r^2\right)}$$

  - (x_0, y_0) – specify position in the image
  - (α, β) – effective width and length
  - (u_0, v_0) – modulation

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

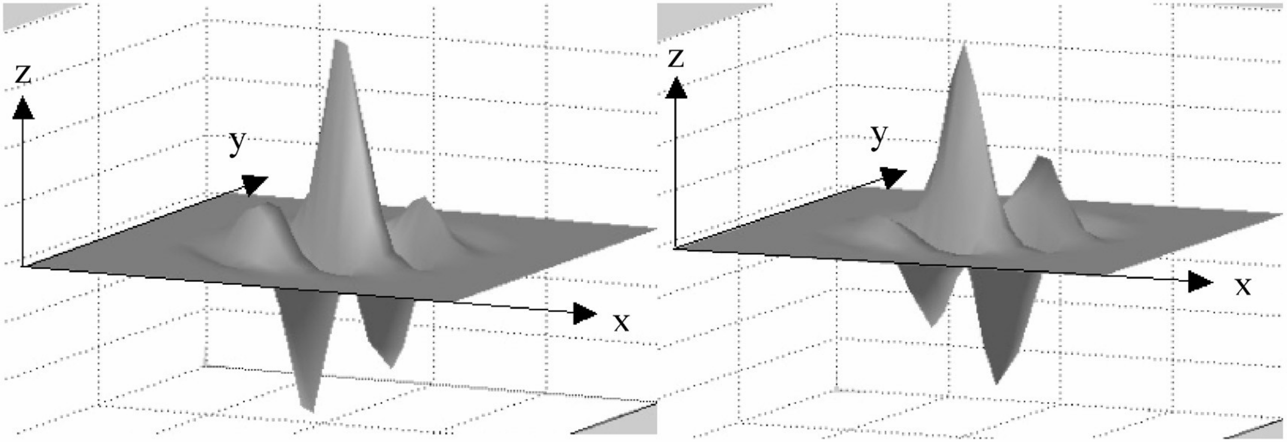


Gaussian envelope

1D Gabor wavelet

Gabor filters

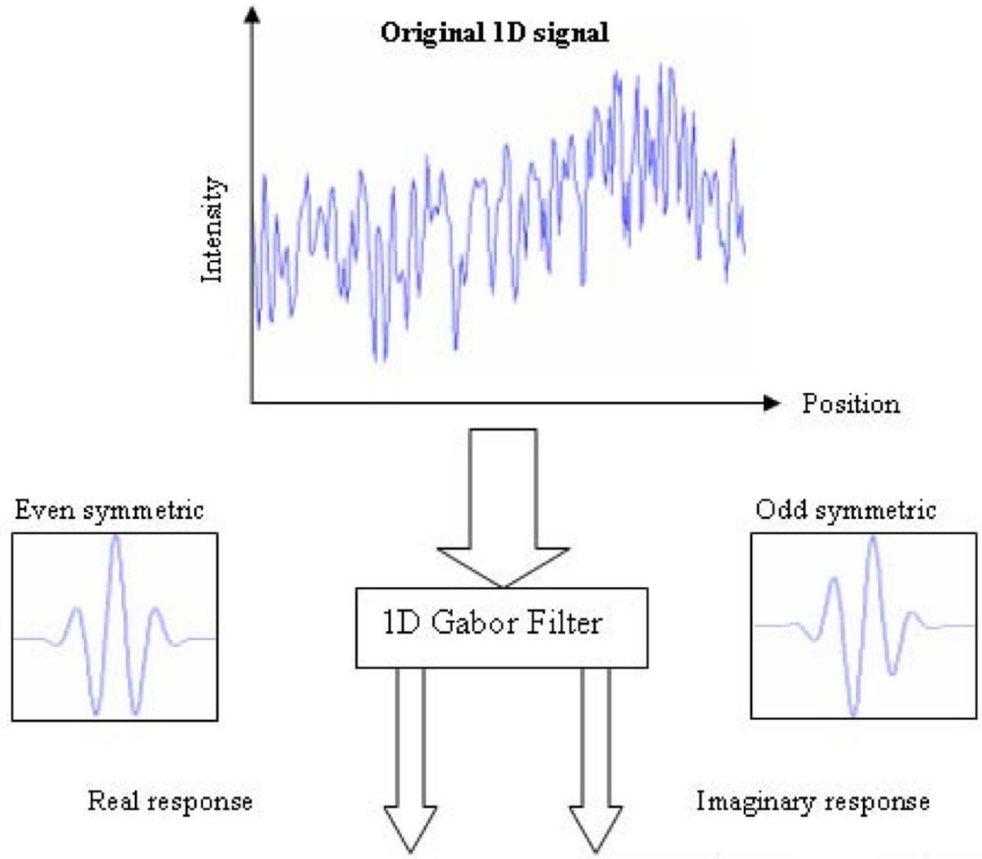
- Daugman makes use of **2D version** of Gabor filters. In order to compress the data the output of the filters is demodulated by quantising the phase information into **four levels**, for each quadrant in the complex plane.



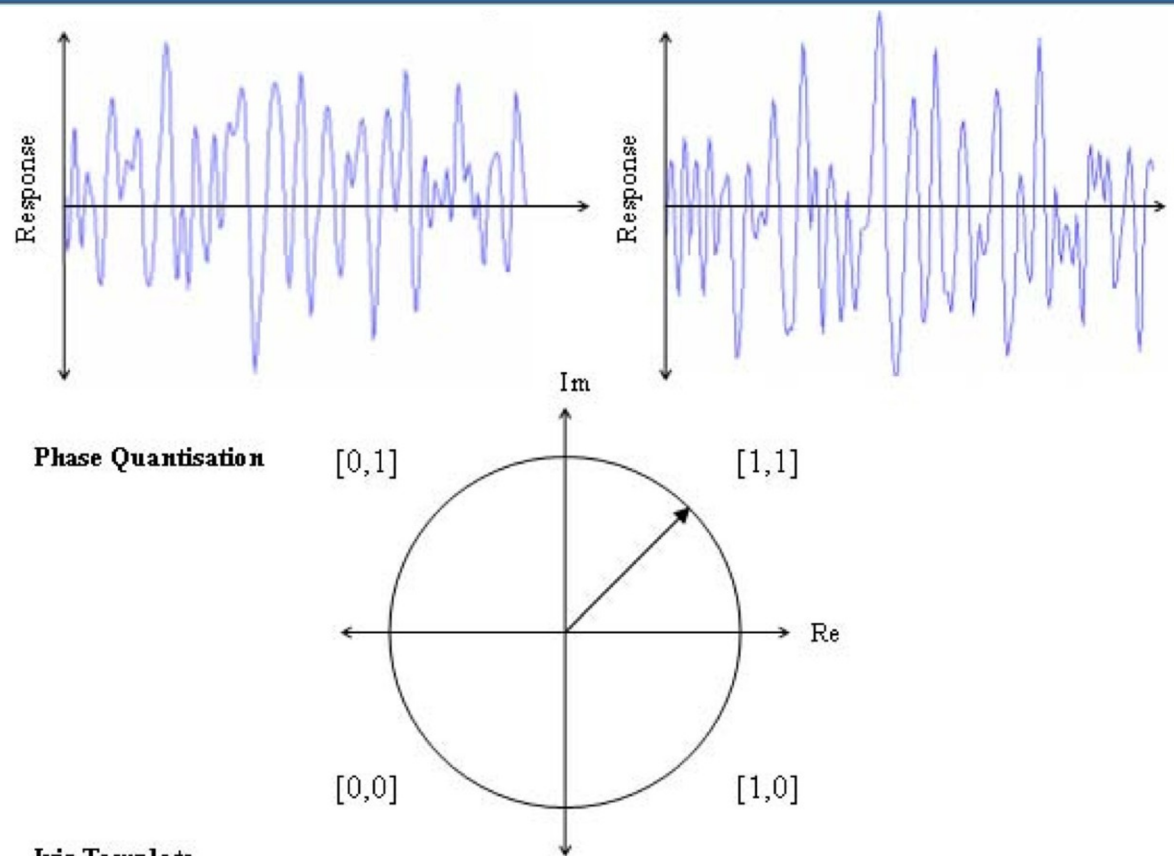
A quadrature pair of 2D Gabor filters

Re component or even symetric filter (*cosine*) Im component or odd symmetric filter (*sine*)

