Noisy Iris Detection

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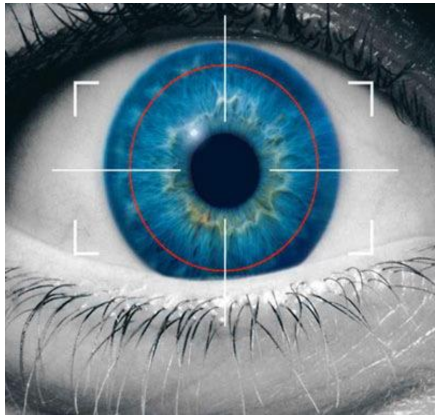
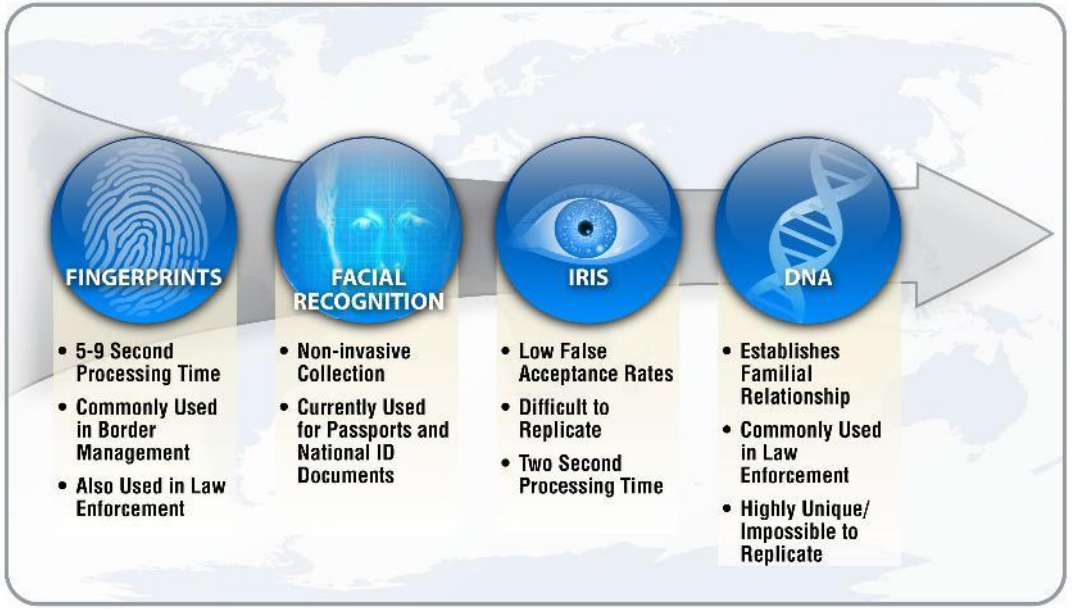
AGENDA



1. Biometric Overview
2. **IRIS and Daugman**
3. NICE I: Iris Segmentation (Detection)
4. NICE II: Iris Coding and Matching (Recognition)
5. Dataset Evaluations
6. MICHE: Mobile Iris Challenge Evaluation
7. Multibiometric Involving Iris
8. Conclusions

Some Desirable Properties

	Universality	Distinctiveness	Permanence	Collectability	Performance	Acceptability	Unspoofability
Fingerprint	M	H	H	M	H	M	M
Iris	H	H	H	M	H	L	H
Retina	H	H	M	L	H	L	H
Hand Geometry	M	M	M	H	M	M	M
Palmprint	M	H	H	M	H	M	M
Hand Vein	M	M	M	M	M	M	H
Voice	M	L	L	M	L	H	L
Face	H	L	M	H	L	H	L
Face Therm.	H	H	L	H	M	H	H
DNA	H	H	H	L	H	L	L



Some Desirable Properties (cont)

Biometric Trait	*Comfort*	*Accuracy*	*Availability*	*Costs*
Finger Print	ooooooo	ooooooo	oooo	ooo
Signature (dynamic)	ooo	oooo	ooooo	oooo
Facial geometry	ooooooooo	oooo	ooooooo	ooooo
Iris	oooooooo	ooooooooo	oooooooo	oooooooo
Retina	oooooo	oooooooo	ooooo	ooooooo
Hand geometry	oooooo	ooooo	oooooo	ooooo
Finger geometry	ooooooo	ooo	ooooooo	oooo
Vein Structure of the back of the hand	oooooo	oooooo	oooooo	ooooo
Ear form	ooooo	oooo	ooooooo	ooooo
Voice	oooo	oo	ooo	oo
DNA	o	ooooooo	ooooooooo	ooooooooo
Odor	?	oo	ooooooo	?
Keyboard strokes	oooo	o	oo	o
Comparison: Password	ooooo	oo	oooooooo	o

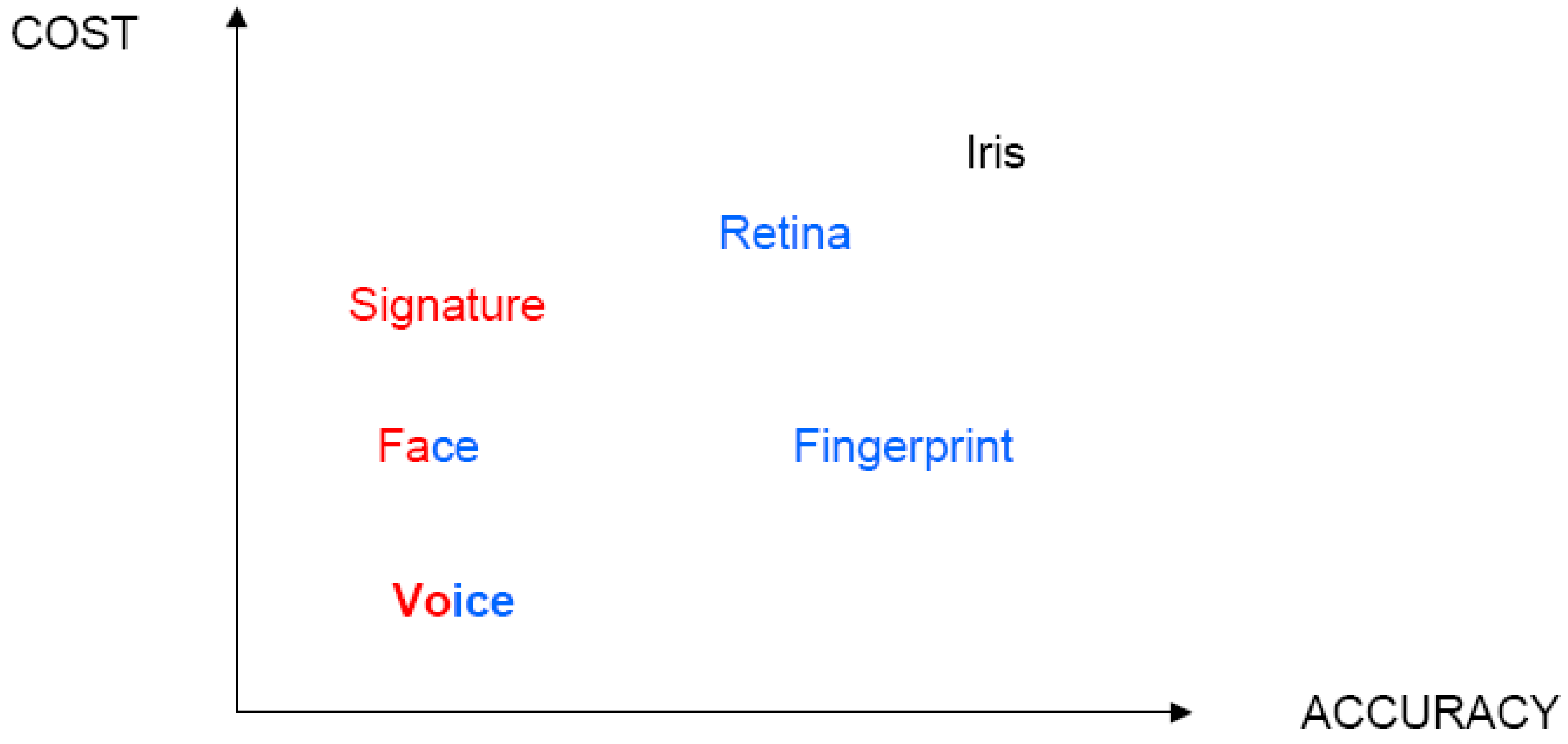
green = best red = worst

Biometric Overview

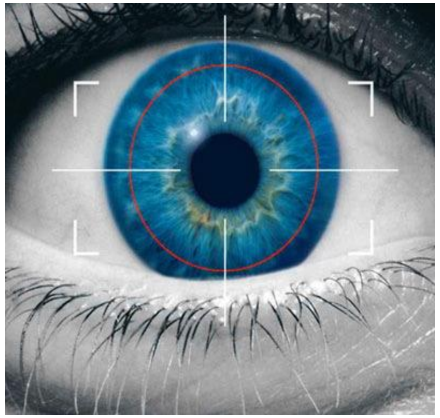
Biometric characteristic	*genotypic**	*randotypic**	*behavioral***
Fingerprint (only minutia)	o	ooo	o
Signature (dynamic)	oo	o	ooo
Facial geometry	ooo	o	o
Iris pattern	o	ooo	o
Retina (Vein structure)	o	ooo	o
Hand geometry	ooo	o	o
Finger geometry	ooo	o	o
Vein structure of the hand	o	ooo	o
Ear form	ooo	o	o
Voice (Tone)	ooo	o	oo
DNA	ooo	o	o
Odor	ooo	o	o
Keyboard Strokes	o	o	ooo

