ISEL
INSTITUTO SUPERIOR
DE ENGENHARIA DE LISBOA

PROCESSAMENTO DE IMAGEM E BIOMETRIA

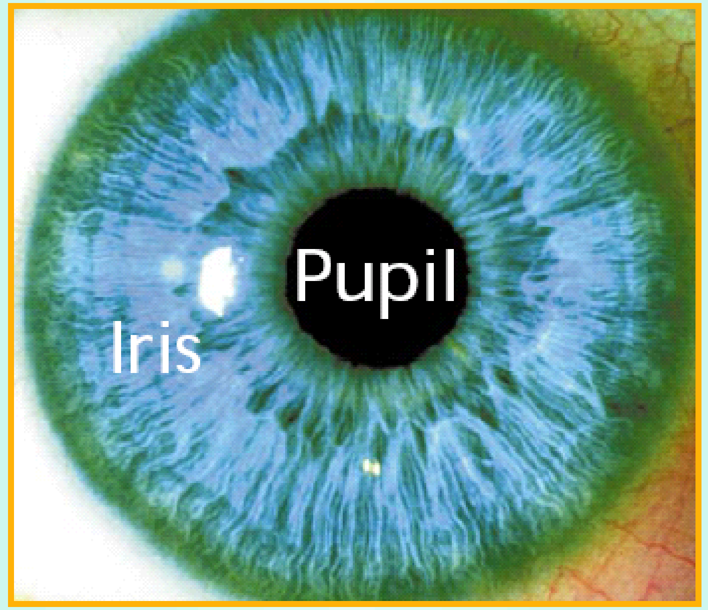
IMAGE PROCESSING AND BIOMETRICS

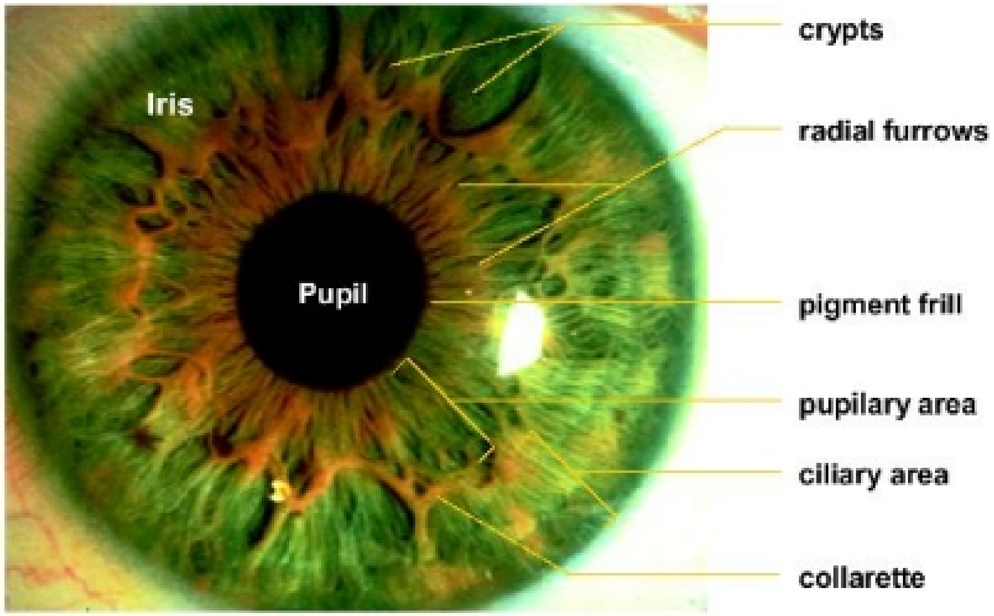
9. **BIOMETRIC SYSTEMS – part 2**

Summary

- Iris
- Iris Recognition System
- Face
- Face Recognition System

Iris (1)





- Iris is the annular region of the eye; responsible for controlling and directing light to the retina.
- Bounded by the pupil and the sclera (white part of the eye); iris is small (11 mm)
- Its visual texture stabilizes during the first two years of life and carries distinctive information useful for identification

- **<u>Each iris texture is unique</u>; irises of identical twins are different**

Iris (2)

The colored part of the eye is called the *iris*. It controls light levels inside the eye similar to the aperture on a camera

The round opening in the center of the iris is called the pupil.

The iris is embedded with tiny muscles that dilate (widen) and constrict (narrow) the pupil size

The sphincter muscle lies around the very edge of the pupil.

In bright light, the sphincter contracts, causing the pupil to constrict

Iris (3)

The dilator muscle runs radially through the iris, like spokes on a wheel

This muscle dilates the eye in dim lighting.

The iris is flat and divides the front of the eye (anterior chamber) from the back of the eye (posterior chamber).

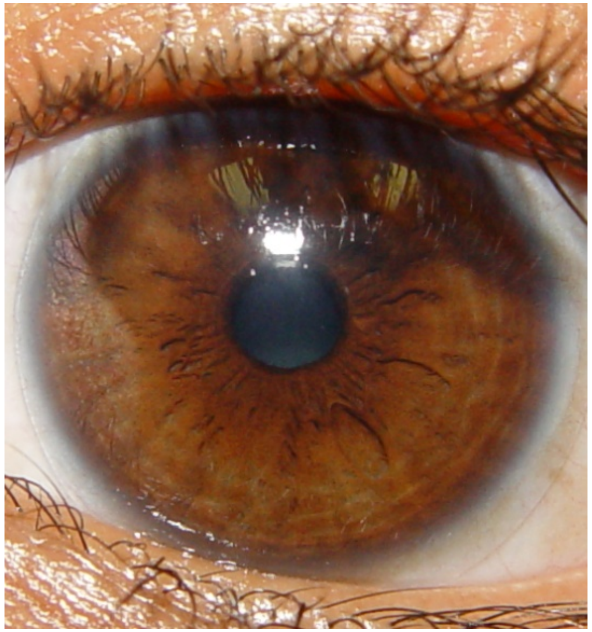
Its color comes from microscopic pigment cells called melanin

The color, texture, and patterns of each person's iris are as unique as a fingerprint
http://www.stlukeseye.com/anatomy/Iris.asp

Iris Capturing Devices

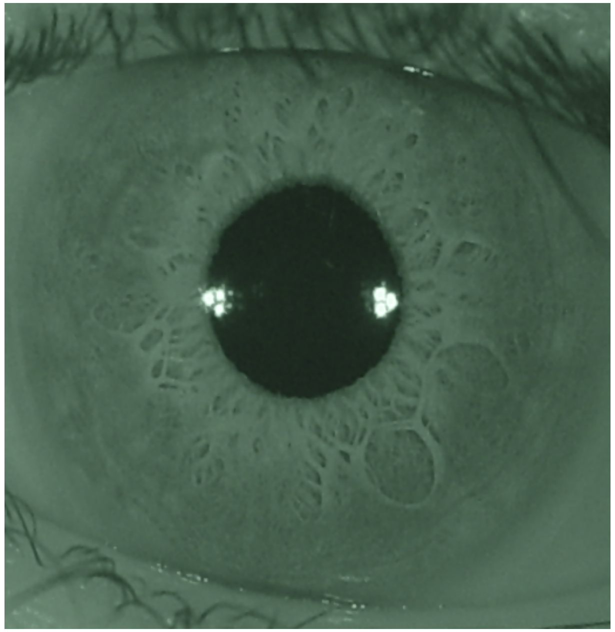
Iris Images

- Different cameras -> different images



RGB

Gray-Scale



Infra-Red

Iris Image Databases (1)

CASIA (***C**hinese **A**cademy of **S**cience **I**nstitute of **A**utomation*), Beijing, China

http://www.sinobiometrics.com

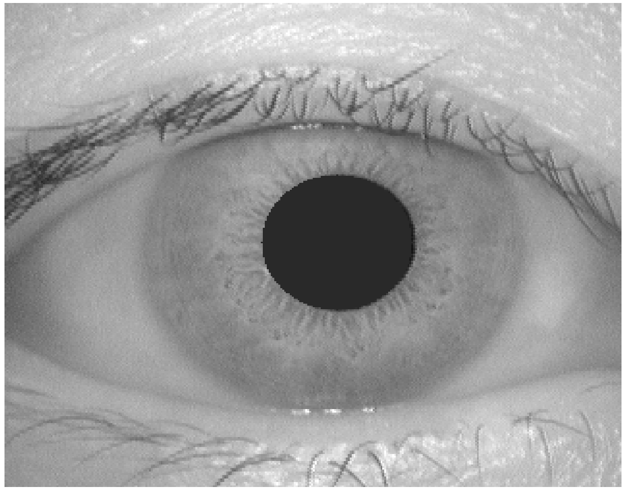
- Images collected under near infra-red illumination
- 8 bit gray-scale images; resolution 320 x 280 pixels

Version 1

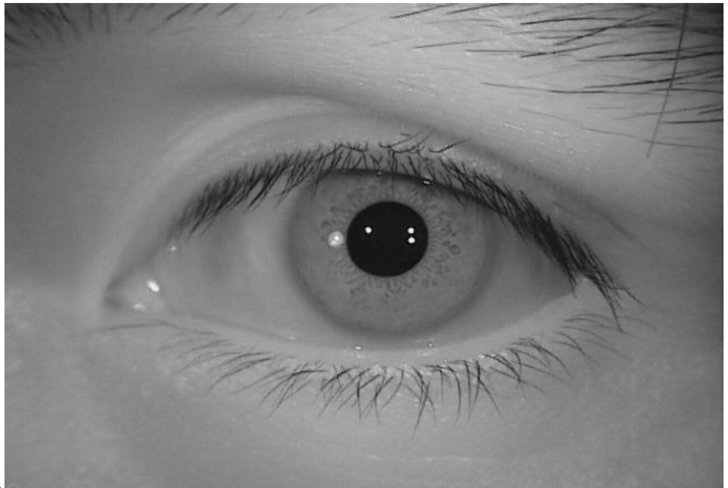
- 756 images of 108 individuals
- subset of Version 3 interval class)

Version 3

- 22051 images of more than 700 individuals
- 3 classes: *interval*, *lamp*, *twins*