An illustration of the Feature Encoding Process



An illustration of the Feature Encoding Process

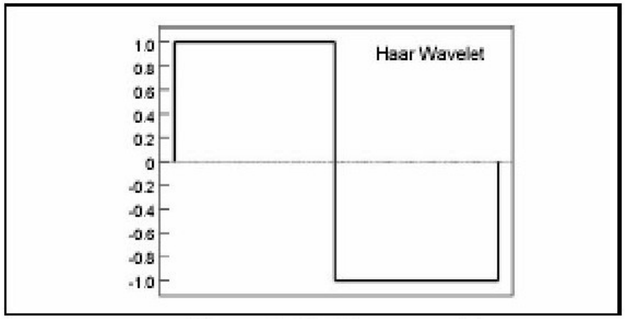


Iris Template

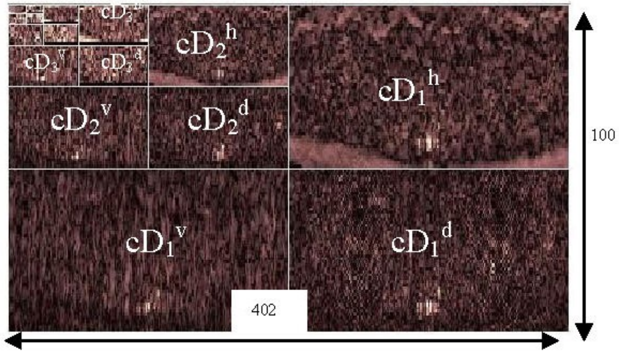
01 00 00 10 11 11 01 01 00 10 10 11 11 01 01 00 10 10 11 01 01 01 01 01 00
10 10 01 11 00 01 11 10 11 10 10 00 10 01 10 00 11 01 10 11 00 01 01 11 10

Haar wavelet

- A feature vector is computed from **multi-dimensional filtering**.
- A mapped image can be decomposed using Haar wavelet into a maximum of **5 levels**.
- To eliminate redundancy, each image applied can be represented as the combination of **6 matrices**.
- These matrices are combined to build one single vector characterizing the iris patterns - a **feature vector.**
- Haar wavelet transform has a **compact biometric template** and its recognition rate is slightly better than Gabor transform by **0.9%.**



Haar wavelet



Conceptual diagram for organizing a feature vector

Matching Algorithms

1) **Hamming Distance:**

- Gives a measure of how many bits are the same between two bit patterns.
- In comparing the bit patterns X and Y, HD is defined as the sum of disagreeing bits over N, the total number of bits in the bit pattern.

$$HD = \frac{1}{N}\sum_{j=1}^{N} C_A(j) \oplus C_B(j)$$

- This way, two identical vectors will have distance 0, while two completely different, 1.

Matching Algorithms

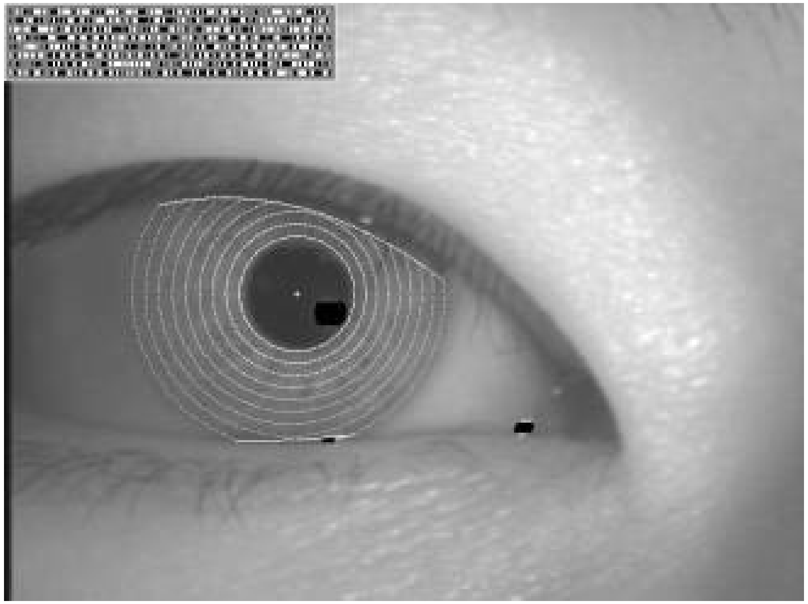
2) <u>Weighted Euclidean Distance:</u>

- Gives a measure of how similar a collection of values are between two templates.

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

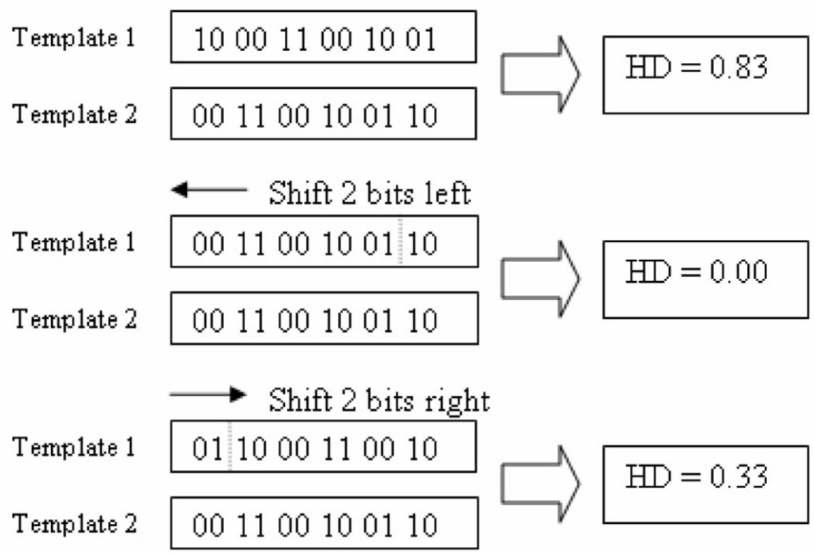
3) <u>Normalised Correlation:</u>

$$\frac{\sum_{i=1}^{n}\sum_{j=1}^{m}(p_1[i,j]-\mu_1)(p_2[i,j]-\mu_2)}{nm\sigma_1\sigma_2}$$