Biometric Trait	*Permanence over time*
Fingerprint (Minutia)	oooooo
Signature(dynamic)	oooo
Facial structure	ooooo
Iris pattern	ooooooooo
Retina	oooooooo
Hand geometry	ooooooo
Finger geometry	ooooooo
Vein structure of the back of the hand	oooooo
Ear form	oooooo
Voice (Tone)	ooo
DNA	ooooooooo
Odor	oooooo ?
Keyboard strokes	oooo

Comparison of biometric techniques



AGENDA



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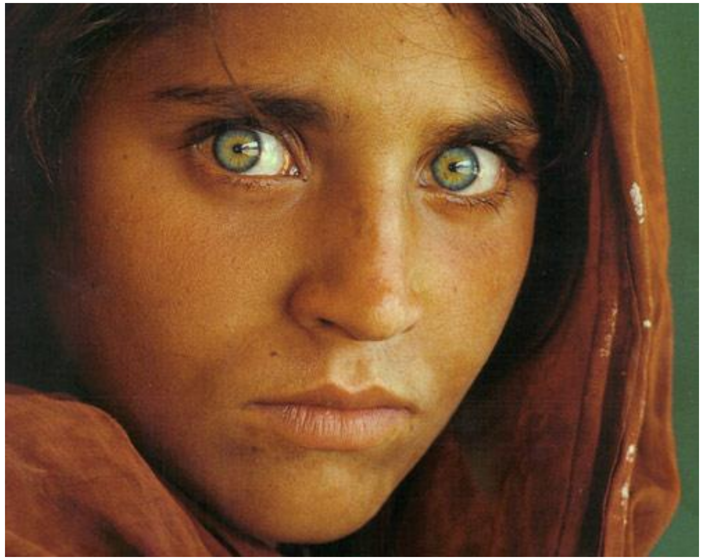
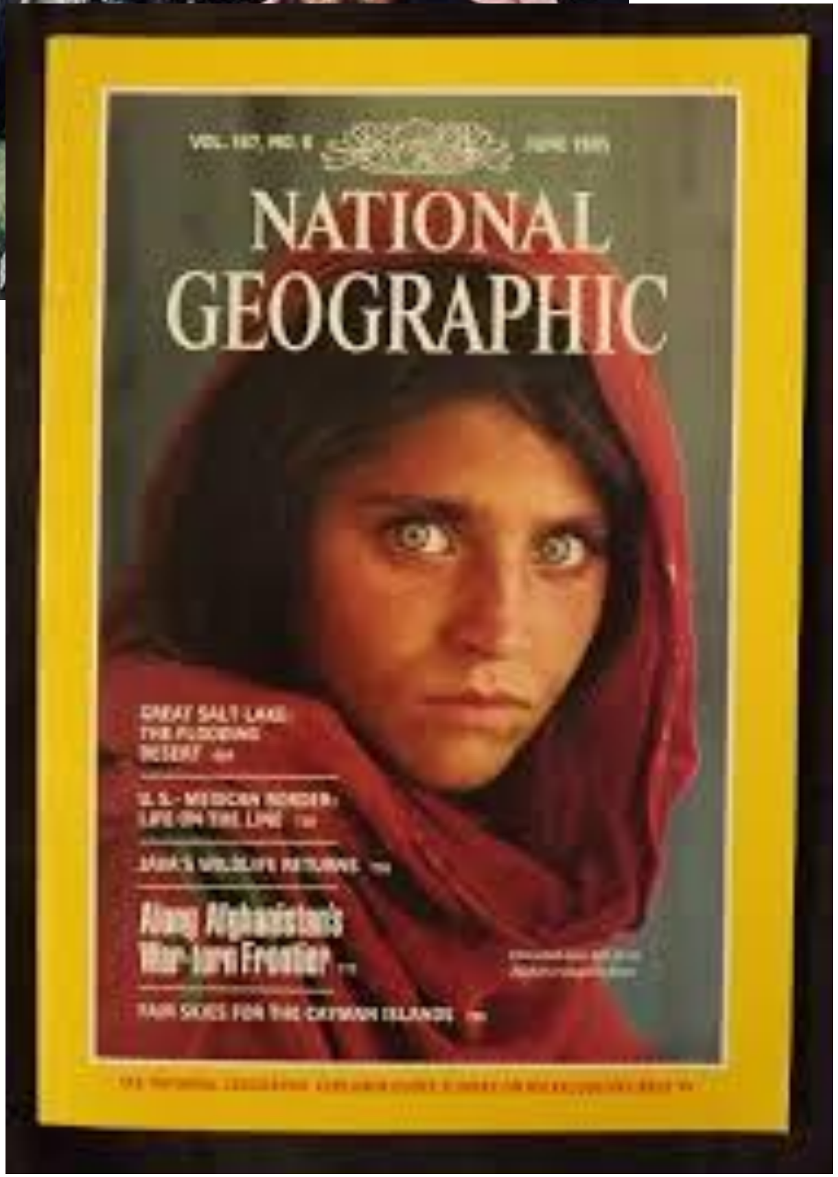
The Afghan Monna Lisa

- **1984: in a refugee camp in Pakistan**
- **2002: (18 years later) in Afghanistan**

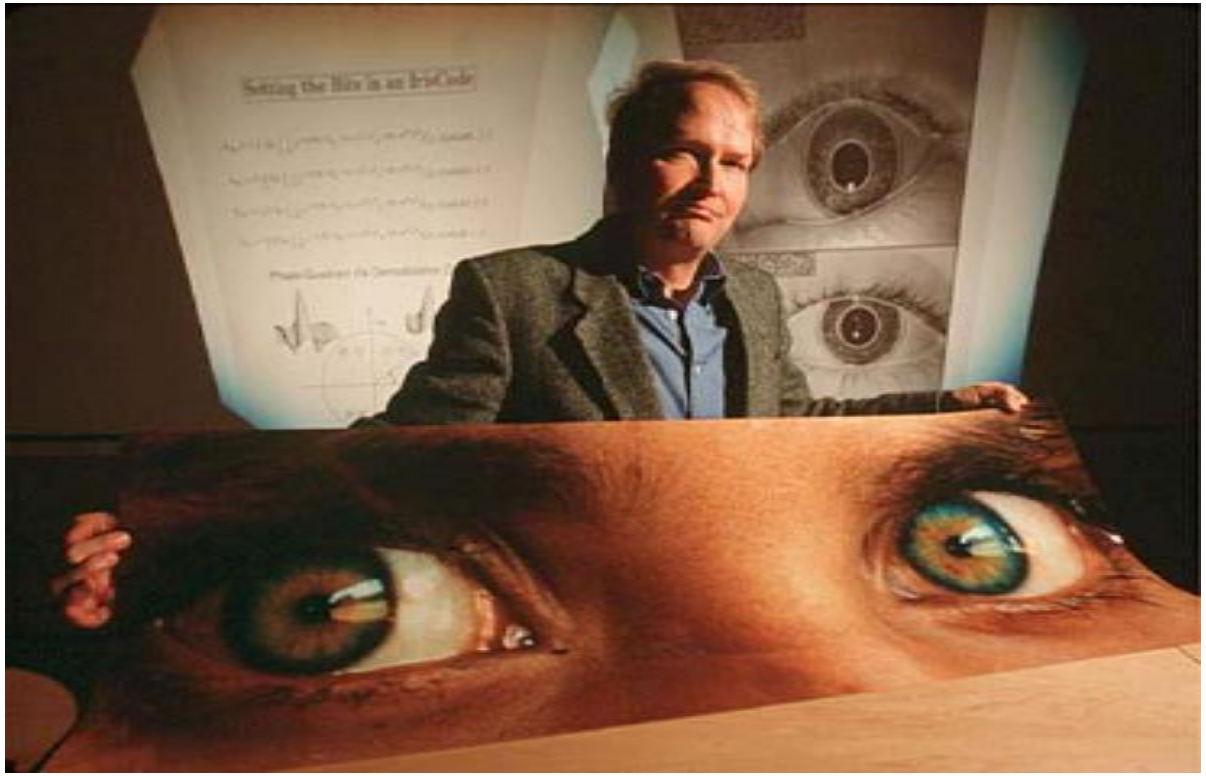
photographed twice by McCurry from National Geographic.





