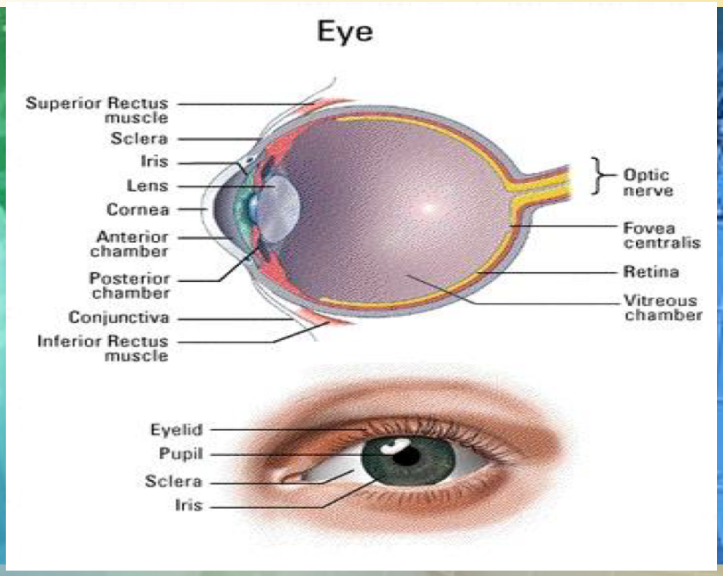
Iris Recognition



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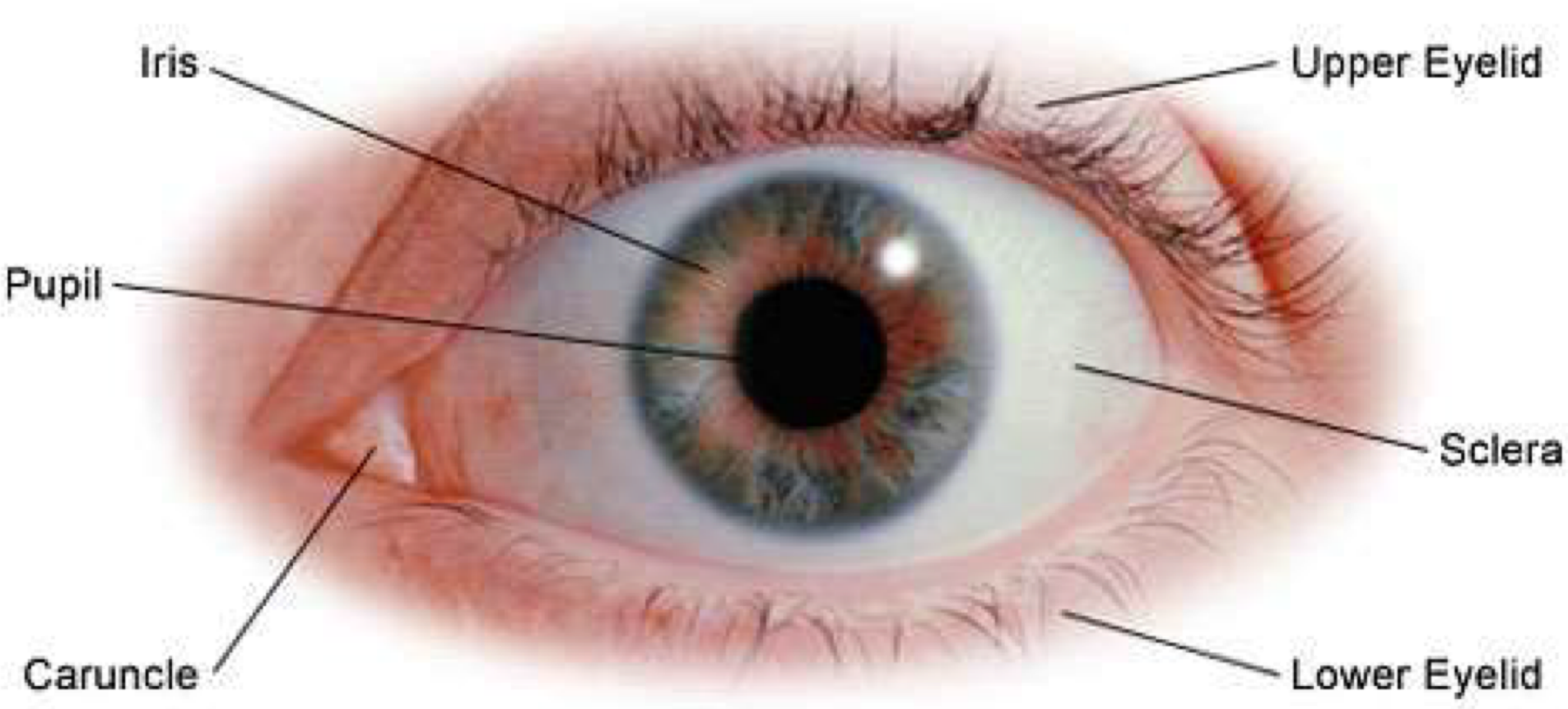
Data SecuriTy Applied Research Lab