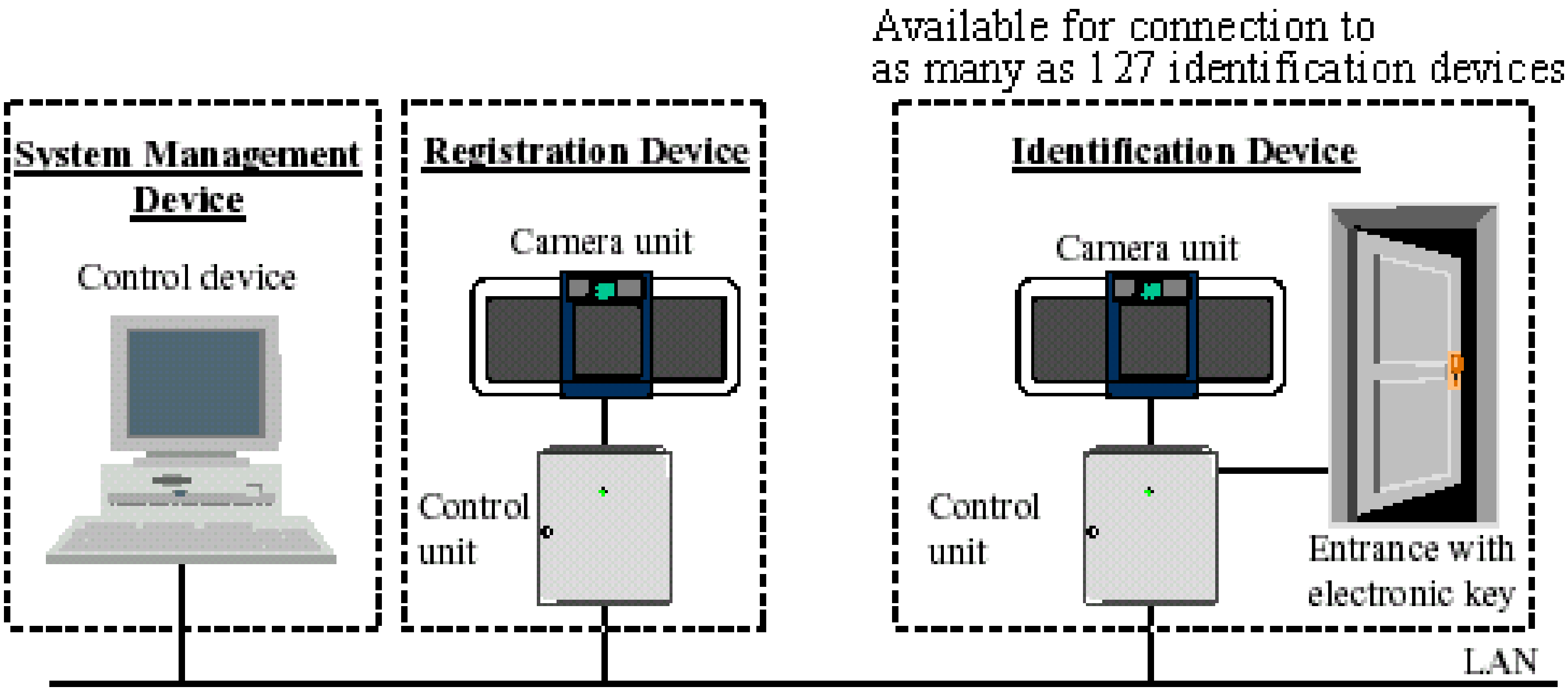
Implementation

- **Maximum HD (threshold)** that exists between two irises belonging to the same person is ca.**0.32**.
- **Normalising rotational inconsistencies:** done by shifting one template left and right bit-wise and calculating a number of HD values from succesive shifts.
- From these values, only **the lowest** is taken (best match).
- **The actual number of shifts** required is determined by the maximum angle difference between two images of the same eye.



An Ilustration of the shifting process

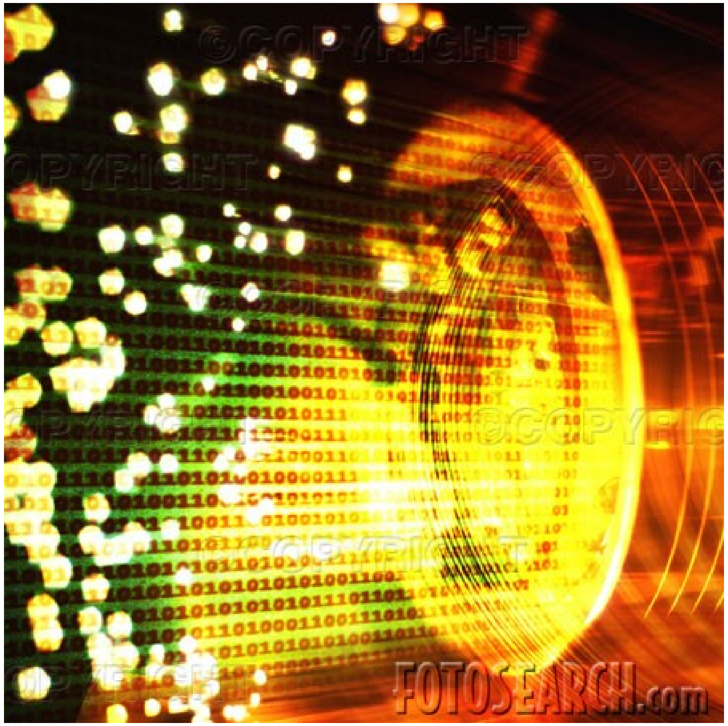
Iris Recognition Hardware system



Structure of Overall Iris Recognition Systems

The Characteristics of Iris Cameras

- One or two narrow view cameras, having large focal length (about 30-50 mm).
- For a successful iris recognition, the diameter of iris region should be more than **200 pixels** in a 640x480 pixel image.
- Convencional narrow view camera tends to have small ***DOF****** and the input image can be defocused according to the user's movement.
- To increase the *DOF* range, the lens aperture is made smaller, or the position of eye to be captured is made farther from camera lens.



** Depth Of Field – is a distance range in which the object can be clearly captured in the camera image.*

Auto Zooming and Focusing

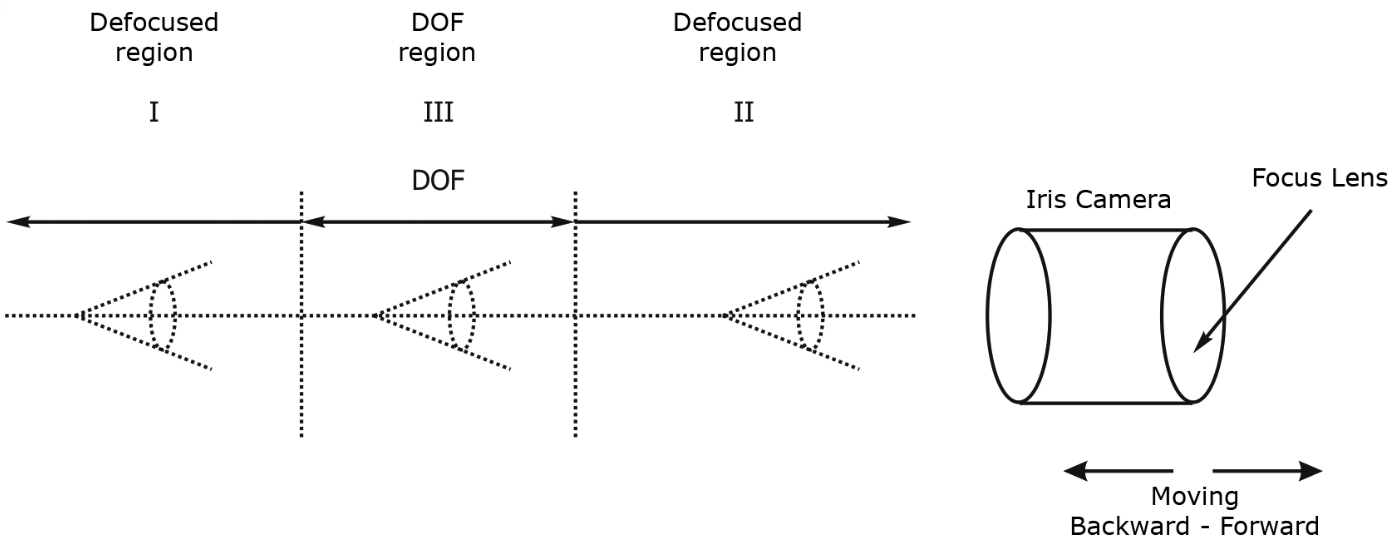
- Though the *DOF* of single focal cameras may be small, **the movement of focus lens can make large *DOF*** of the narrow view camera.