The Afghan Monna Lisa

John Daugman and the Eyes (Iris) of Sharbat Gula

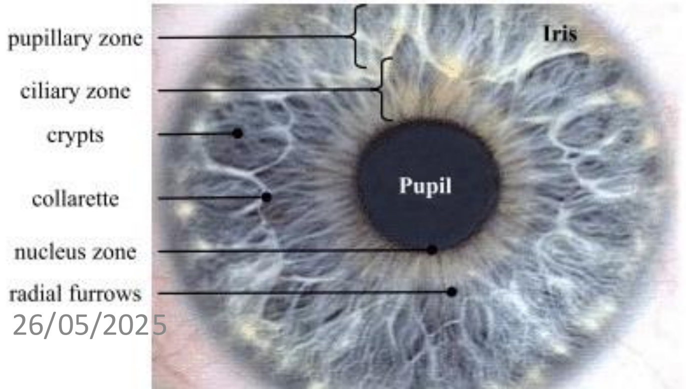


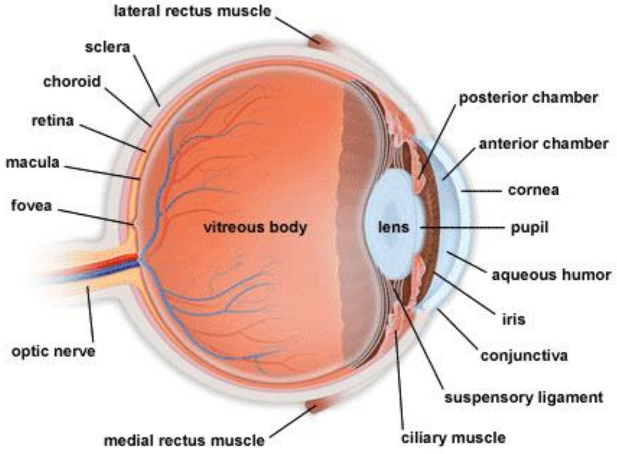
Left eye: HD=0.24; Right eye: HD=0.31

- If the HD (Hamming distance) is < 0.33 the chances of the two codes coming from different irises is 1 in 2.9 million

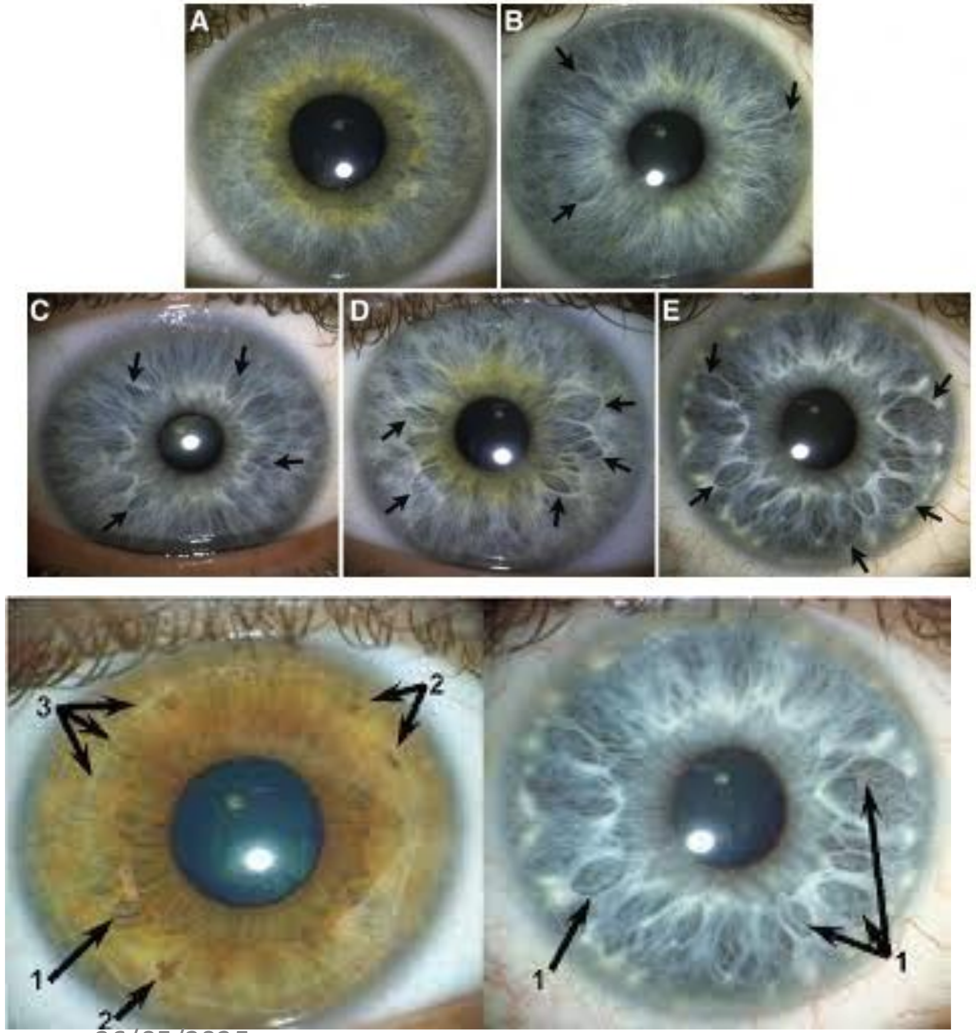
Iris

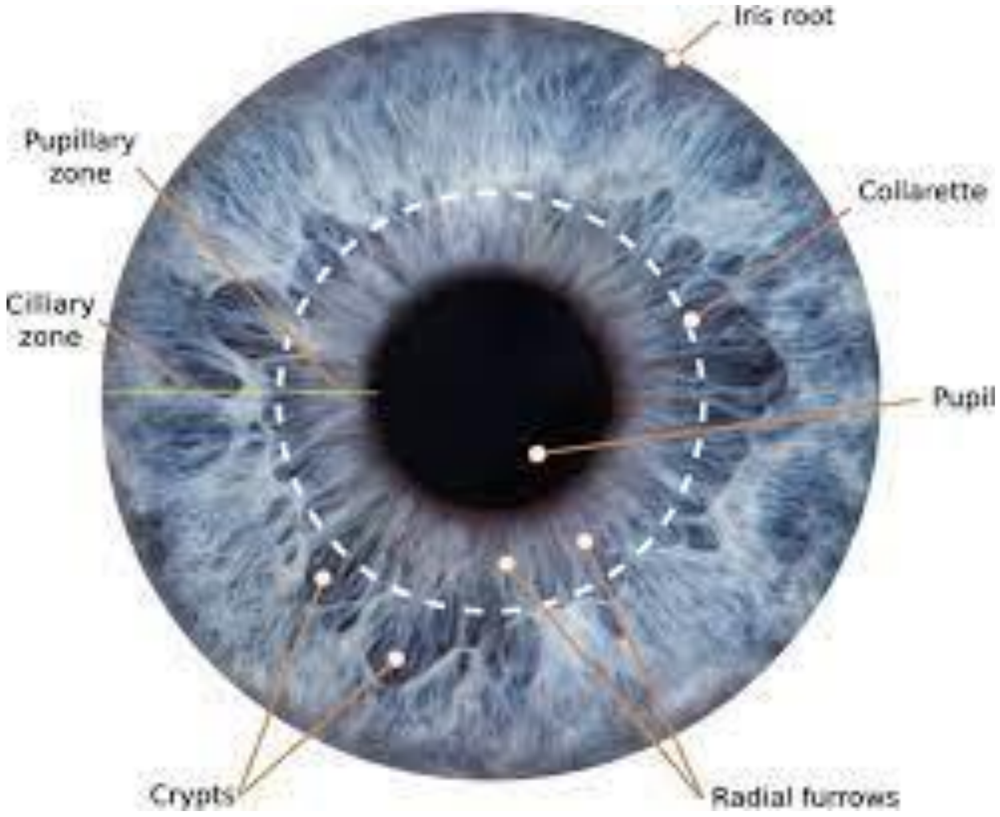
- The iris is a muscle membrane of the eye, of variable color, with both shape and function of a diaphragm
- It is pigmented, located posterior to the cornea and in front of the lens, and is perforated by pupil.
- It consists of a flat layer of muscle fibers which circularly surround the pupil, a thin layer of smooth muscle fibers by means of which the pupil is dilated (thereby regulating the amount of light that enters the eye) and posteriorly by two layers of epithelial pigmented cells
- Iris colour, “regular” texture (mostly by furrows) and “irregular” patterns (e.g., freckles and crypts) provide a very high level of discrimination, which is comparable to fingerprints