Interval



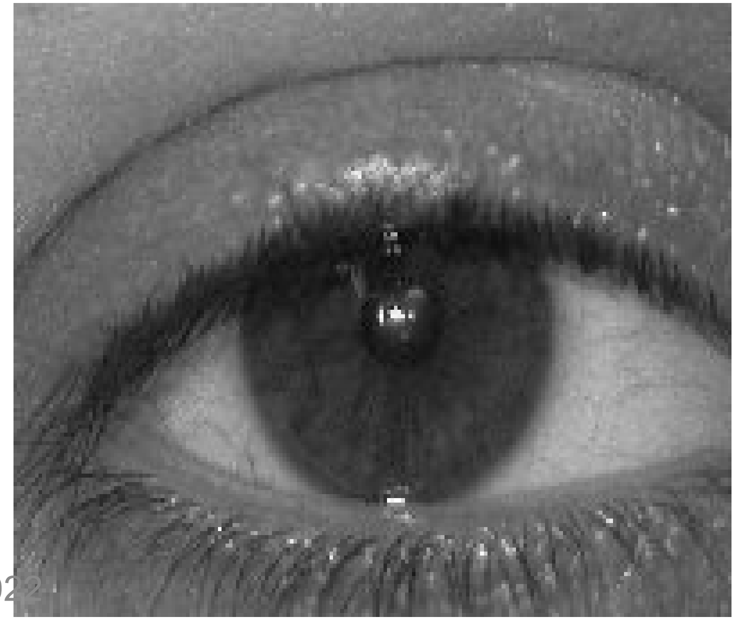
Lamp

Iris Image Databases (2)

UBIRIS (**U**niversidade da **B**eira **I**nterior I**RIS**),
Covilhã, Portugal [2005]

http://iris.di.ubi.pt/index.html

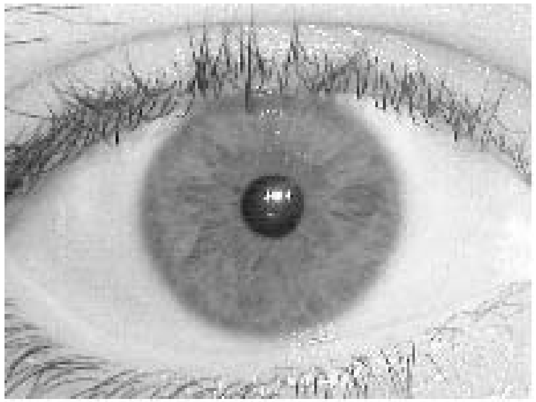
- acquisition done with a NIKON E5700 digital RGB camera (noisy, with minimum user cooperation)
- 1877 images of 241 individuals (two sessions)
- resolution 200 x 150 pixels
- gray-scale versions



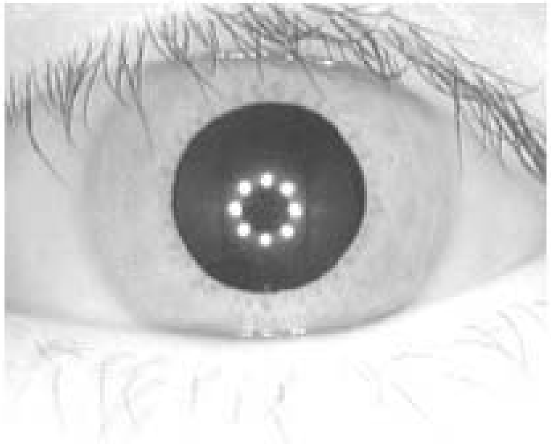
H. Proença, L. Alexandre, UBIRIS: a noisy iris image database, Lecture Notes in Computer Science – ICIAP 2005 - 13th International Conference on Image Analysis and Processing, 1:970--977.

Iris Image Databases (3)

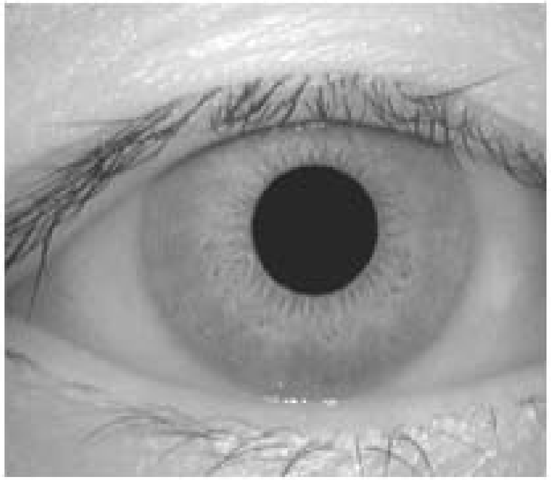
Database	# Images	Resolution
CASIA V1	756	320 x 280
CASIA V3	22051	320 x 280
UBIRIS	1877	200 x 150



UBIRIS



CASIA V3

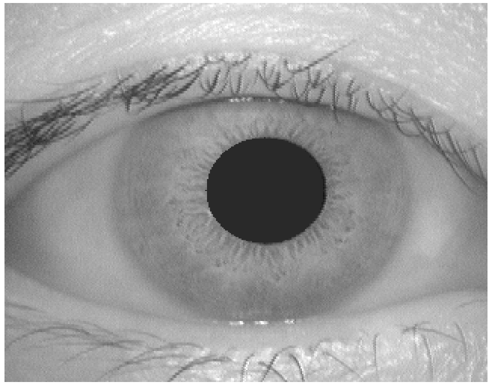


CASIA V1

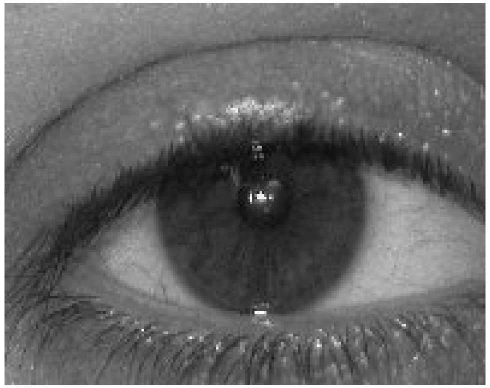
Iris Image Databases (4)

Analysis of the pupil diameter (in pixels)

Measure	CASIA	UBIRIS
Mean	86.2	23.7
Median	87	24
Mode	77	25
Minimum	65	17
Maximum	119	31
Standard Deviation	11.5	2.9
Sample Variance	132.7	8.3