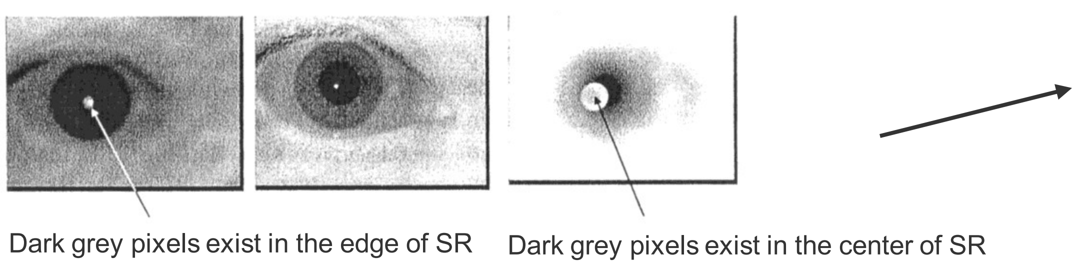
- In addtition to the focus lens, a **zoom lens** is added to make the magnification ratio of 200 pixels/cm.

- For focusing algorithm, a SR is used, generated by **IR-LED** illuminator.

- If the position of the user's eye is not in the *DOF* of the focus lens, the input eye image is defocused and the SR image becomes bigger.

Auto Zooming and Focusing

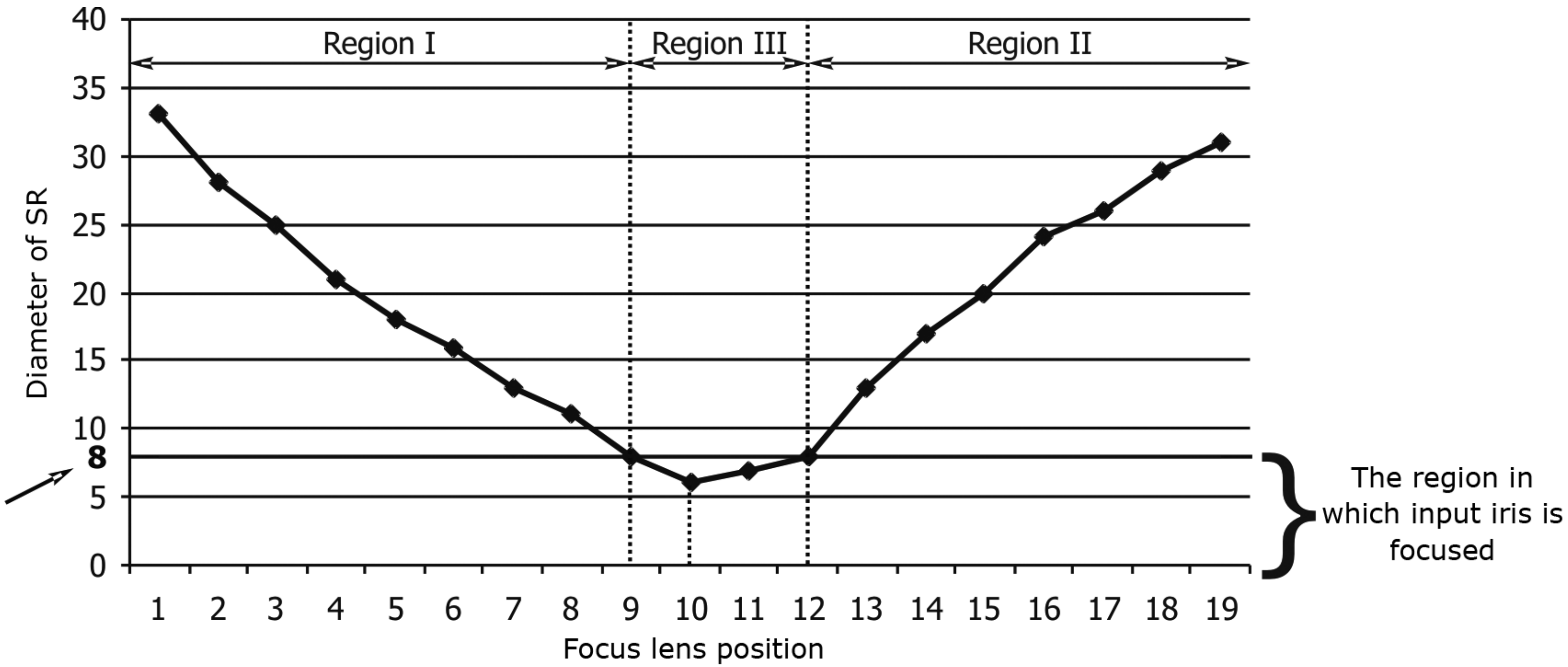




The amount of lens movement step is determined from the size of SR in image!

The DOF region and the defocused region

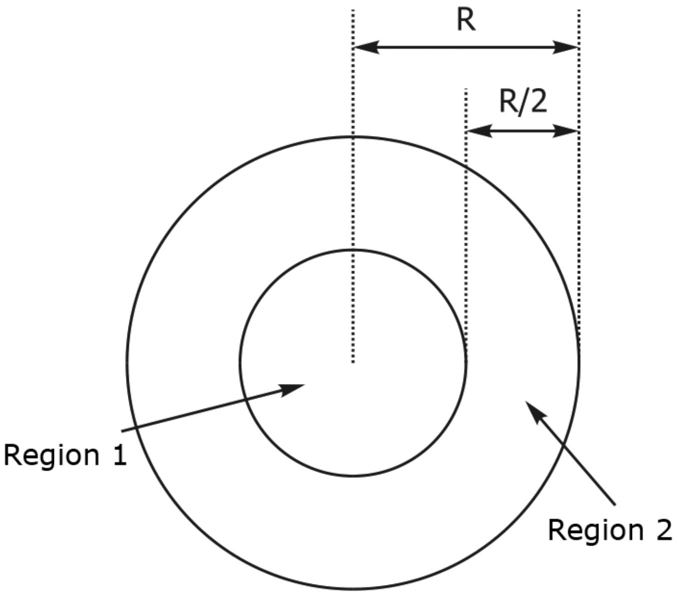
Auto Zooming and Focusing



Focus lens position vs. diameter of SR

Detecting SR in Input Image

- To determine the moving direction of focus lens, the detected SR is divided into two regions and the average grey level of each region is calculated.
- When a user wears glasses, some large SR(s) from glass surface may happen, particularly if the surface is not smooth.
- To overcome such a problem, a successive On/Off scheme of two IR-LED illuminators is used (16.7 ms).