Iris Pattern: Cripts and Furrows





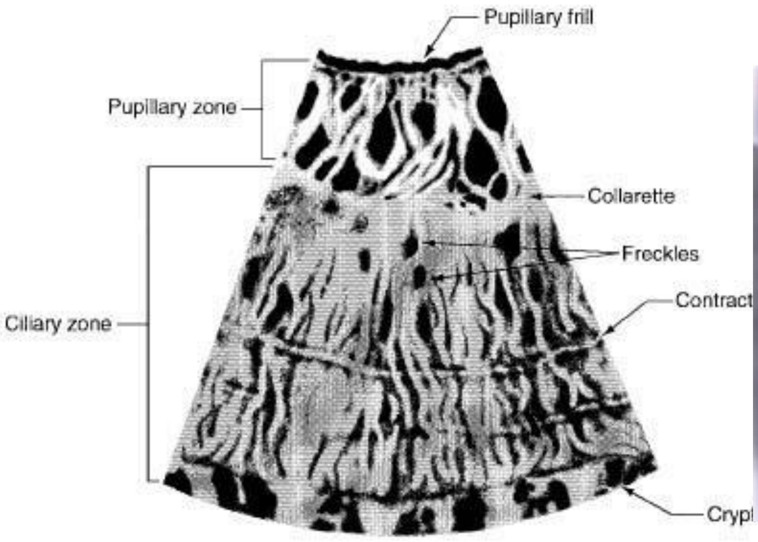
Iris

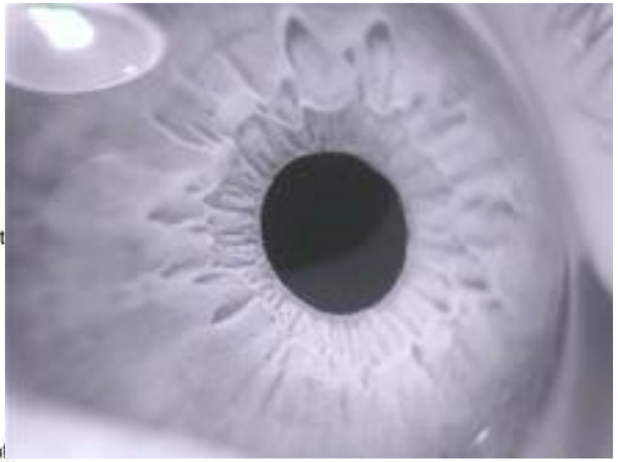
Pros

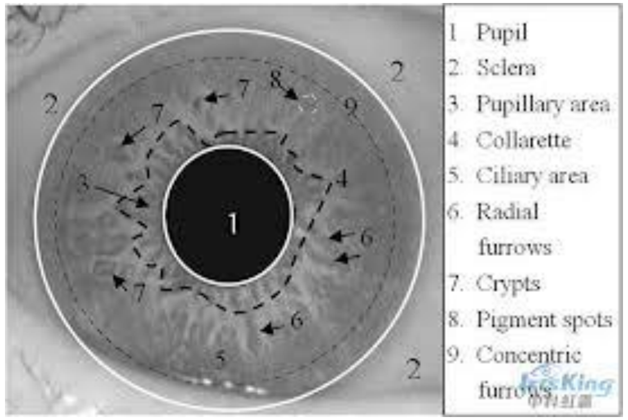
- Iris is visible yet well protected
- It is a time invariant and extremely distinguishing trait
- Its image can be acquired without direct contact
- Acquisition: near infrared and visible wavelenghts

Cons

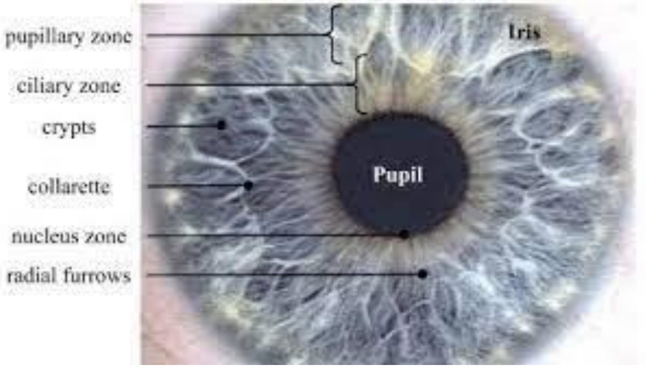
- Iris' surface is very limited: only about 3.64 cm2
- A "good" acquisition requires a distance of less than one meter to guarantee a sufficient resolution, depending on the input device.







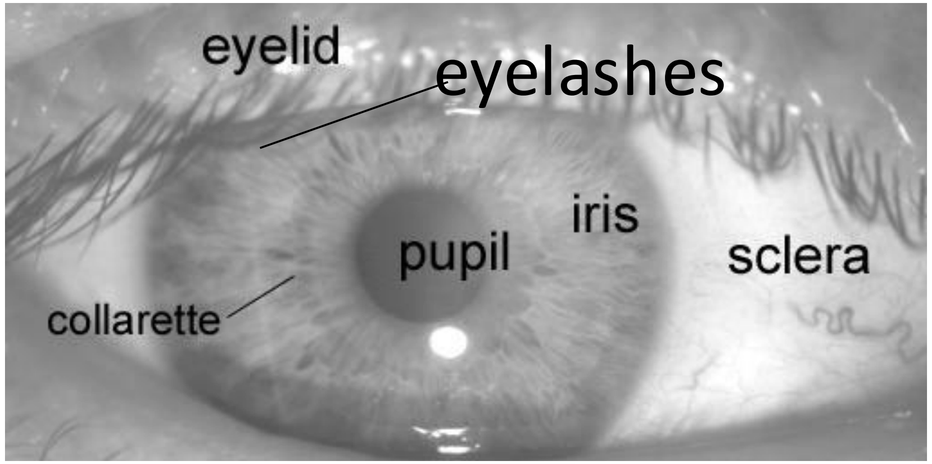
Near Infrared

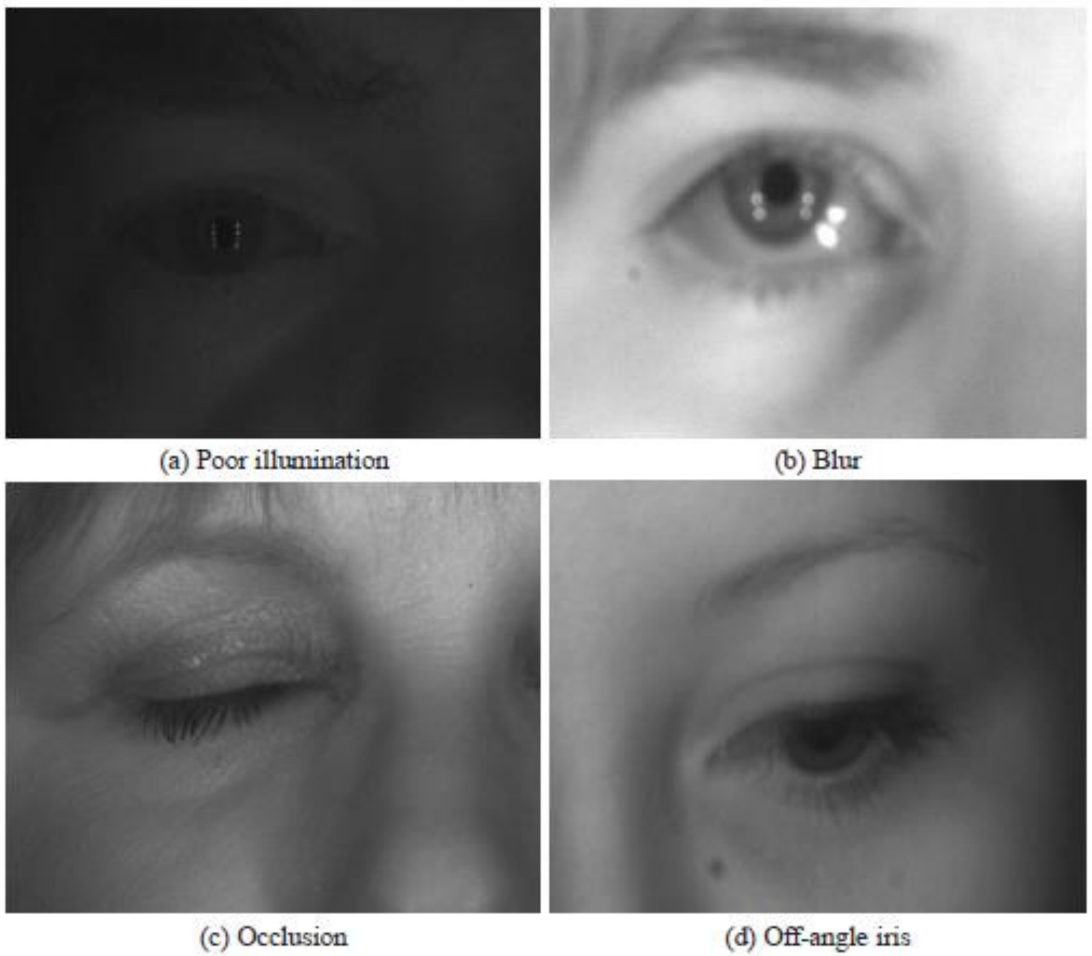


Visible Wavelenghts

Processing Phases on the Periocular Region

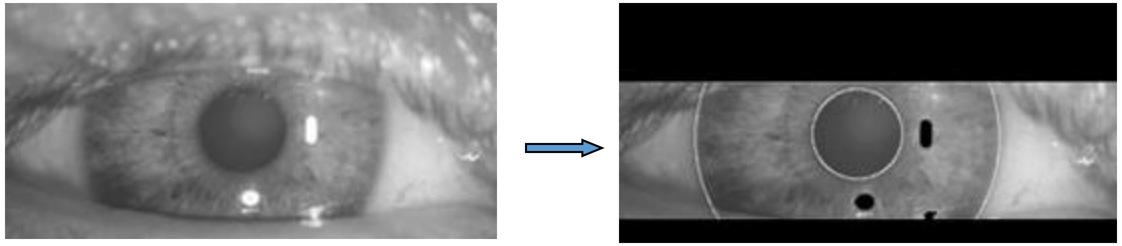
- The presence of a number of noisy elements requires a good pre-processing/segmentation