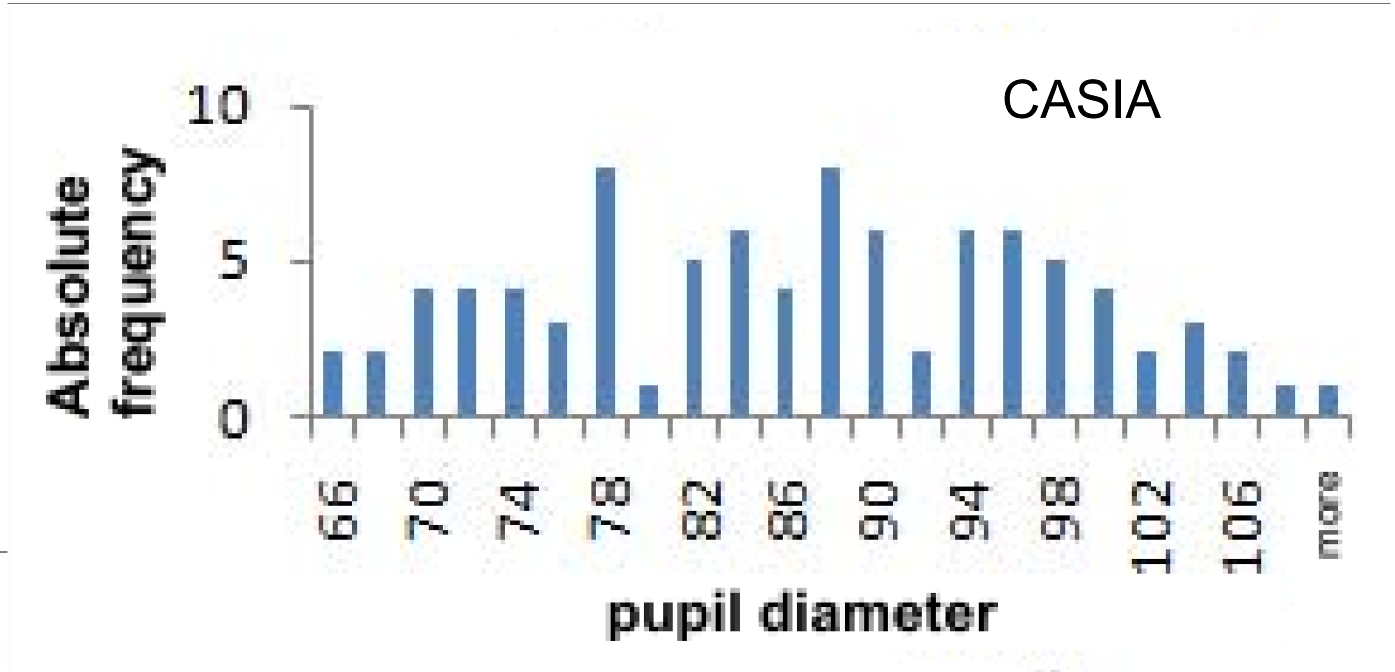
CASIA

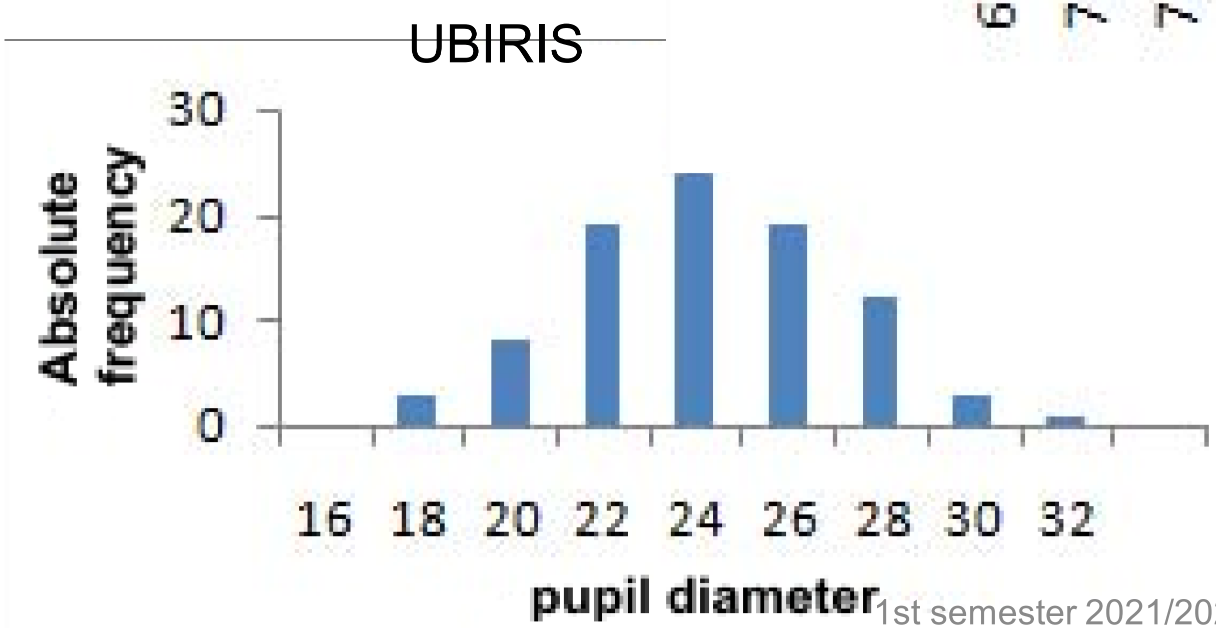


UBIRIS

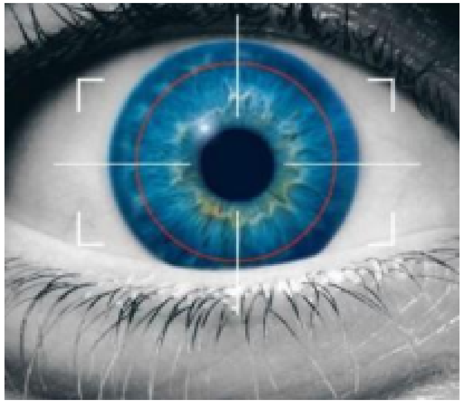
Iris Image Databases (5)

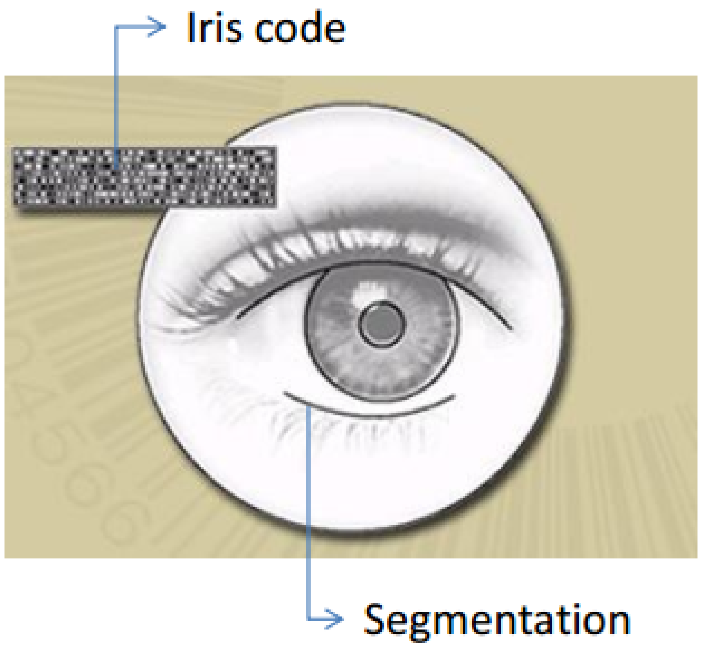
Histograms of pupil diameter





Iris Recognition





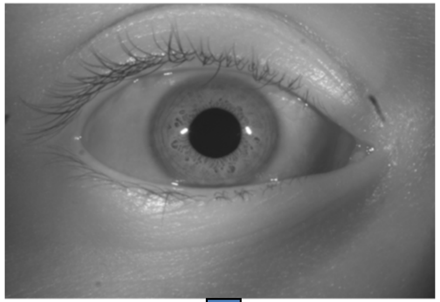
Iris Recognition Algorithms

- Some techniques have been proposed for Iris Authentication and Identification

- Daugman (1993), Boles (1997) and Wildes (1997) were the precursors

1. Daugman
   - Gabor Demodulation (PAMI 1993)
2. Lim, Lee, Byeon, Kim
   - Wavelet Features (ETRIJ 2001)
3. Bae, Noh, Kim
   - Independent Component Analysis (AVBPA 2003)
4. Ma, Tan, Wang, Zhang
   - Key local variations (IEEE TIP 2004)

Iris Recognition Process



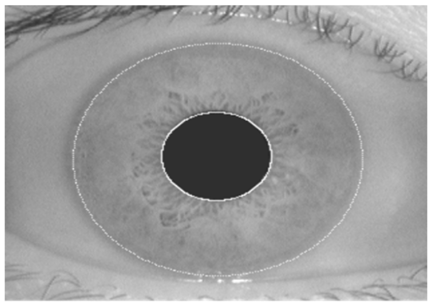
- Daugmans' Algorithm
- Made up of 4 stages

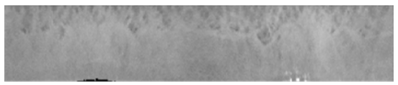
Accept/ Reject

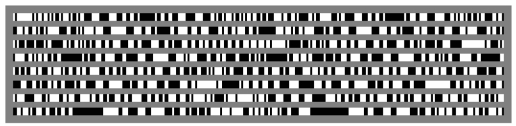
Localization and Segmentation → **Normalization and Unwrapping** → **Feature Extraction / Encoding** → **Comparison Matching**

Stage 1 | Stage 2 | Stage 3 | Stage 4

Template Database





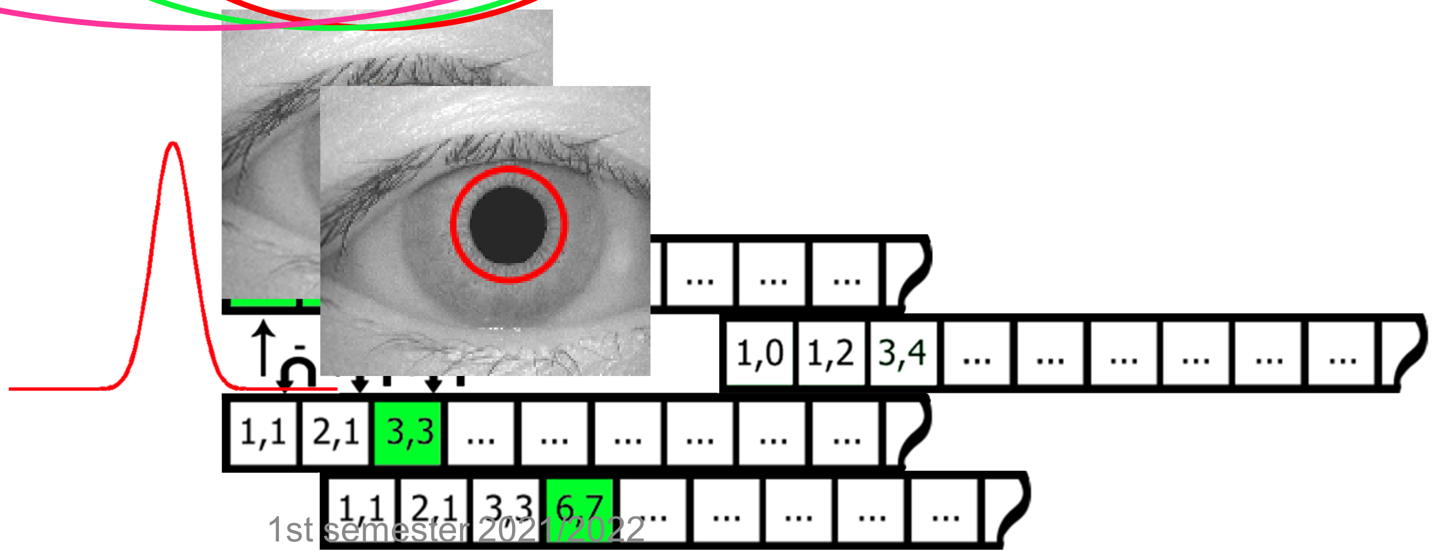


- *J. Daugman, "Statistical Richness of Visual Phase Information: Update on Recognizing Persons by Iris Patterns", International Journal of Computer Vision, 2001.*
- *J. Daugman, "Biometric Personal Identification System Based On Iris Analysis", US Patent 5291560, 1994*

Stage I: Segmentation

- Localizes the inner and outer boundaries of the iris
- Search for a circle where occurs a maximum change in pixel values
- Integro-differential operator (the most demanding stage)