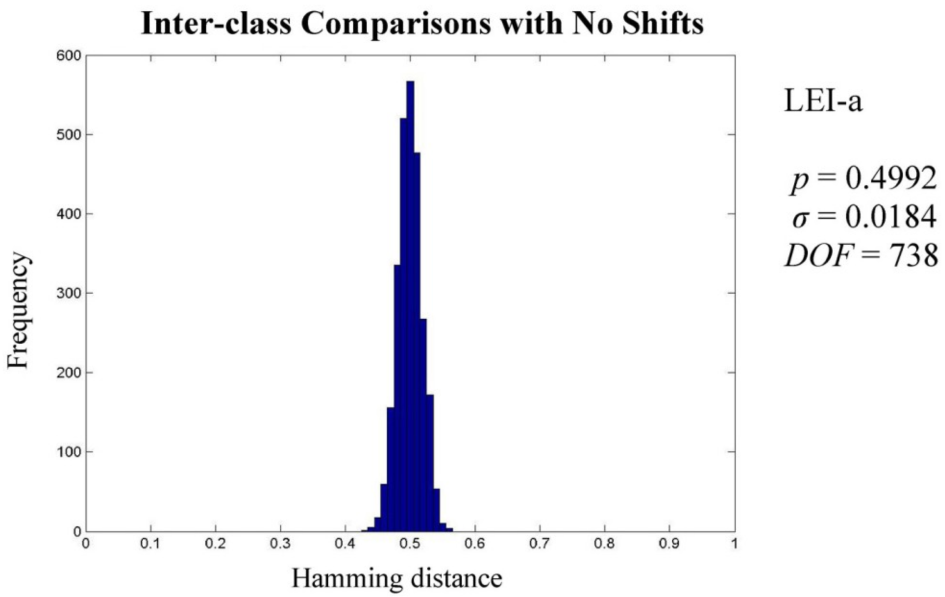
Detected Specular Reflection

Experimental Results

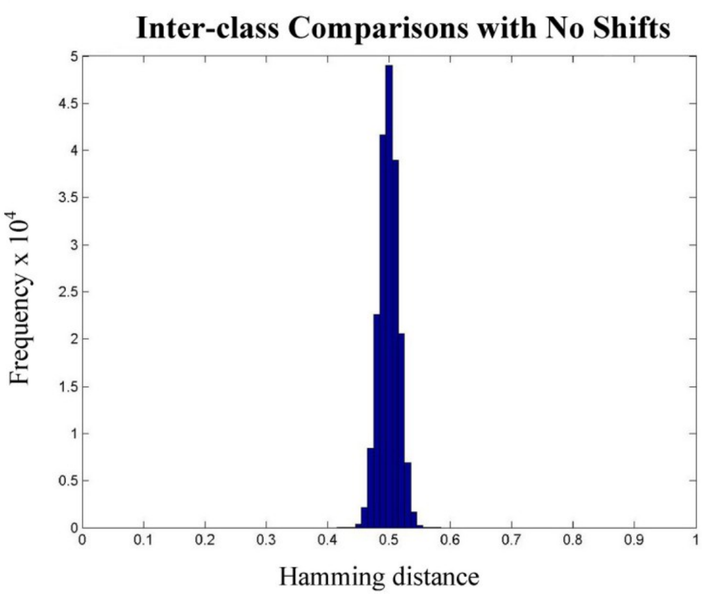
- **The performance** of the system as a whole is examined.
- Finding the **best separation** to minimise false matching.
- **Uniqueness** of human iris patterns.
- Optimal values for system parameters:
  - **Radial** and **angular resolution**, *r* and *θ*
  - **Filter parameters** (number of filters *N*, base wavelength and filter bandwidths)
- **The number of shifts** required to account for rotational inconsistencies.

Uniqueness of Iris Patterns

- <u>A test of **statistical independence**:</u>
- Uniqueness is determined by comparing templates generated from different eyes and examining distribution of *HD* values.
- **The mean *HD*** for comparisons between inter-class iris templates is around **0.5**.
- The templates are shifted left and right to account for rotational inconsistencies and **the lowest *HD*** is taken as **the actual one**.
- As the number of shifts increases, the mean *HD* for inter-class comparisons will decrease accordingly.

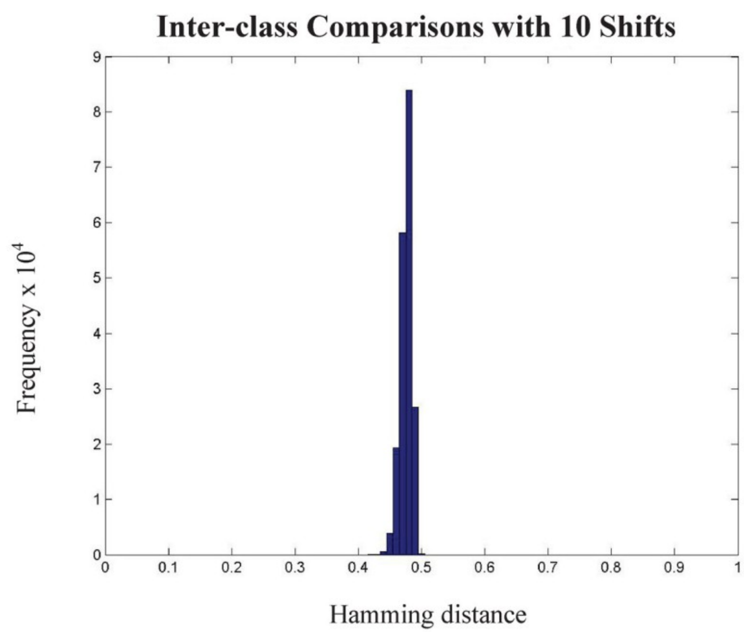


Uniqueness of Iris Patterns



CASIA-a

$p = 0.4993$
$\sigma = 0.0153$
$DOF = 1068$



CASIA-a

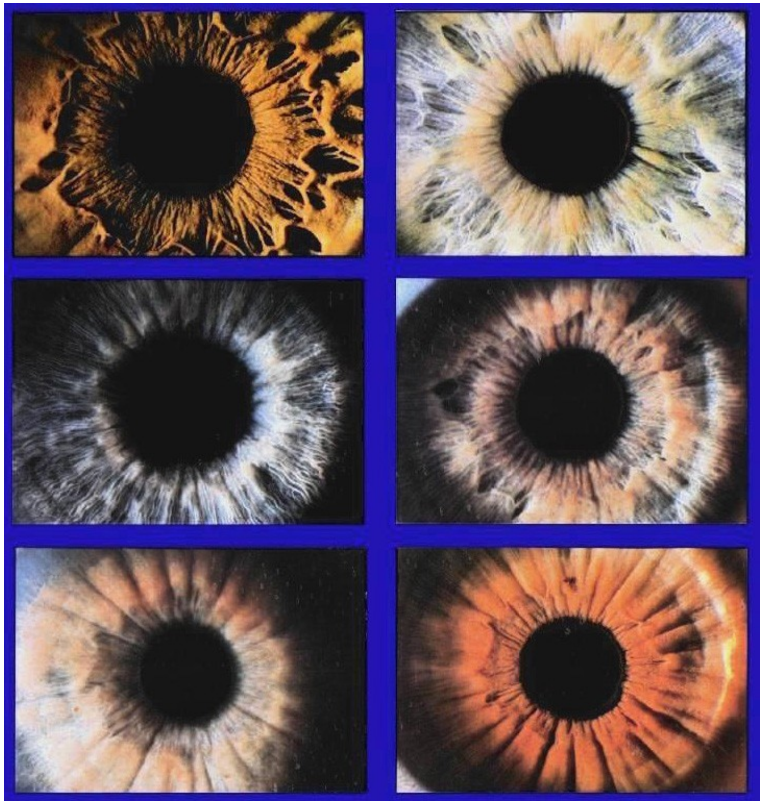
$p = 0.4757$
$\sigma = 0.0089$
$DOF = 3149$

Recognition of Individuals

- System key objective: achieving a distinct separation of intra-class and inter-class *HD*.
- A separation *HD* value is chosen.
- **The metric**: "decidability" – based on the mean and standard deviation of the intra-class and inter class distributions:

$$d' = \frac{|\mu_S - \mu_D|}{\sqrt{\frac{(\sigma_S^2 + \sigma_D^2)}{2}}}$$

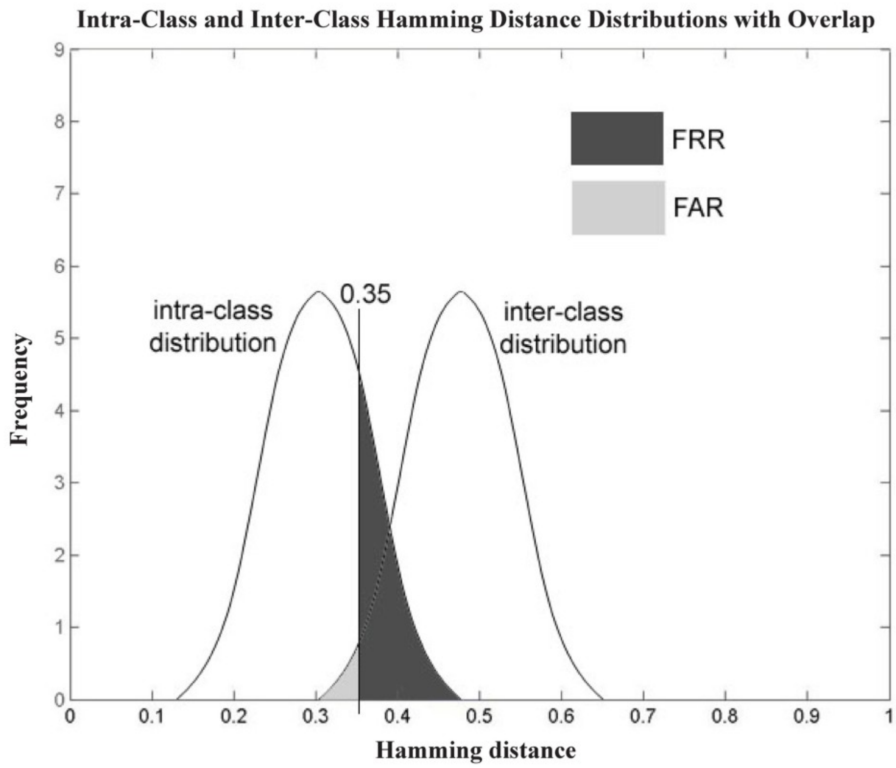
- With pre-determined separation HD, a decision of matching can be made.



Recognition of Individuals

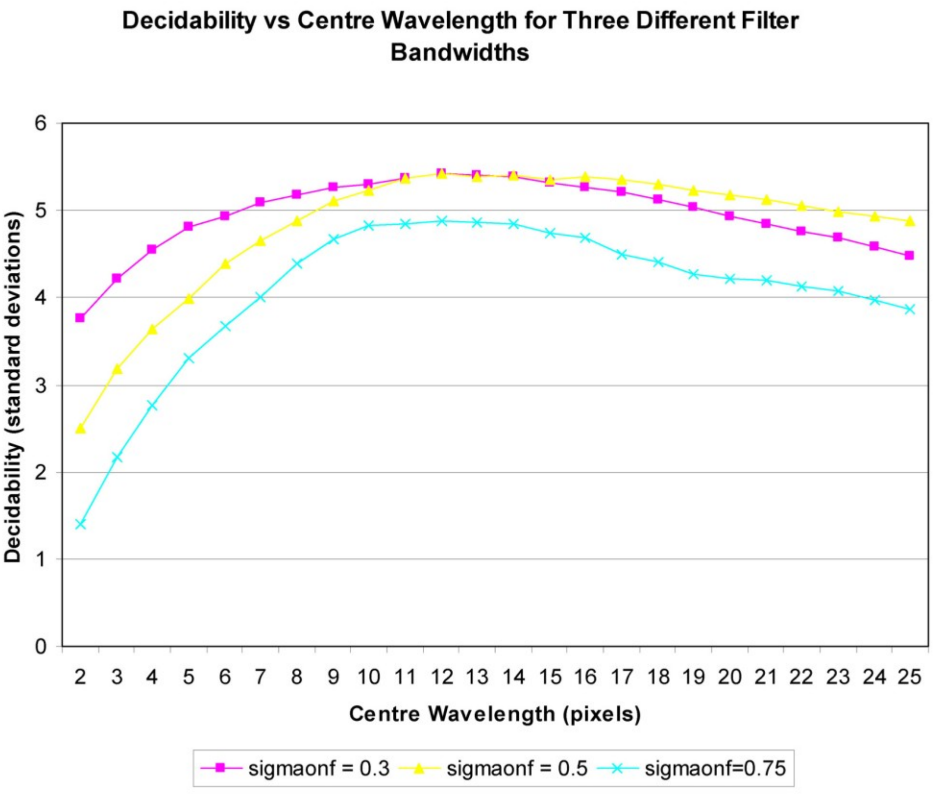
- **FRR – False Reject Rate** (Type I error).
- **FAR – False Accept Rate** (Type II error).
- These rates can be calculated by the amount of overlap between two distributions.

$$FAR = \frac{\int_0^{\kappa} P_{diff}(x)dx}{\int_0^{1} P_{diff}(x)dx} \qquad FRR = \frac{\int_{\kappa}^{1} P_{same}(x)dx}{\int_0^{1} P_{same}(x)dx}$$



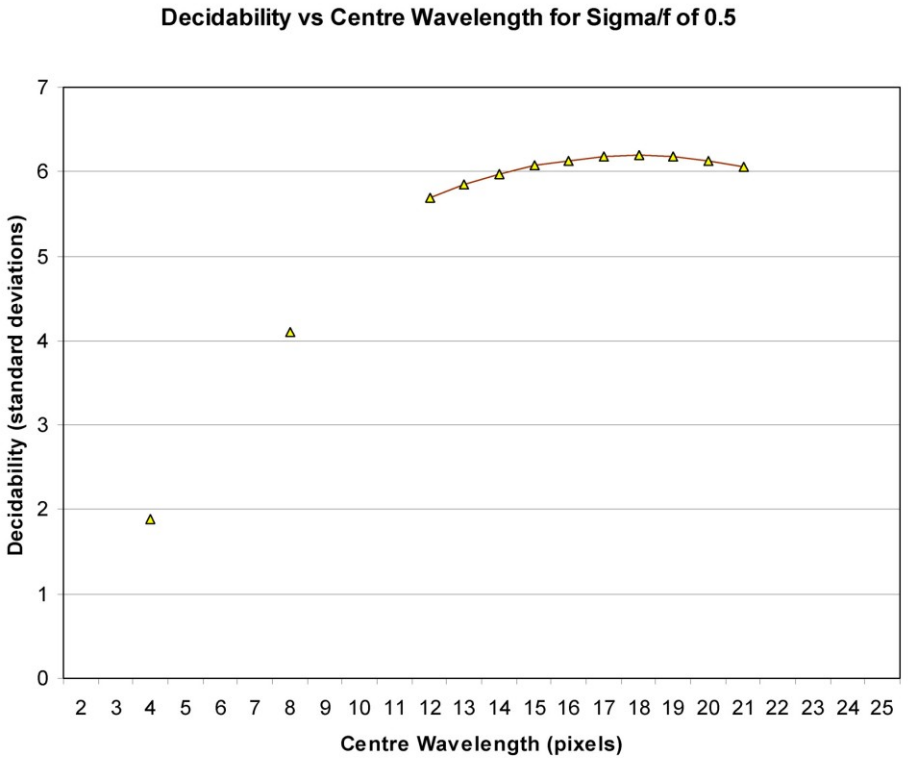
Filter Parameters

- The outputs of each filter shoud be **independent**.
- The bandwidths of each filter **must not overlap** in the frequency domain.
- Centre frequences must be **spread out**.