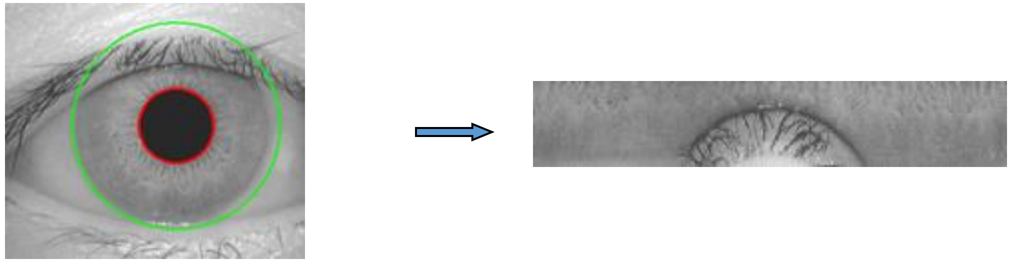


Processing phases

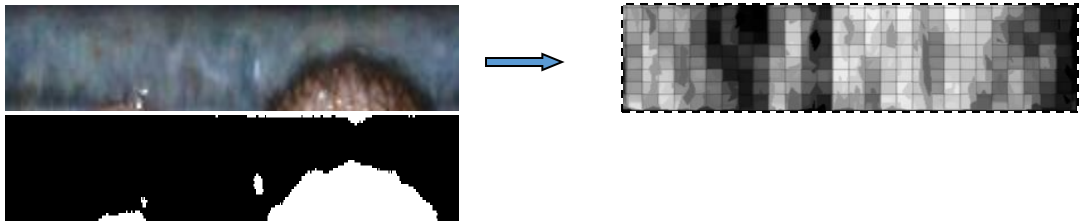
- Detection\Segmentation



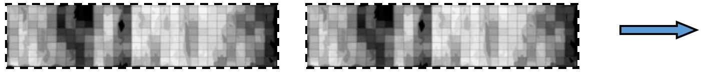
- Normalization



- Coding

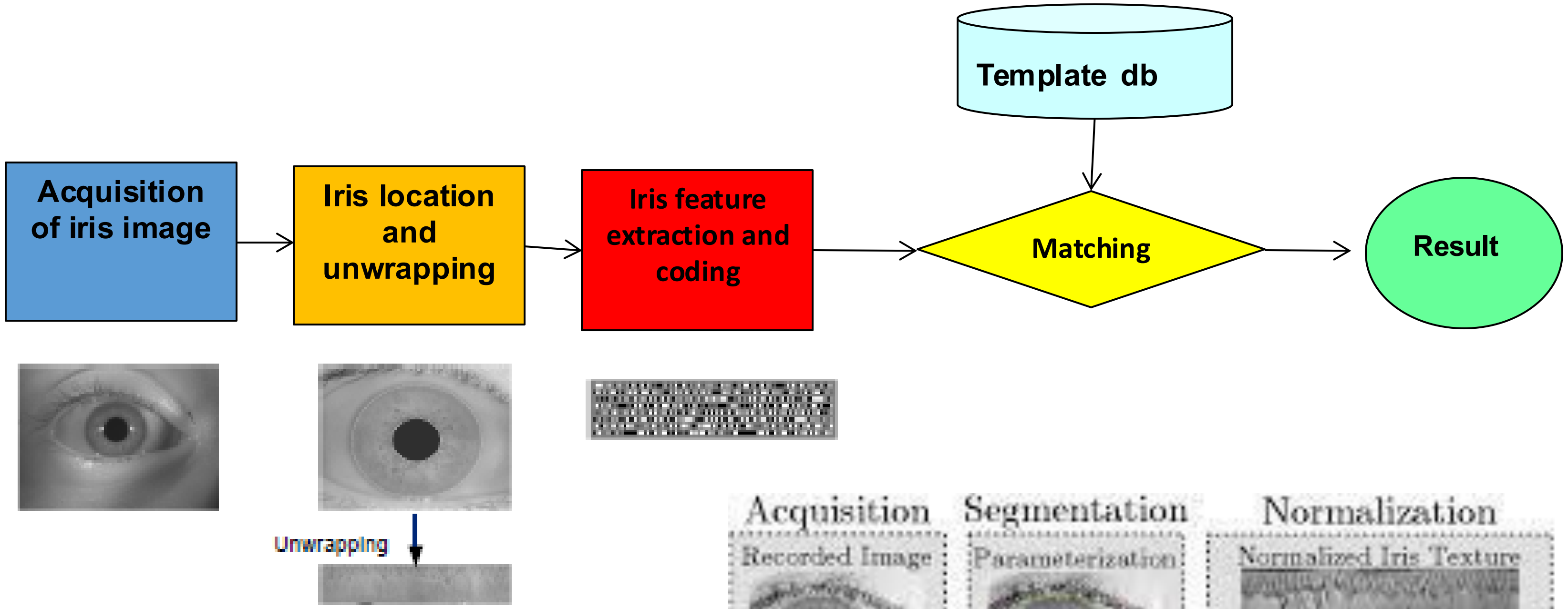


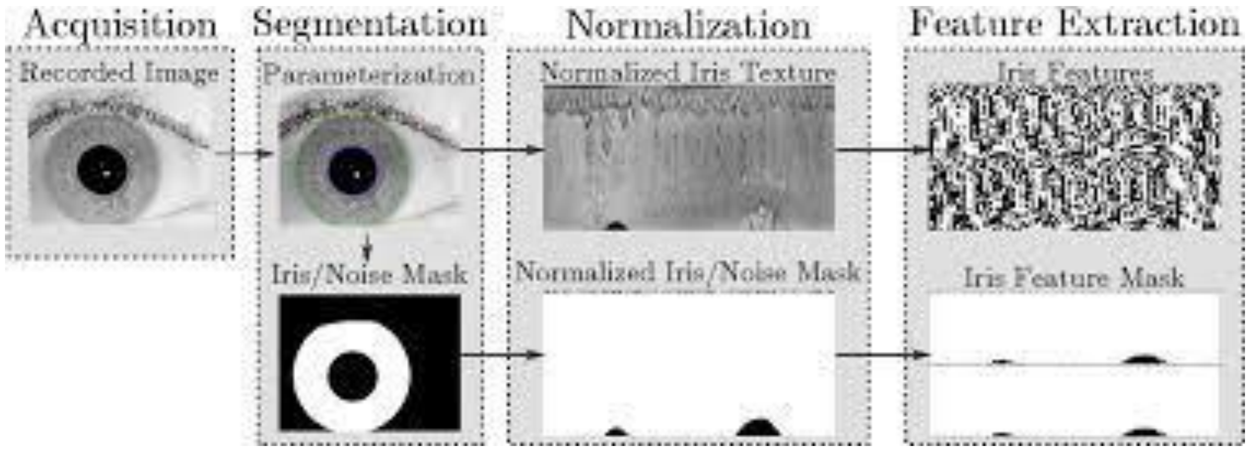
- Matching



δ

The first and most famous: Daugman





Daugman: Iris Location

- The approach uses a kind of circular edge detector to localize both the pupil and the iris (integro-differential operator)
- The operator exploits the convolution of the image with a Gaussian smoothing function with center r_0 and standard deviation σ

$$G_\sigma(r) = \left(1/\sqrt{2\pi}\sigma\right)\exp\left[-(r-r_0)^2/2\sigma^2\right]$$

- The operator looks for a circular path along which pixel variation is maximized, by varying the center *r* and radius *(x0, y0)* of a candidate circular contour

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

- When the candidate circle has the same radius and center of the iris, the operator should provide a peak

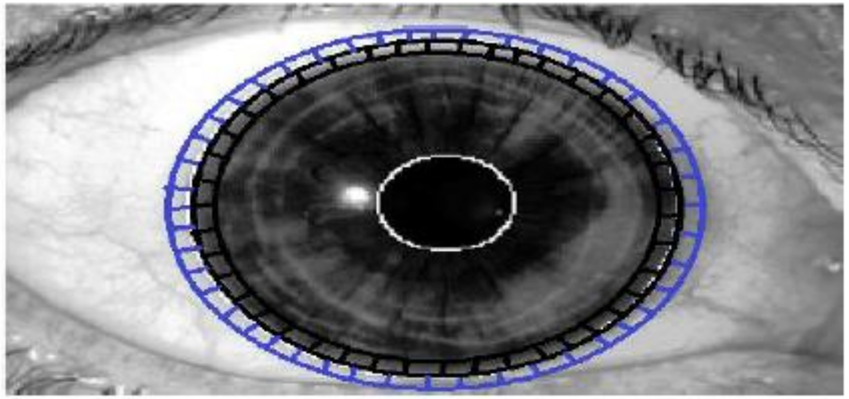
$$\max_{(r,x_0,y_0)}\left|G_\sigma(r) * \frac{\partial}{\partial r}\oint_{r,x_0,y_0}\frac{I(x,y)}{2\pi r}ds\right|$$

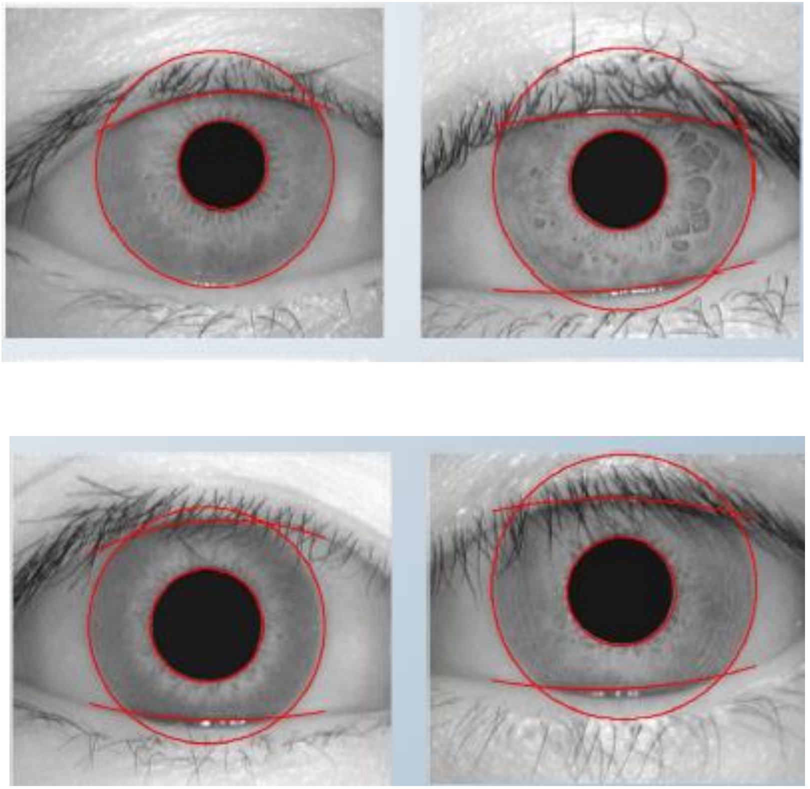
I(x, y) is the intensity of the pixel at coordinates *(x, y)* in the image of an iris.
r denotes the radius of various circular regions with the center coordinates at *(x0, y0)*.
σ is the standard deviation of the Gaussian distribution.
$G_\sigma(r)$ denotes a Gaussian filter of scale sigma (σ).
(x_0, y_0) is the assumed centre coordinates of the iris.
s is the contour of the circle given by the parameters (*r, x0, y0*).