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

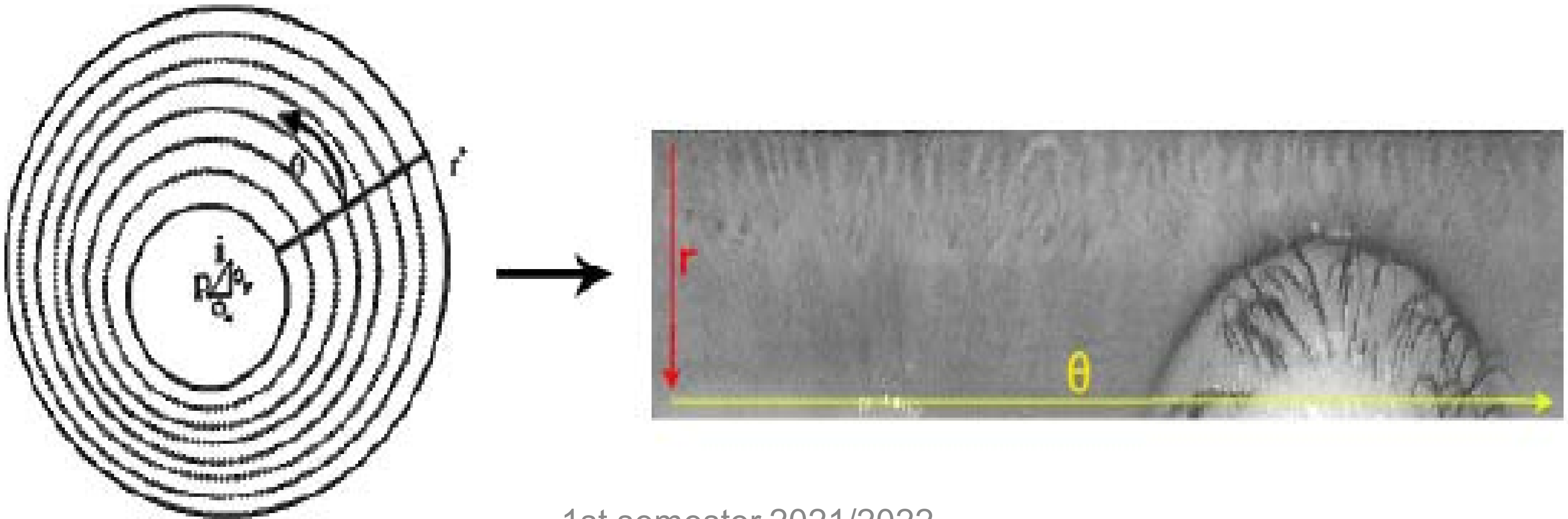


Stage II: Normalization

- Iris region is transformed into a normalized image
- Cartesian image is mapped into polar coordinates
- Compares iris with different sizes (pupil dilation)
- *Rubber-Sheet Model*
- Fixed resolution 100x360 pixels

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

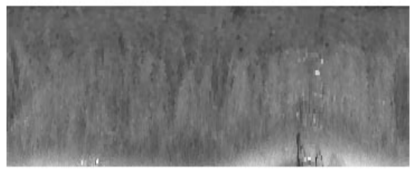
$$\begin{cases} x(r,\theta) = (1-r)x_{pupil}(\theta) + r.x_{iris}(\theta) \\ y(r,\theta) = (1-r)y_{pupil}(\theta) + r.y_{iris}(\theta) \end{cases}$$



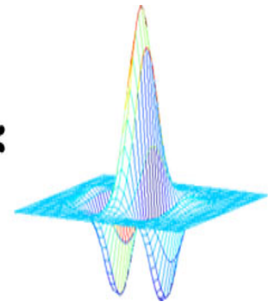
Stage III: Feature Extraction

- Gabor filtering in polar coordinate system

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



*

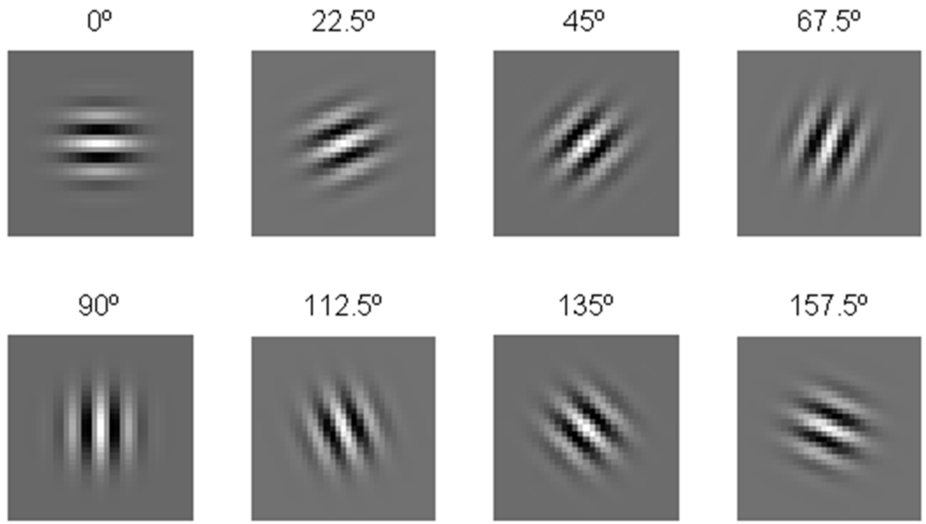


- Daugman*:
  - 8 different α,β from 0.15 to 1.2mm
- Ours:
  - 8 orientations

$$\left\{0, \frac{\pi}{8}, \frac{\pi}{4}, \frac{3\pi}{8}, \frac{\pi}{2}, \frac{5\pi}{8}, \frac{3\pi}{4}, \frac{7\pi}{8}\right\}$$

  - 4 frequencies

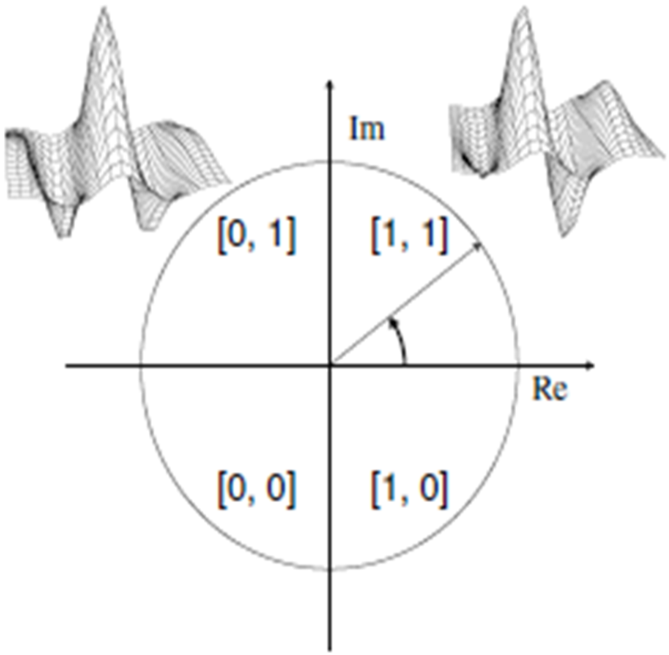
{0.05; 0.1; 0.12; 0.19} rad/s



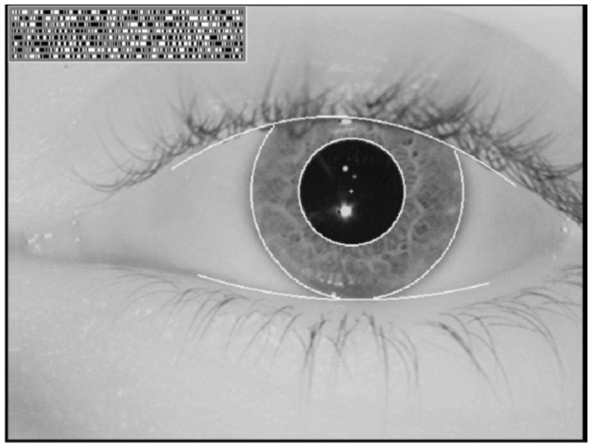
* ***J.Daugman, "How Iris Recognition Works",*** **IEEE Trans. on Circuits and Systems for Video Technology, Vol. 14, no. 1, January 2004**

Stage III: Encoding

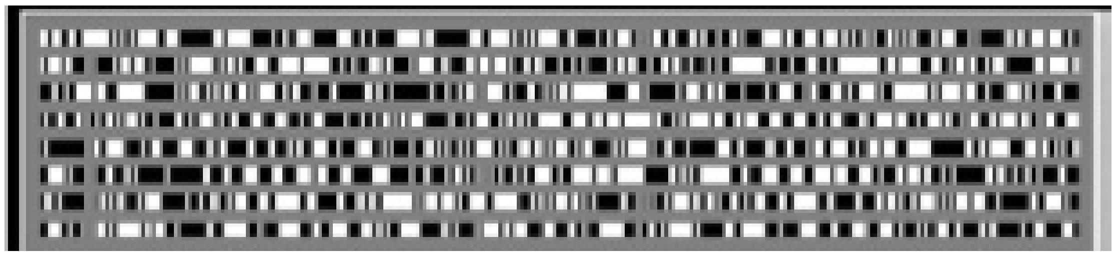
- Demodulation and phase quantization



$$g_{\{\mathrm{Re,Im}\}} = \mathrm{sgn}_{\{\mathrm{Re,Im}\}} \iint_{\rho\phi} I(\rho,\phi) e^{i\omega(\theta_0-\phi)} e^{-(r_0-\rho)^2/\alpha^2} e^{-(\theta_0-\phi)^2/\beta^2} \rho d\rho d\phi$$



IRIS Code: 2048 bits



J.Daugman, "Statistical Richness of Visual Phase Information: Update on Recognizing Persons by Iris Patterns", International Journal of Computer Vision, 2001.