Filter Parameters

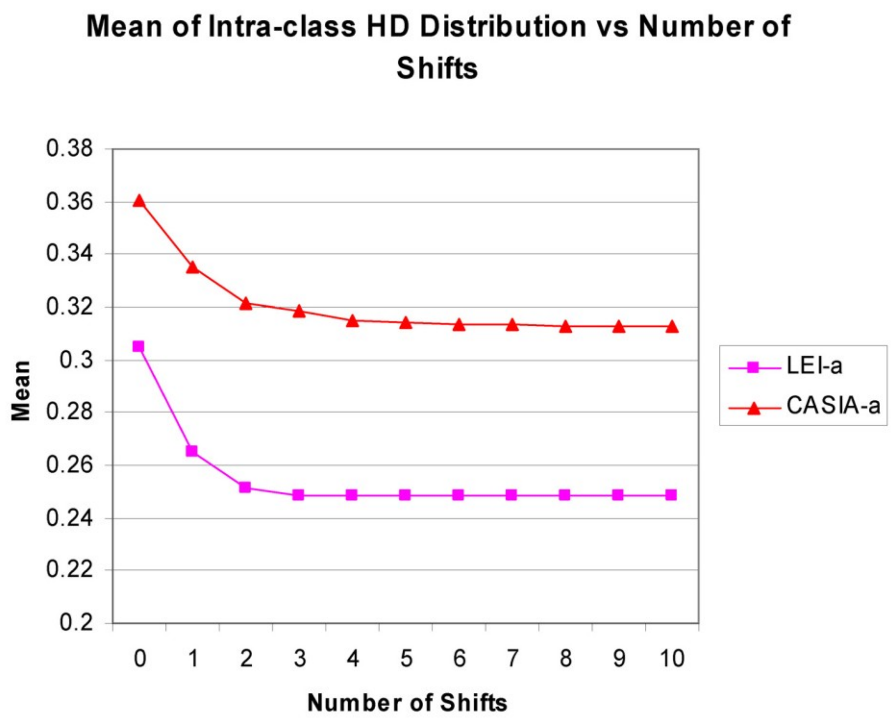
- An <u>optimum centre wavelength</u> which produces max.decidability **depends on the data set**.
- <u>Optimum number of filters</u> is just **one**.
- <u>Optimum σ/f value</u> is **0.5**, corresponding a filter bandwidth of around **2 octaves**.

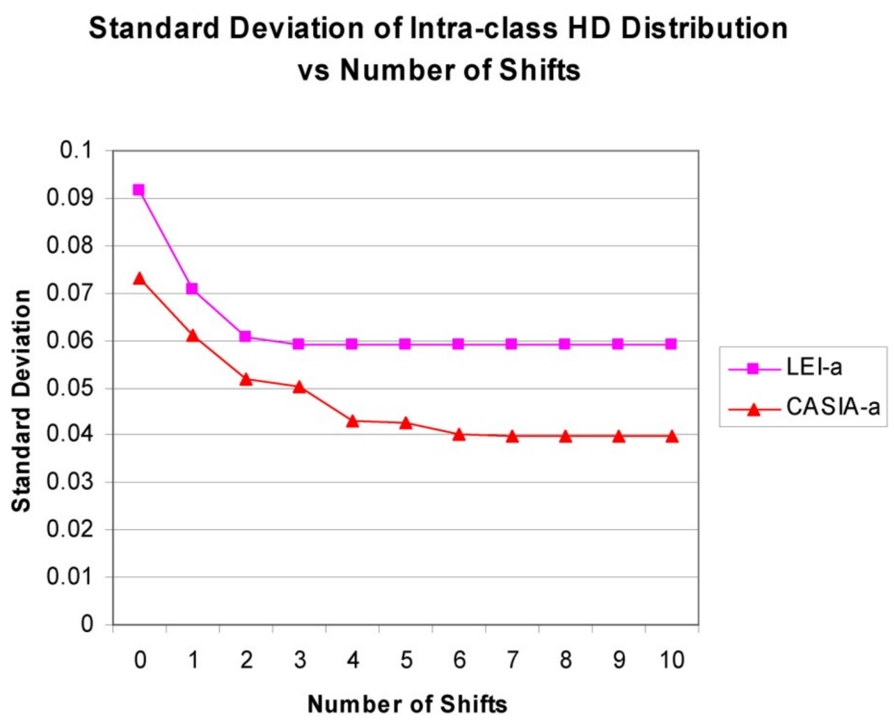


Template Resolution

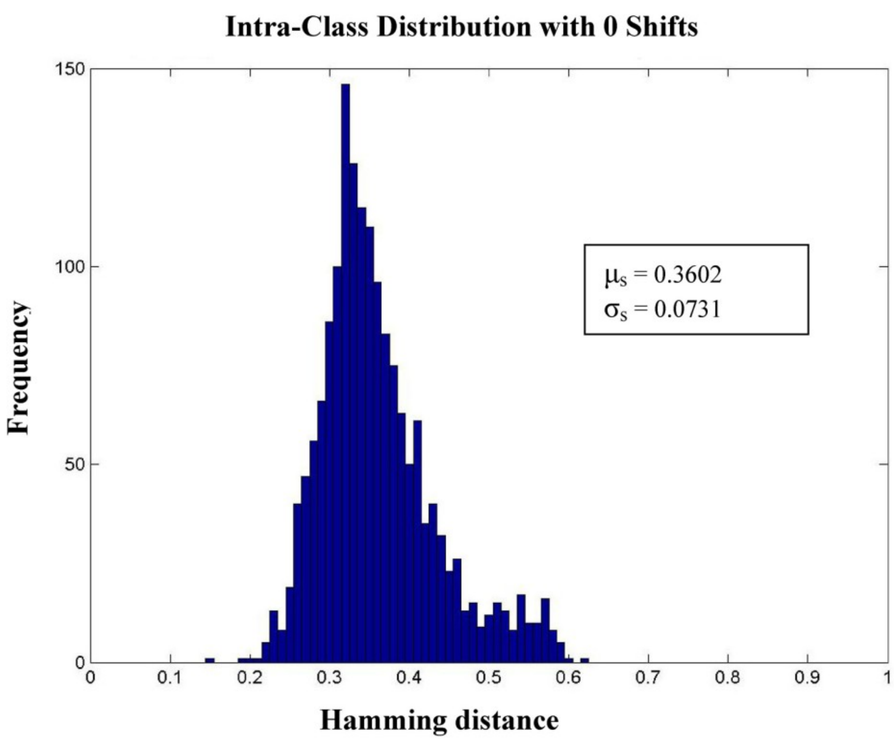
- A factor, significally influencing the recognition rate, is the **radial and angular resolution** used during normalisation.
- The optimum template sizes, depending on the data set, is found to be **20x240** pixels up to **32x240** pixels.
- A lower radial resolution can be used with only minor effect on decidability, providing more compact and efficient encoding.