1. **La pupilla è più scura rispetto all'iride che a sua volta è più scura della sclera: si determina una variazione significativa di luminosità nel passaggio da pupilla a iride e da iride a sclera;**
2. **La pupilla e l'iride hanno forma circolare;**

- **Daugman, sfruttando 1 e 2, genera una serie di circonferenze con un raggio incrementale ed un centro prefissato, riducendo la localizzazione dell'iride e della pupilla ad un problema di ottimizzazione: si individua (integrale curvilineo) la direzione che comporta il maggior incremento di luminosità: il massimo si raggiungerà quando si è individuato il centro ed il raggio della pupilla o dell'iride.**

Daugman: iris and eyelids location





The effect of light reflection

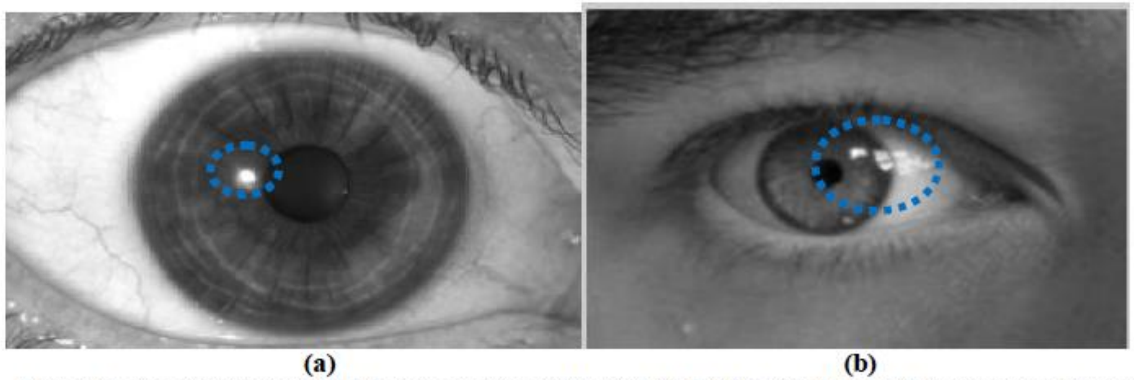


Figure 3-1: (a) Light reflection affected eye image of size 164 by 246 pixels (b) Light reflection affected eye image of size 178 by 238 pixels.

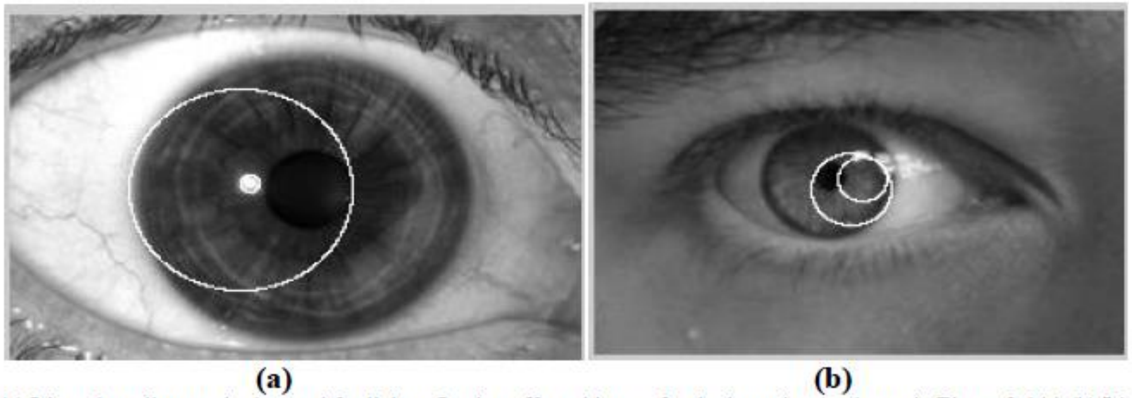


Figure 3-2: (a) Iris and pupil wrongly detected for light reflection affected image for the input image shown in Figure 3-1(a) (b) Iris and pupil wrongly detected for light reflection affected image as shown in Figure-3-1(b).

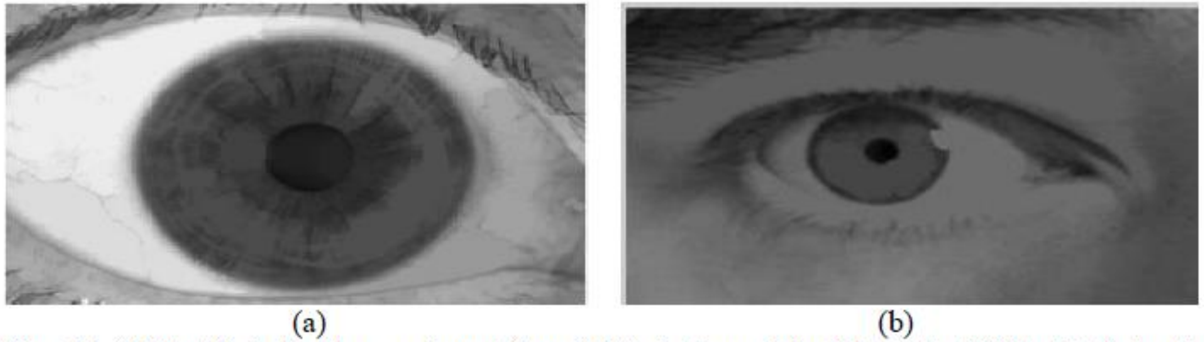
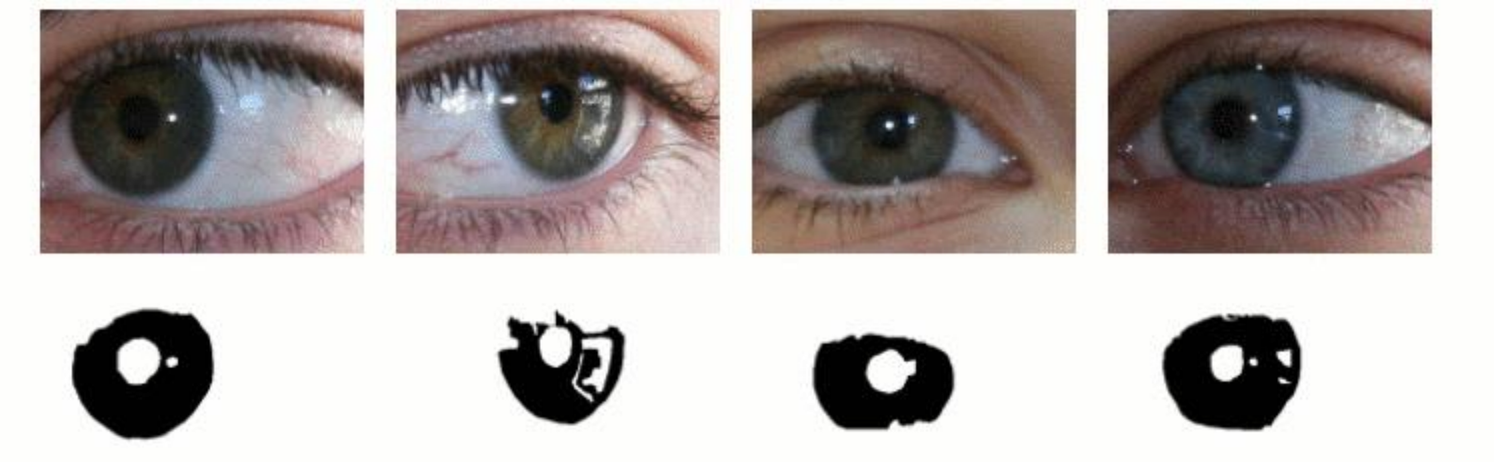


Figure 3-3: (a) Output for the input image as shown in Figure 3-1(a) after the morphological operation (b) Output for the input image as shown in Figure 3-1(b) after applying the morphological operation

General Iris Segmentation



From http://nice2.di.ubi.pt/

NICE: Noisy Iris Challenge Evaluation

- Iris biometric evaluation initiative that received worldwide participations
- Two phases:
  - **NICE.I** evaluated iris segmentation and noise detection techniques
  - **NICE.II** evaluated encoding and matching strategies for biometric signatures.

NICE I

NICE I Committees

Contest Chairs:

- **Hugo Proença**, Department of Computer Science, SOCIA Lab., IT-Networks and Multimedia Group, University of Beira Interior.
- **Luís A. Alexandre**, Department of Computer Science, SOCIA Lab., IT-Networks and Multimedia Group, University of Beira Interior.

Organizing Committee:

- **David Carvalho,** Department of Computer Science, University of Beira Interior.
- **João Oliveira,** Department of Computer Science, SOCIA Lab., University of Beira Interior.
- **Ricardo Santos,** Department of Computer Science, SOCIA Lab., University of Beira Interior.
- **Sílvio Filipe,** Department of Computer Science, SOCIA Lab., University of Beira Interior.