Stage IV: Matching

- Binary comparison between IrisCodes
  - 1 to 1 for authentication
  - 1 to N for identification
- Compute the Hamming Distance (HD) between two IrisCodes

$$HD = \frac{\| (codeA \otimes codeB) \cap maskA \cap maskB \|}{\| maskA \cap maskB \|}$$

- Prevent corruption by eyelashes and eyelids

**** J. Daugman, "High confidence visual recognition of persons by a test of statistical independence." IEEE Trans. on PAMI, 1993***

Iris Recognition – some issues

- Reflections and non-uniform illumination are present in UBIRIS Images

- Due to this, segmentation and localization of iris and pupil can fail

- Pre-processing is therefore necessary:
  - Reflection Removal (2 methods)
    - Based on morphologic filtering
  - Pupil Enhancement and Isolation

Iris Recognition

- Daugmans integro-differential operator for Segmentation and Localization is time consuming
- Simplify the operator:

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

  - Remove Gaussian smoothing
  - Finite difference approximation
  - Interchange convolution and integration

- Modification on the Segmentation Stage
  – Template Matching Approach

Reflection Removal – Method A

Input: In, input image with 256 gray levels

Output: Out, output image without reflections on the pupil

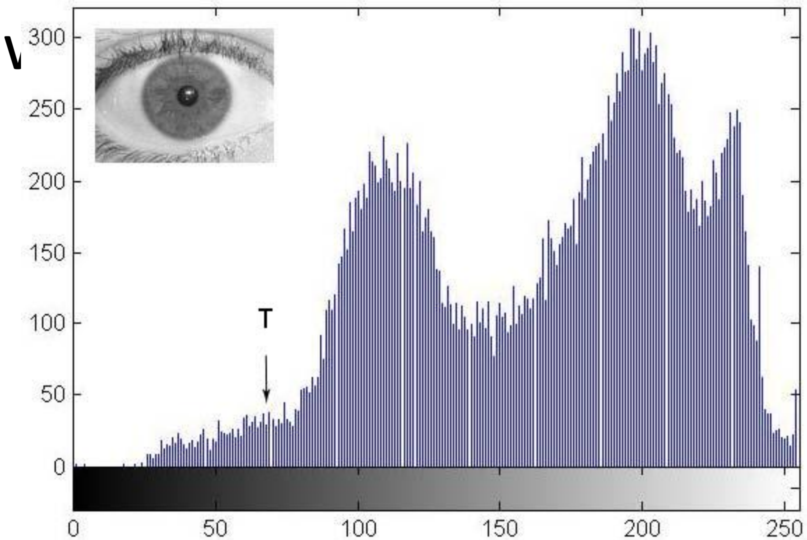
---

1. From the histogram of In, compute a threshold T to locate the pupil pixels.

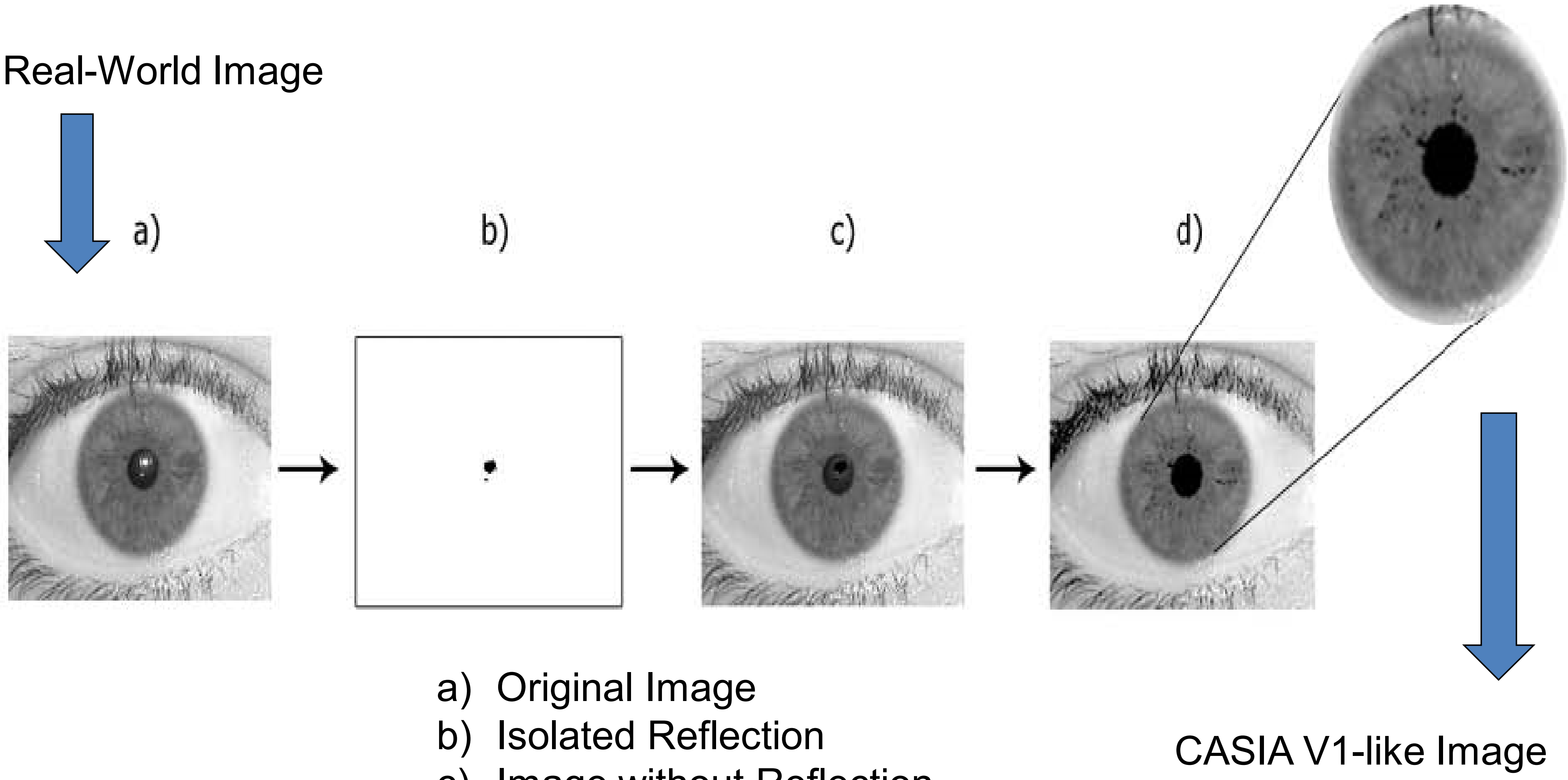
2. Set the pupil pixels (gray level below T) to zero.

3. Locate and isolate the reflection area, v
and apply a filling morphologic filter.

4. Out <- image with the reflection area
pixels set to zero.



Reflection Removal – Method A



a) Original Image
b) Isolated Reflection
c) Image without Reflection
d) Image with an Uniform Pupil

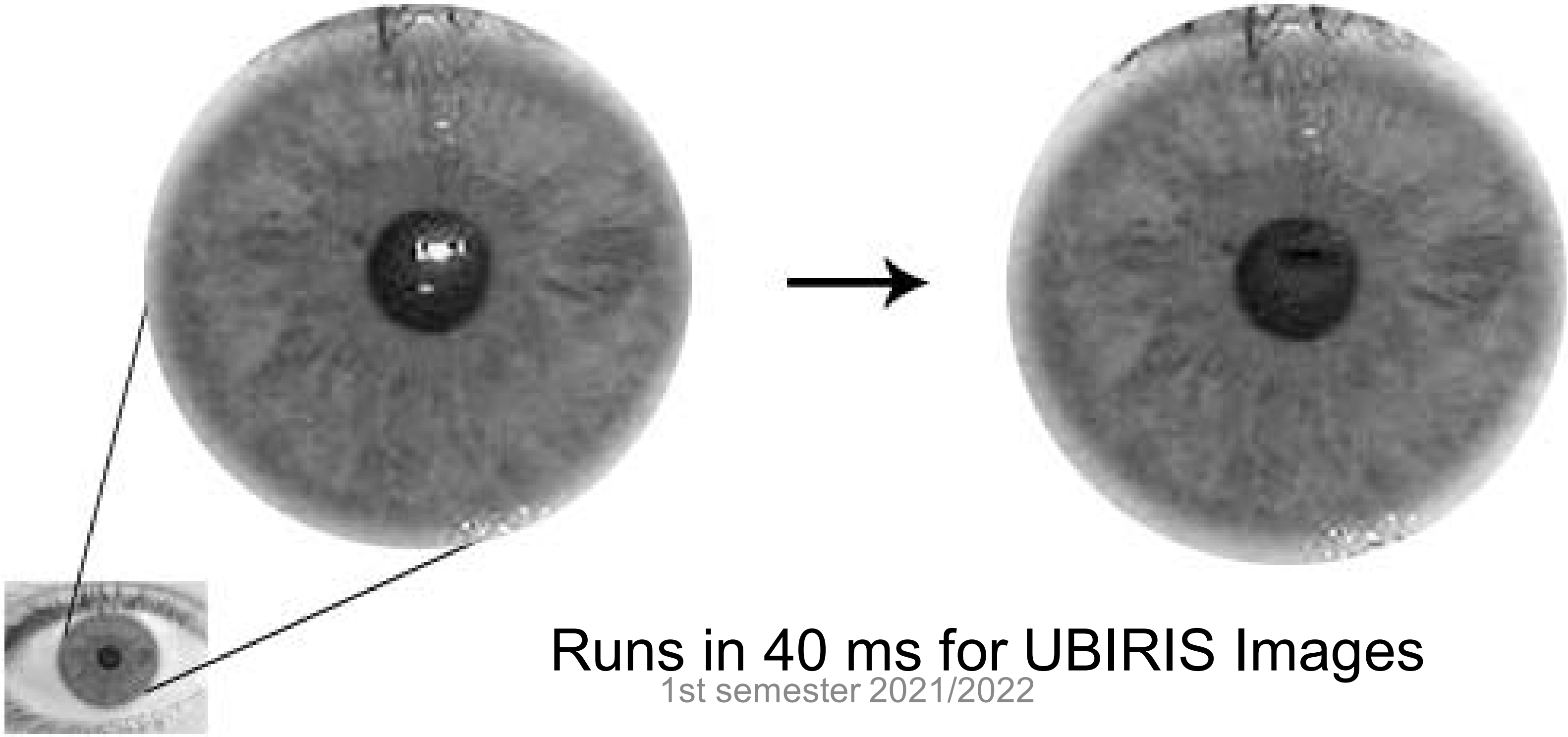
Reflection Removal – Method B

Input: In, input image with 256 gray levels

Output: Out, output image without reflections on the pupil

---

1. NIn <- negative version of Iin
2. Let Ip be the output of the morphologic filling filter on Nin.
3. Out <- negative version of Ip.