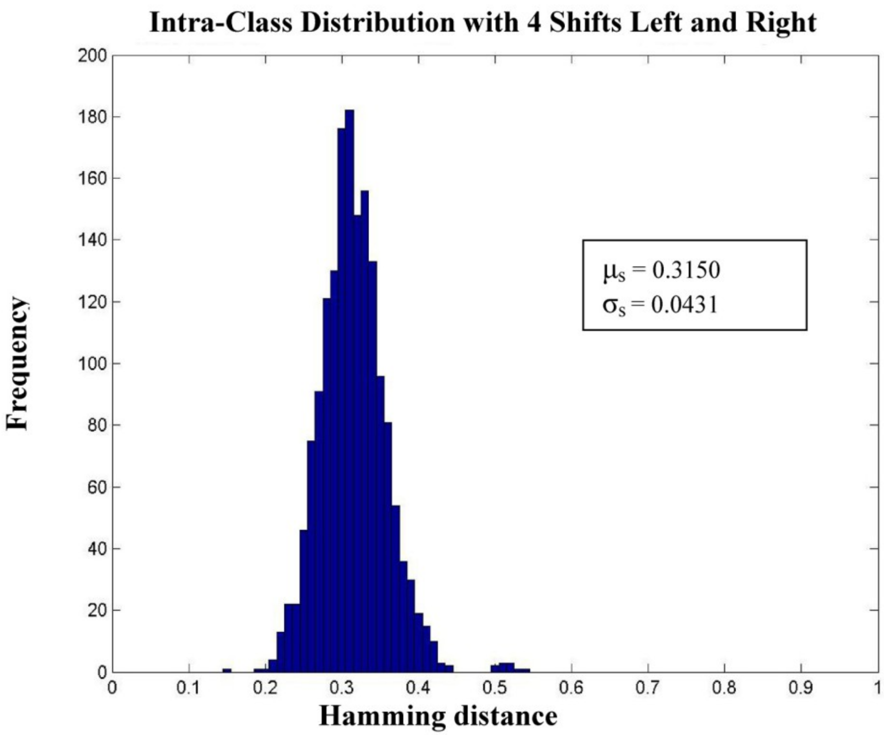
Number of shifts





Number of shifts

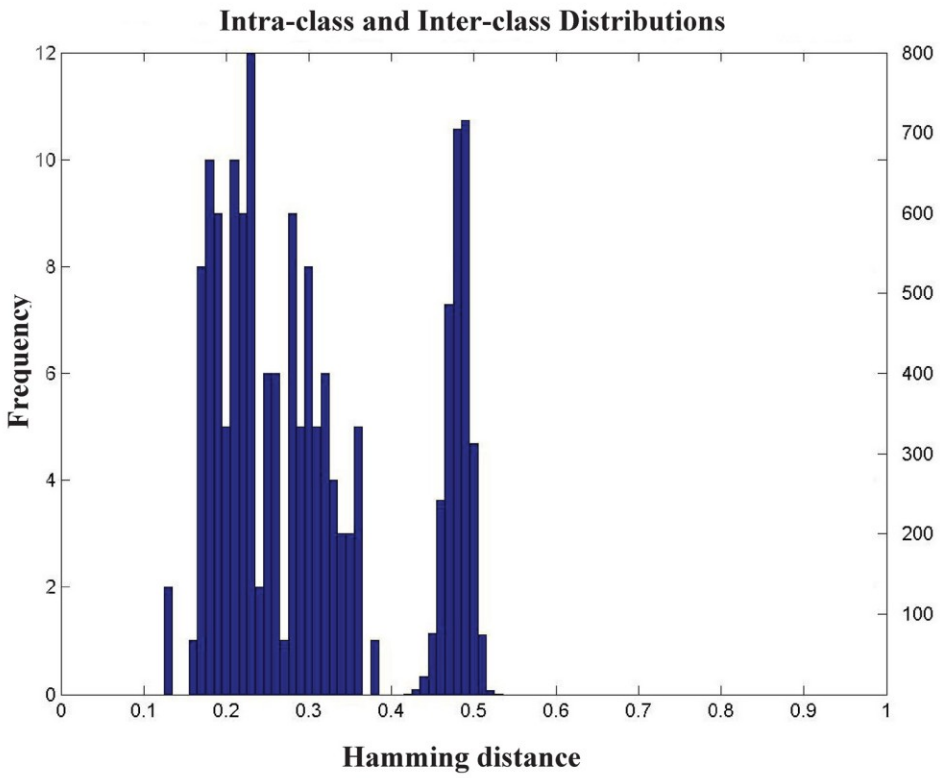




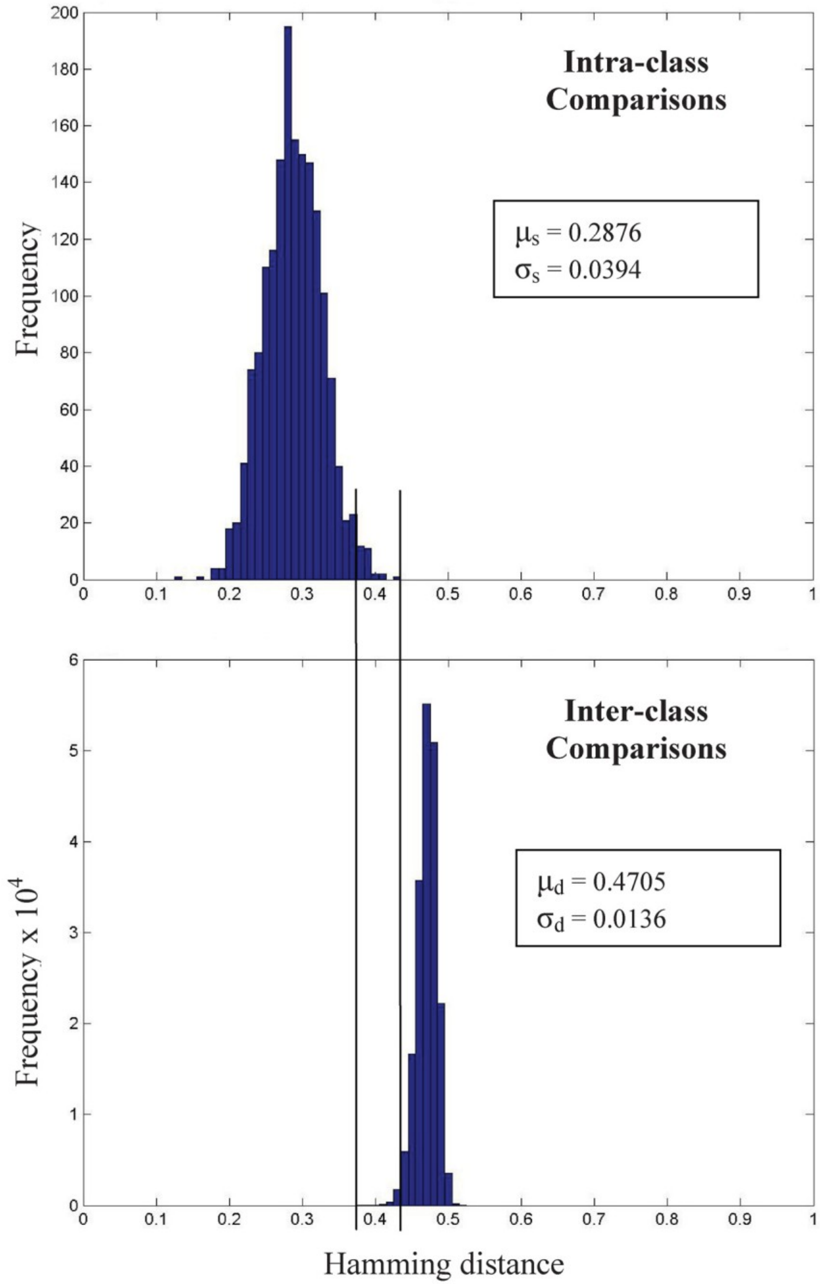
CASIA-a data set

The performance of the Iris Recognition system

- Optimum encoding:
  - 1D Log Gabor filter, σ/f = 0.5
  - Centre wavelength: 12 ÷ 18 pixels
  - Template size: 20x240 pixels
  - Number of shifts: 3 ÷ 8
- Good separation of intra-class and inter-class *HD* values – separation point: **0.4**.
- In case of no overlapping of the *HD* distribution, a **perfect recognition** is possible.



‘CASIA’ database



Summary of Work

- Automatic segmentation algorithm using **Hough transform**.
- The segmented iris region is normalised to eliminate dimensional inconsistencies using **Daugman's rubber sheet model**.
- Features are encoded by convolving the normalised iris region with **1D Log-Gabor filter** and phase quantising the output to produce a bit-wise template.
- Matching metric – **Hamming distance**.

Summary of Findings

- Segmentation is **the critical stage** of iris recognition, dependent on the imaging quality of eye images.
- Encoding process requires **only one** 1D Log-Gabor filter.
- **Optimum centre wavelength** is found to be dependent on imaging conditions.
- FAR = 0.005%
  FRR = 0.238%

- The results confirm that iris recognition is a **reliable** and **accurate** biometric technology.

Anomalies

- Color contact lenses.
- The **border** of any contact lens is slightly visible in an eye image, which may confuse the segmentation algorithm.
- **Spectacles** may introduce too much Specular Reflection (SR).
- A **high-resolution photograph** of a human eye could also be presented to an iris recognition camera.

Suggestions for Future Work

- A more elaborate **eyelid and eyelash detection system**.
- Improvement in speed – by implementing computationally intensive parts in C or C++.
- *Frame grabber* - for capturing a number of images.
- Using **both eyes** to improve recognition rate?...

Any questions?

Thank you for your attention!