NICE I (2)

- NICE I received a total of 97 participants from over 22 countries.
- **September 30th, 2008**: The deadline for the final submission of the participations
- **October 15th, 2008:** The classification of the best participants is available.

NICE I (3)

- The **UBIRIS** databases were developed by the **SOCIA Lab**. (Soft Computing and Image Analysis Group) of the University of Beira Interior (Portugal).
- They contain visible wavelength iris images captured in heterogeneous lighting conditions, which leaded to the appearance of highly degraded images.
- The imaging framework used in the acquisition of the UBIRIS data set was installed in a lounge under both natural and artificial lighting sources.

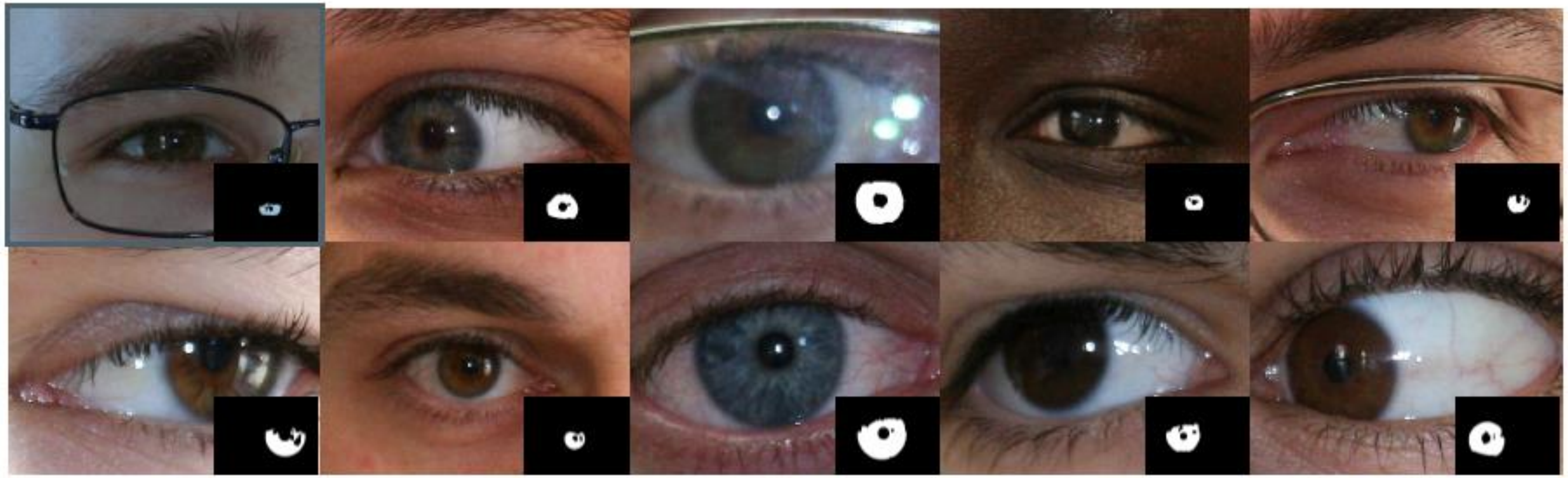
NICE I (4)

- A large majority of the volunteers were:
  - Latin Caucasian (approximately 90%)
  - black (8%)
  - Asian (2%).
- Approximately 60% of the volunteers participated in both imaging sessions, whereas 40% participated exclusively in one or the other.

NICE I (5)

- Several marks placed on the floor between three and ten meters away from the acquisition device
- Two distinct acquisition sessions performed each lasting two weeks and separated by an interval of one week.
- From the first to the second session, both the location and orientation of the acquisition device and artificial light sources were changed.

NICE I (6)

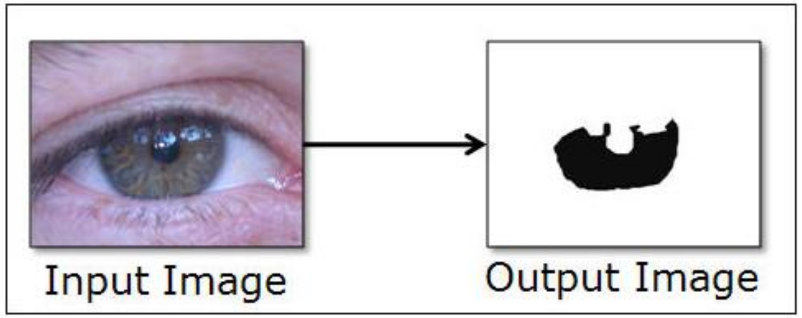


NICE I (7)

The Protocol

- The submitted application executable can be written in any programming language and must run in standalone mode, in one of the operating systems:"Windows XP, Service Pack 2" or "Fedora Core 6".

- There will be no internet access during the NICE.I evaluation. Thus, the application executable will need to be installed and executed without access to the internet.



NICE I (8)

Evaluation

1. Let **Alg** denote the submitted executable, which performs the segmentation of the noise free regions of the iris.
2. Let **$I=\{I_1,\ldots,I_n\}$** be the data set containing the input close-up iris images.
3. Let **$O=\{O_1,\ldots,O_n\}$** be the output images correspondent to the above described inputs, such that **$Alg(I_i)=O_i$**.
4. Let **$C=\{C_1,\ldots,C_n\}$** be the manually classified binary iris images, given by the NICE.I Organizing Committee. **It must be assumed that** each **C_i** contains the perfect iris segmentation and noise detection result for the input image **I_i**.
5. All the images of **I**, **O** and **C** have the same dimensions: **c** columns and **r** rows.

The **classification error rate (E^1)** of the **Alg** participation on the input image **I_i (E_i)** is given by the proportion of correspondent disagreeing pixels (through the logical exclusive-or operator) over all the image:

$$E_i = \frac{1}{c \times r} \sum_{c'} \sum_{r'} O(c', r') \otimes C(c', r') \qquad (1)$$

where **$O(c',r')$** and **$C(c',r')$** are, respectively, pixels of the output and class images.

The classification error rate **(E^1)** of the **Alg** participation is given by the average of the errors on the input images E_i:

$$E = \frac{1}{n} \sum_{i} E_i \qquad (2)$$

The value of **(E^1)** is closed in the [0, 1] interval and **will be the measure of evaluation and classification of the NICE.I participations**. In this context, "1" and "0" will be respectively the worst and optimal values.

NICE I (9)

- The best 8 participants, that achieved the lowest test error rates were invited to publish their approach in a Special Issue on the Segmentation of Visible Wavelength Iris Images Captured At-a-distance and On-the-move Image, *Elsevier Image and Vision Computing 28 (2010)*

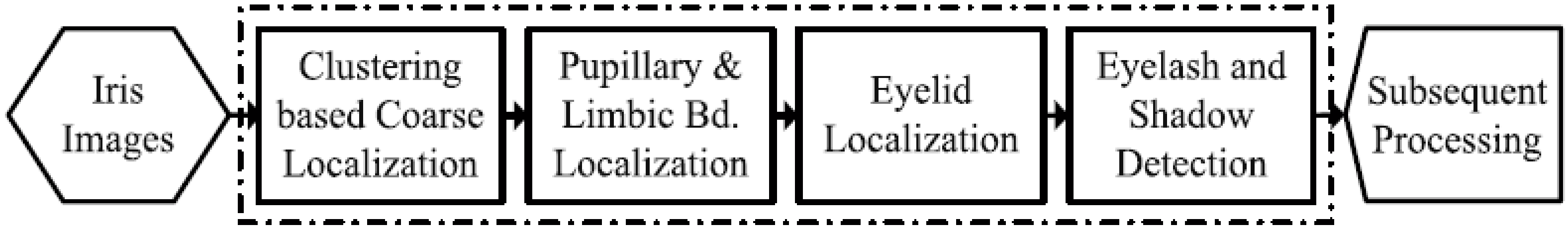
Ranking	Username	Affiliation	Country	Error (E1)
1	CASIA	National Laboratory of Pattern Recognition, Institute of Automation, Chinese Academy of Sciences	China	0,0131
2	DMCS	Department of Microelectronics and Computer Science, Technical University of Lodz	Poland	0,0162
3	Palmeida	Department of Computer Science, University of Beira Interior	Portugal	0,0180
4	PeihuaLi	College of Computer Science and Technology, Heilongjiang University	China	0,0224
5	Kang Ryoung Park	Dept. of Electronics Engineering, Dongguk University, Biometrics Engineering Research Center	Korea	0,0282
6	CATE	Department of Electrical and Computer Engineering, Florida International University	USA	0,0297
7	Dtibiolab	Biolab, Department of Information Technologies, University of Milan	Italy	0,0301
8	Font	Department of Electronic Engineering, Universidad Politécnica de Madrid	Spain	0,0305

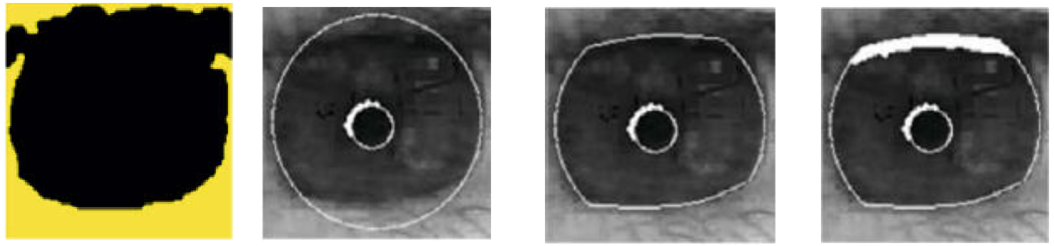
NICE II (6)