Runs in 40 ms for UBIRIS Images

Pupil Enhancement/Isolation

Input: In, input image with 256 gray levels

τ, standard deviation for the gaussian filter

T, minimum number of pupil pixels

Output: Out, binary output image with isolated pupil

---

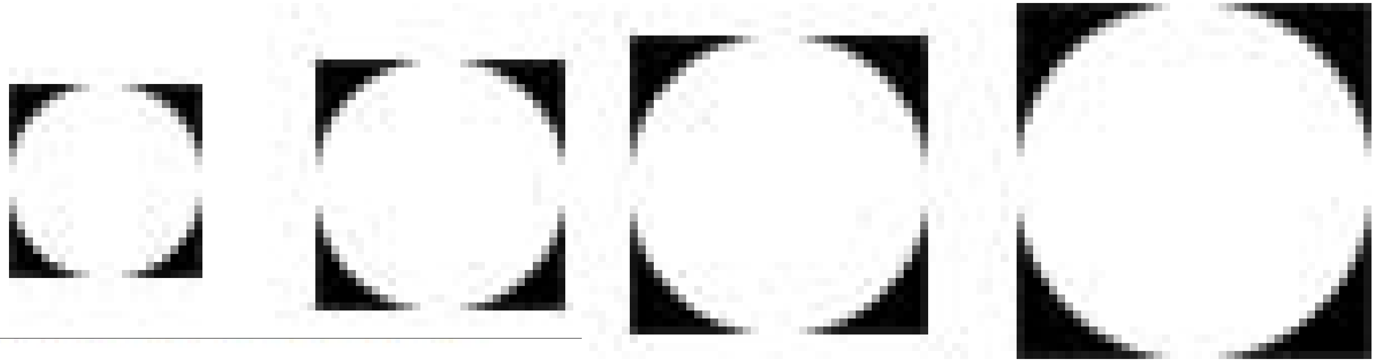
1. Remove reflections (methods A or B) on Iin.
2. Apply a gaussian filter $G\tau$ to smooth the image.
3. Apply the Canny Edge detector for pupil and iris detection; retain only the pupil area.
4. While the number of white pixels is below T,

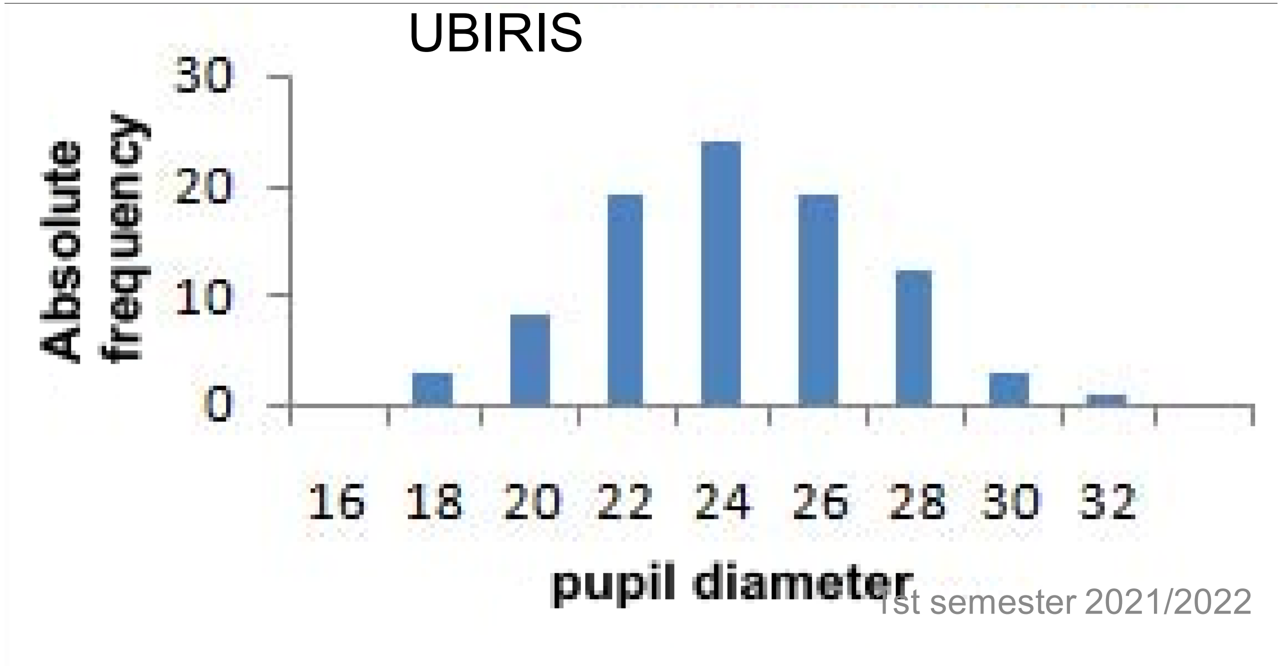
   dilate the detected contours.
5. Out <- output of the filling morphologic filter.

Template Matching

A strategy for the *Segmentation Phase*

Template Matching (TM) by cross-correlation between iris images and several circular templates





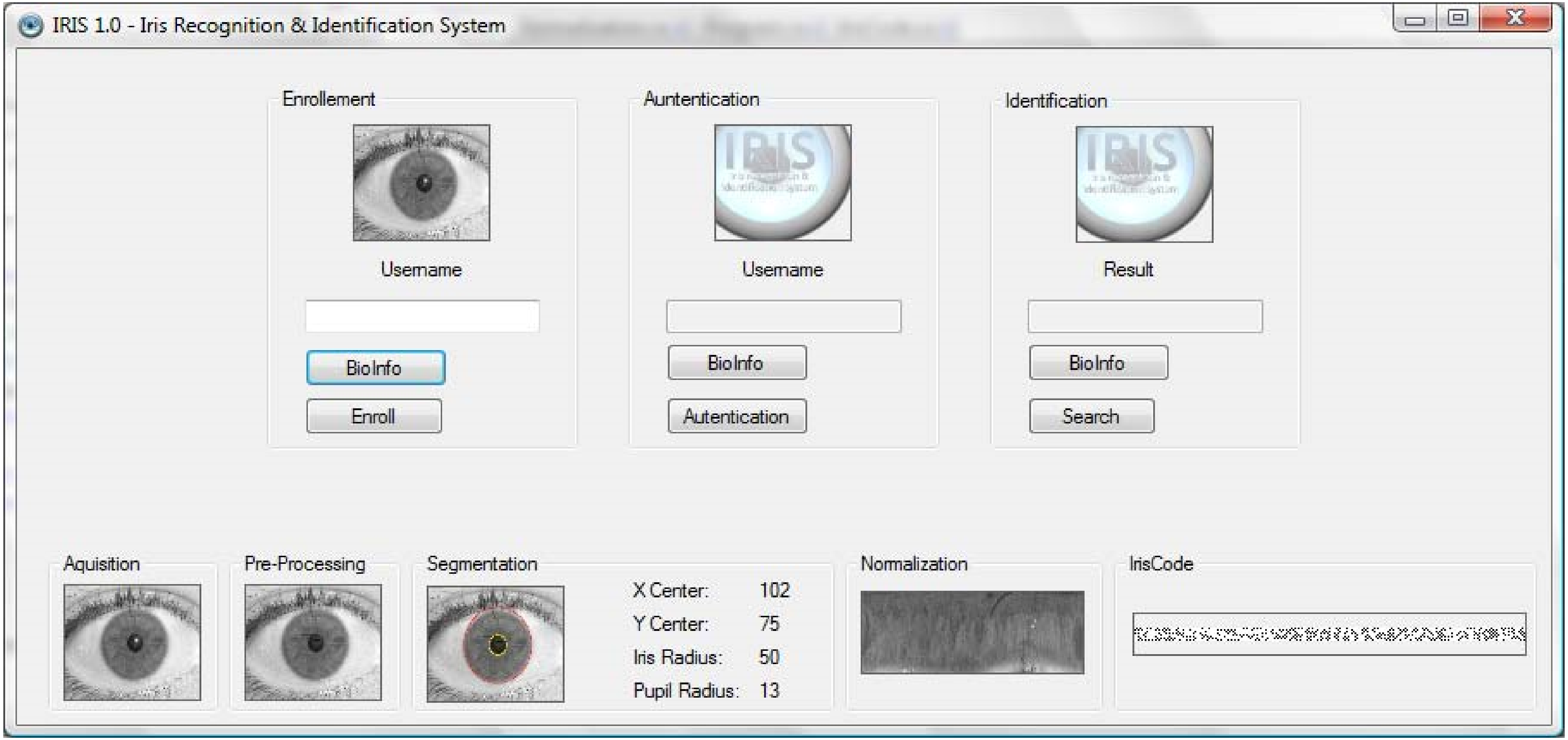
Diameters
D={ 20, 22, 24, 26, 28, 30 }

Steps of 2 pixels

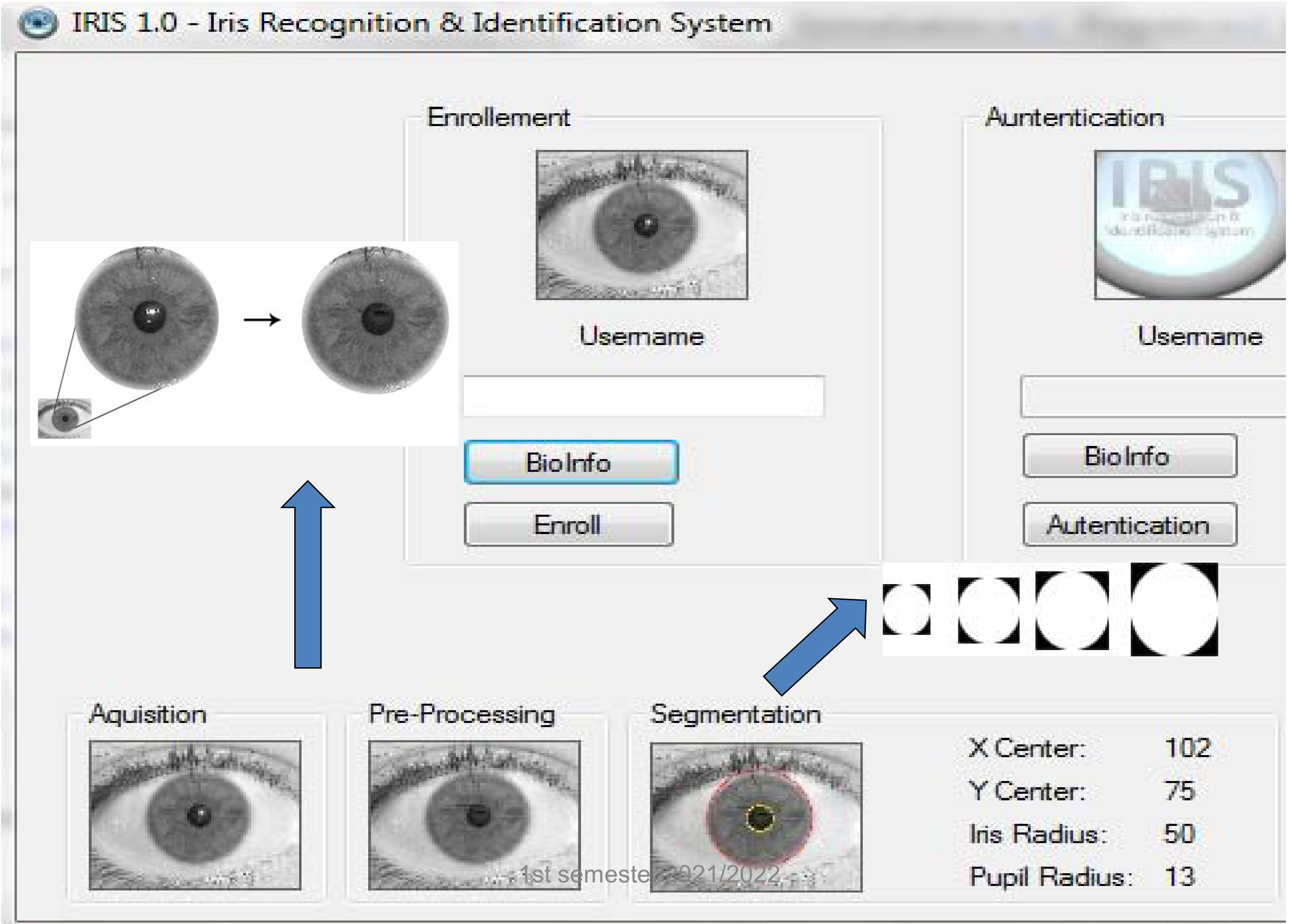
Invariant to rotation

Software Prototype (1)

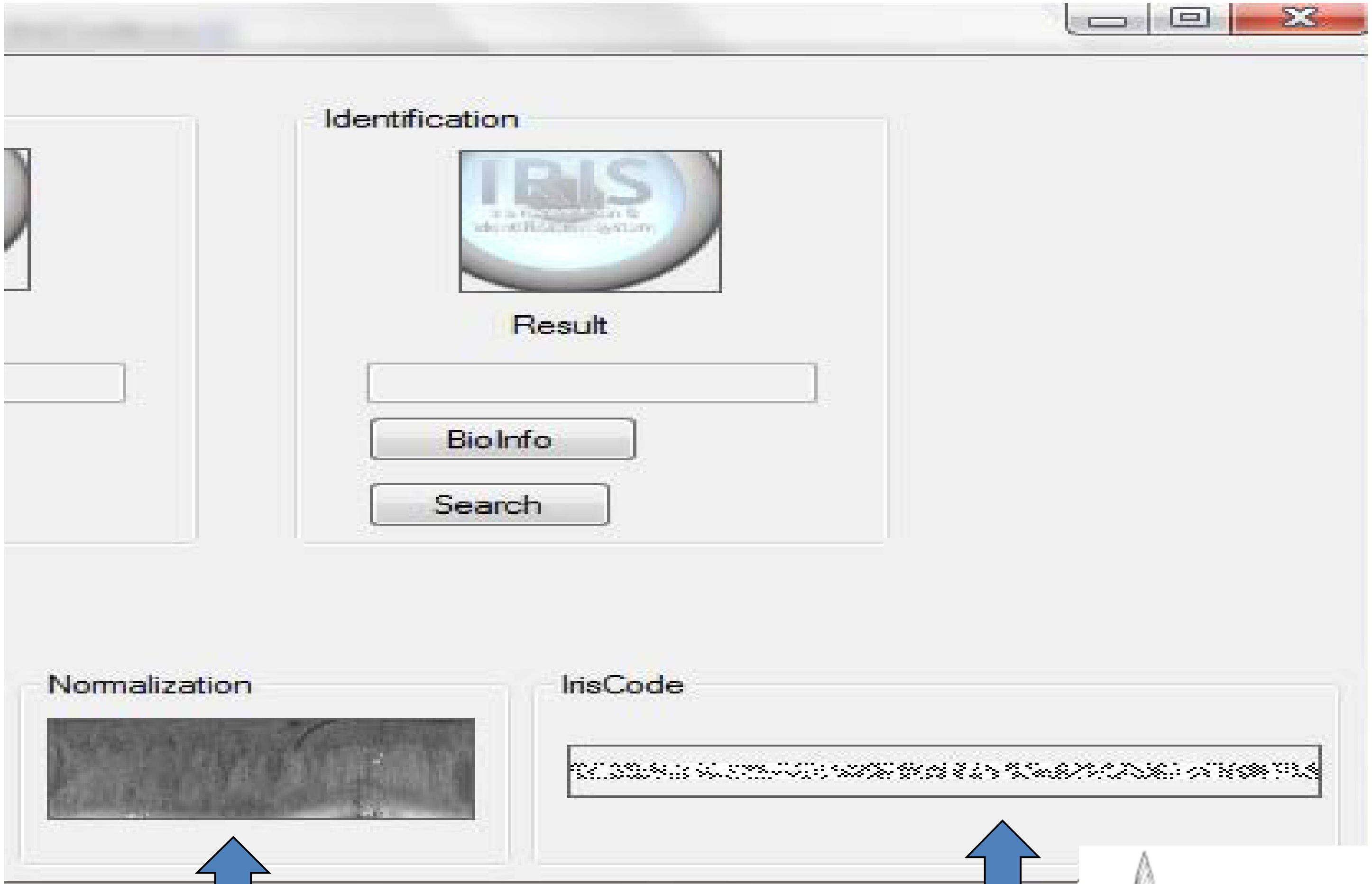
C# software

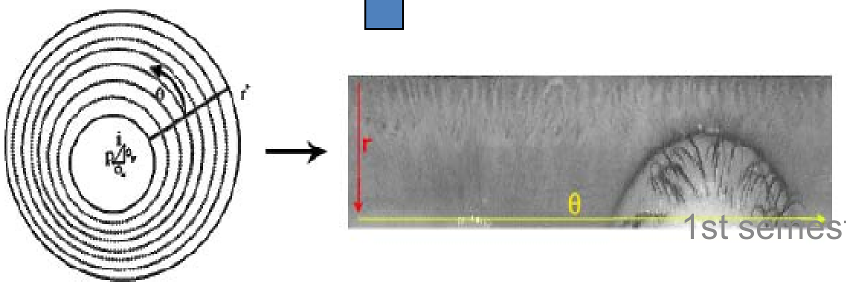


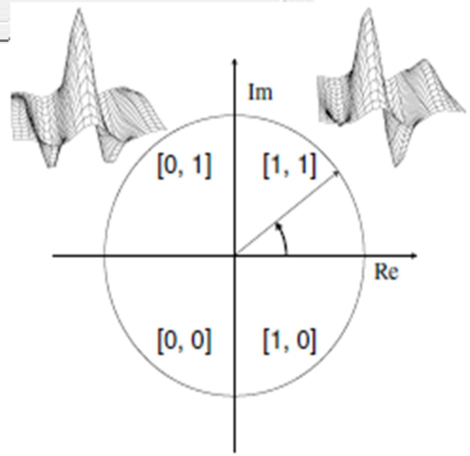
Software Prototype (2)



Software Prototype (3)







Experimental Results (1)

Percentage of Success of the Segmentation Phase

Integro-Differential (ID) Operator vs Template Matching

Database	# Images	ID Operator	TM	TM + ID
UBIRIS	1877	95.7 %	96.3 %	96.3 %
CASIA V1	756	98.4 %	98.5 %	98.7 %
CASIA V3	756	94.0 %	98.8 %	98.8 %

- The ID Operator is 7 to 10 times slower than the Template Matching Technique
- Cross Correlation can be done by FFT and IFFT
- No advantage in combining both techniques

Experimental Results (2)

Using Gabor filters with 8 orientations and 4 frequencies

- Orientations $\left\{0, \frac{\pi}{8}, \frac{\pi}{4}, \frac{3\pi}{8}, \frac{\pi}{2}, \frac{5\pi}{8}, \frac{3\pi}{4}, \frac{7\pi}{8}\right\}$
- Frequencies {0.05; 0.1; 0.12; 0.19} rad/s