- The best 8 participants, that achieved the the best 8 results were invited to publish their approach in a Special Issue *NICE II NOISY IRIS CHALLENGE EVALUATION PART II, Pattern Recognition Letters,* (Elsevier),vol 33, n° 8, 2012

Ranking	Unsername	Affiliation	Country	Decidability (d')
1	CASIA	National Laboratory of Pattern Recognition, Institute of Automation, Chinese Academy of Sciences	China	**2,5748**
2	Betaeye	Techshino Biometrics Research Center,Department of Mathematics, Northeastern University	China	**1,8213**
3	UBI	University of Beira Interior	Portugal	**1,7786**
4	Parkgr	Biometrics Engineering Research Center (BERC), Dongguk University	Republic of Korea	**1,6398**
5	PeihuaLi	College of Computer Science and Technology, Heilongjiang University	China	**1,4758**
6	BIPLab	University of Salerno	Italy	**1,2565**
7	HLJUCS	College of Computer Science and Technology, Heilongjiang University	China	**1,1892**
8	DMCS	Technical University of Lodz	Poland	**1,0931**

NICE I: the winning algorithm



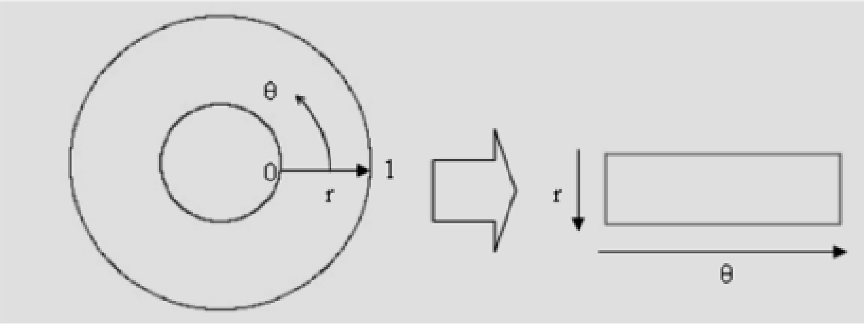


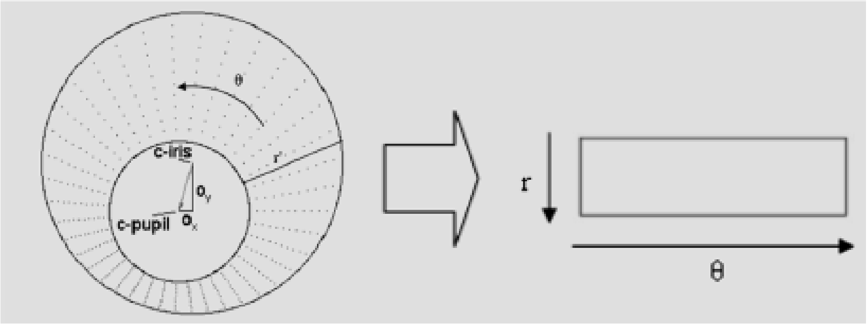
Casia Algorithm by T. Tan, Z. He and Z. Sun (the Chinese Academy of Sciences)

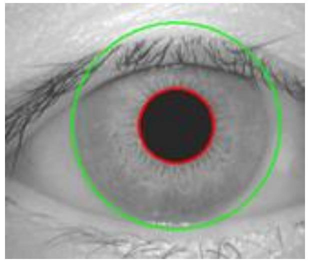
NICE I: the winning algorithm (2)

Daugman: iris unwrapping

- Polar coordinate make iris processing simpler (circular bands become horizontal stripes, the overall iris annulus becomes a rectangle)
- Determining the right centre for the polar coordinates is of paramount importante but …
- … pupil and iris are not perfectly concentric and …
- … size of the pupil can change due to illumination or pathological conditions (drunk or drugs)
- Gaze direction can change the relative positions of sclera, iris and pupil
- It is necessary to devise a normalization procedure: Rubber Sheet Model







Rubber Sheet Model

- The model maps each iris point onto polar coordinates (r, θ), with $r \in [0,1]$ and $\theta \in [0, 2\pi]$.
- The model compensates for pupil dilation and size variations by producing and invariant representation.
- The model does not compensate for rotations. However, during matching, in polar coordinates, this is done by translating the obtained iris template until alignement.
- The transformation works as follows:

$$I\big(x(r,\theta), y(r,\theta)\big) \rightarrow I(r,\theta)$$
$$x(r,\theta) = (1-r) \cdot x_p(\theta) + r \cdot x_l(\theta)$$
$$y(r,\theta) = (1-r) \cdot y_p(\theta) + r \cdot y_l(\theta)$$

- ($x(r,\theta)$, $y(r, \theta)$) are defined as a linear combination of a set of points ($x_p(\theta)$, $y_p(\theta)$) and of a set of points ($x_l(\theta)$, $y_l(\theta)$), which are respectively the coordinates of the pupil contour and and those of the external iris contour (limbus) which delimits the sclera.

Daugman: feature extraction

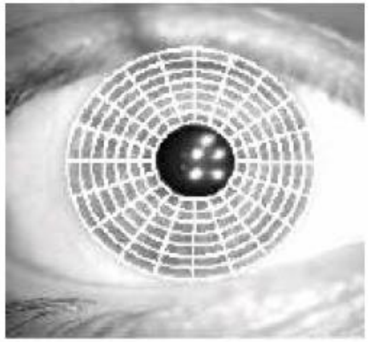
- Feature are extracted by applying Gabor filters to the $I(r,\theta)$ image in polar coordinates

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

(r,θ) is the position, α and β are the filter dimensions and ω its frequency

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

Complex pixel



- For each element with coordinates (r, θ) in the image $I(\rho,\varphi)$, the method computes a pair of bits as follows

$$h_{Re} = 1 \qquad \mathrm{Re}\left(\int_\rho \int_\phi I(\rho,\phi) e^{-i\omega(\theta_0-\phi)} e^{-(r_0-\rho)^2/\alpha^2} e^{-(\theta_0-\phi)^2/\beta^2} \rho \, d\rho \, d\phi \right) \geq 0$$

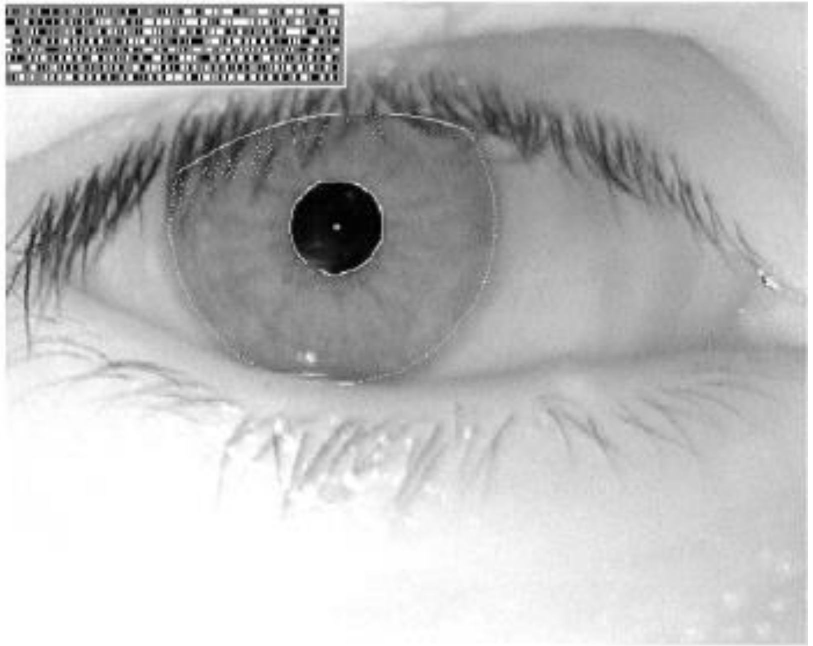
$$h_{Re} = 0 \qquad \mathrm{Re}\left(\int_\rho \int_\phi I(\rho,\phi) e^{-i\omega(\theta_0-\phi)} e^{-(r_0-\rho)^2/\alpha^2} e^{-(\theta_0-\phi)^2/\beta^2} \rho \, d\rho \, d\phi \right) < 0$$

$$h_{Im} = 1 \qquad \mathrm{Im}\left(\int_\rho \int_\phi I(\rho,\phi) e^{-i\omega(\theta_0-\phi)} e^{-(r_0-\rho)^2/\alpha^2} e^{-(\theta_0-\phi)^2/\beta^2} \rho \, d\rho \, d\phi \right) \geq 0$$

$$h_{Im} = 0 \qquad \mathrm{Im}\left(\int_\rho \int_\phi I(\rho,\phi) e^{-i\omega(\theta_0-\phi)} e^{-(r_0-\rho)^2/\alpha^2} e^{-(\theta_0-\phi)^2/\beta^2} \rho \, d\rho \, d\phi \right) < 0$$

$r_0, \theta_0, \alpha, \beta$ e ω are discretized to obtain a 256 byte code, plus a mask of the same size to identify valid iris elements

Iris code



Matching: Hamming distance

$$HD = \frac{1}{N}\sum_{j=1}^{N} A_j \otimes B_j$$

Matching: Hamming distance with mask

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