Database	Recognition Rate
UBIRIS	87.2 %
CASIA V1	88.0 %

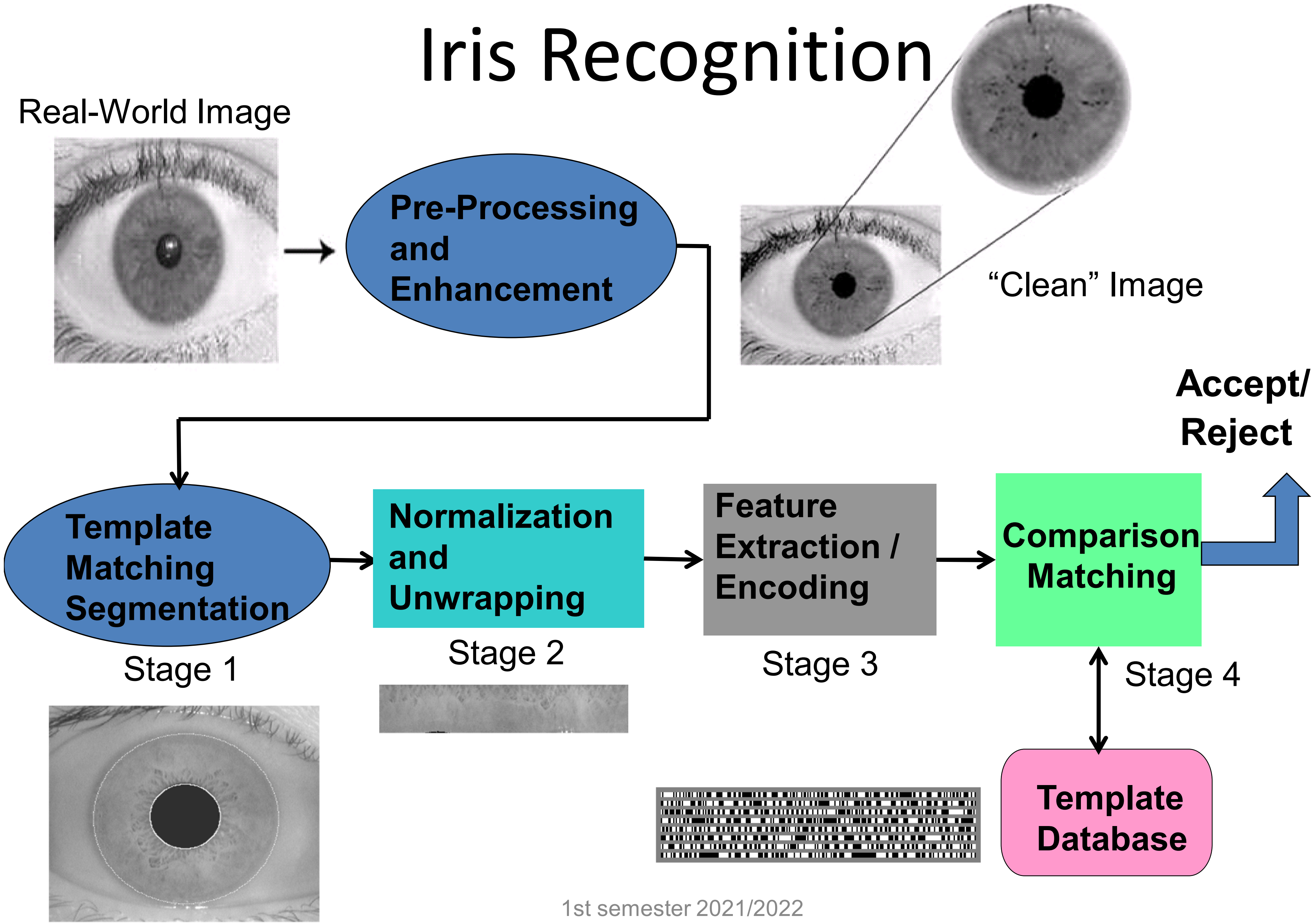
This recognition rate can be improved (future work):

– better choice of orientations and frequencies

– use of a larger IrisCode

– matching with a cyclic rotation on the IrisCode

Iris Recognition



Face

- The (frontal) image of a human face
- Easily recognized by humans
- Color or monochrome images

Face

- Uniqueness property ?!
- Identical twins; a father and his son

Face Detection and Face Recognition

- **Face detection** is the first step for automated **face recognition**

- **Face detection**
  - Consists on detecting/locating a face on an image

- **Face recognition**
  - Identification
  - Verification

https://en.wikipedia.org/wiki/Face_detection

Face Detection

- The Viola-Jones algorithm (four stages)
- https://en.wikipedia.org/wiki/Viola%E2%80%93Jones_object_detection_framework
- https://www.mathworks.com/help/vision/ref/vision.cascadeobjectdetector-system-object.html

Detected faces

Face Recognition

- There are two common techniques for the face recognition task:
  - EigenFaces
  - FisherFaces

EigenFaces (1)

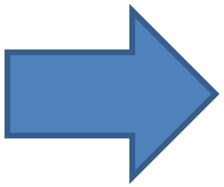
- https://en.wikipedia.org/wiki/Eigenface

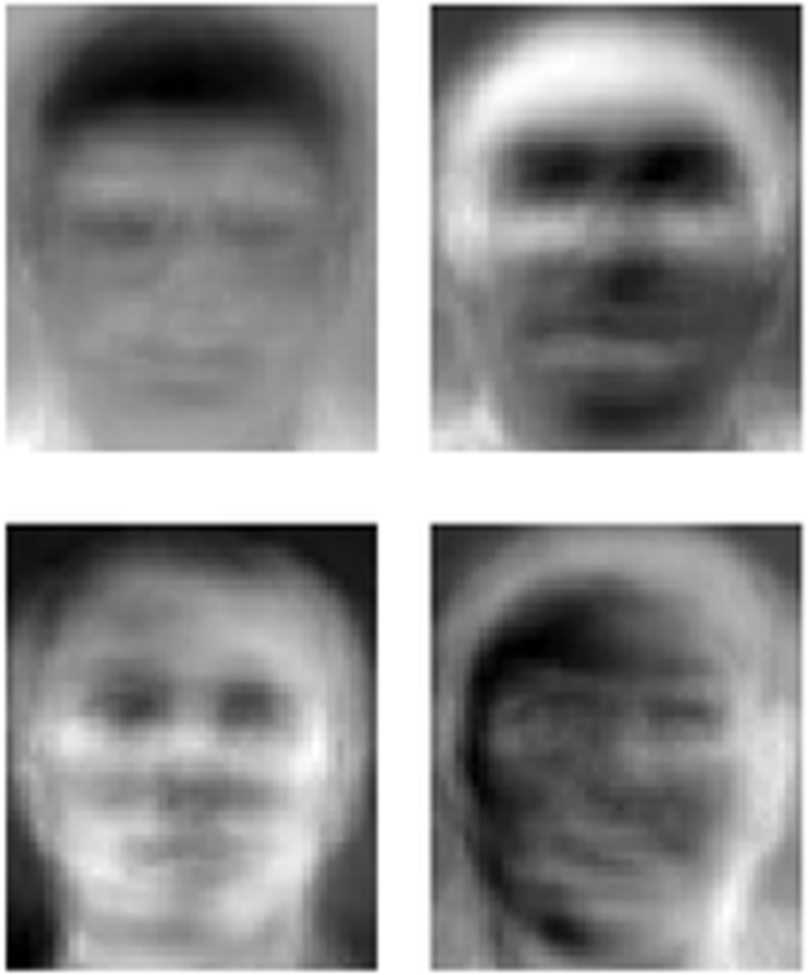
- The eigenvectors are derived from the covariance matrix
- The eigenfaces form a basis set of all images used to construct the covariance matrix
- Performs dimension reduction - a smaller set of basis images represents the original training images
- Classification can be achieved by comparing how faces are represented by the basis set

EigenFaces (2)

- https://en.wikipedia.org/wiki/Eigenface

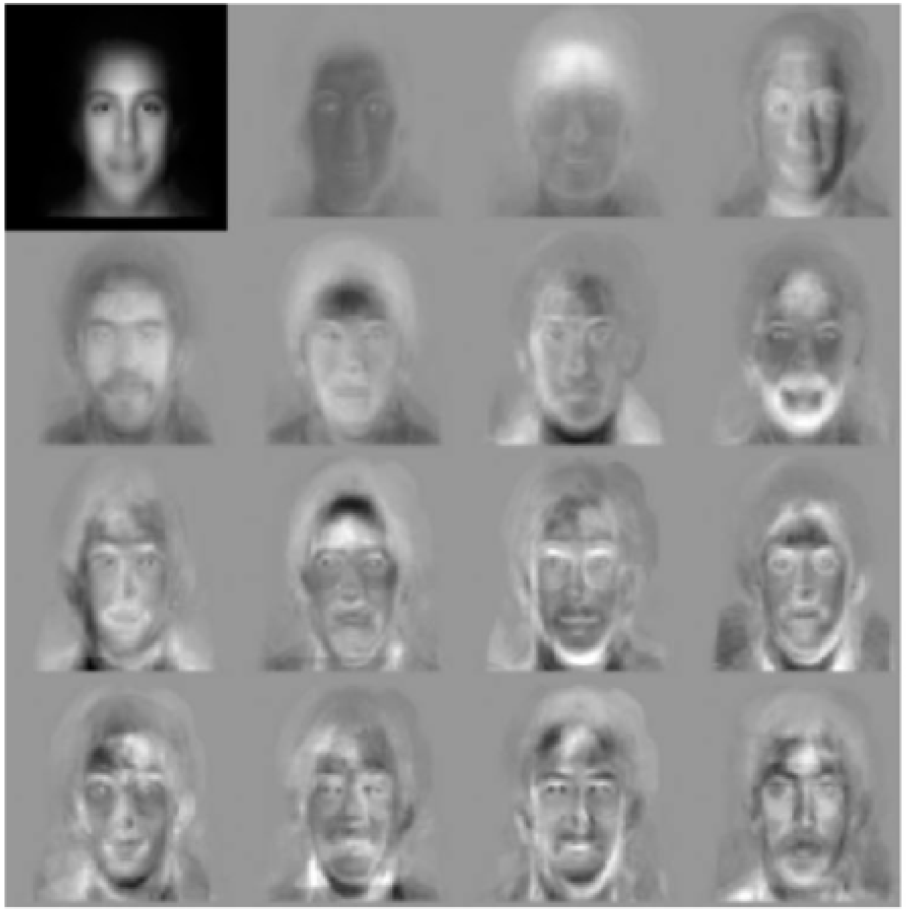
The eigenfaces form a basis set of all images used to construct the covariance matrix





FisherFaces (1)

- https://docs.opencv.org/2.4/modules/contrib/doc/facerec/facerec_tutorial.html#fisherfaces



Bibliography

- A. Jain, P. Flynn, A. Ross, *Handbook of Biometrics*, Springer, 2008, ISBN: 9780387710402

- S. Li, A. Jain, *Handbook of Face Recognition*, Second edition, Springer, 2011, ISBN: 978-0-85729-932-1

- http://biolab.csr.unibo.it/home.asp

- https://facedetection.com/