Outline

- Introduction
  - Design of an iris recognition system
- Iris features
  - Acquisition
  - Extraction: segmetation, normalization, encoding
- Iris matching
  - Quality measure for matching scheme
- Summary

Introduction



Introduction

- French police officer: Alphonse Bertillon in 1885 suggested to use iris for human being
- British ophthalmologist J.H. Doggart in 1949: *like fingerprints, so does the architecture of the iris exhibit variations in every subject examined*
- 1980: Appeared in the Bond films
- American ophthalmologists, L. Flom asand Aran Safir in 1980: patented the idea (and asked John Dougman to create actual algorithms for that →1994)
- 1997: “Panasonic Authenticam” was ready for use in public places like airports

Introduction

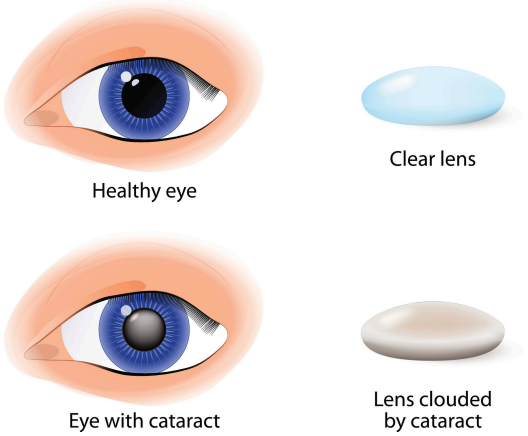
- Iris, (w. fingerprint and face recognition), is internationally standardised since 2006 by ICAO for use in e-passports
  - *ICAO: International Civil Aviation Organization*
- The commercially deployed iris-recognition algorithm, John Daugman's IrisCode, has an unprecedented false match rate (better than 10^{-11} if a Hamming distance threshold of 0.26 is used, meaning that up to 26% of the bits in two IrisCodes are allowed to disagree while still declaring them to be a match)

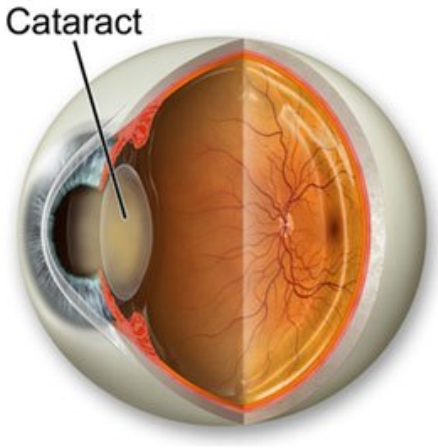
Introduction

- Iris in the United Arab Emirates (UAE) since 2003: >330k people re-entered with either another nationality or name, or even fraudulent travel documents
- Jordan: ATM without bank cards
- India: ~1B people for individual identification

Introduction

- Colour and overall shape of the iris can be affected, the fine texture remains remarkably stable over many decades (some over a period of about 30 years)
- Iris recognition works with clear contact lenses, eyeglasses, and non-mirrored sunglasses
- Study on modern cataract surgery showed that it can change iris texture in such a way that iris pattern recognition is no longer feasible or the probability of falsely rejected subjects is increased

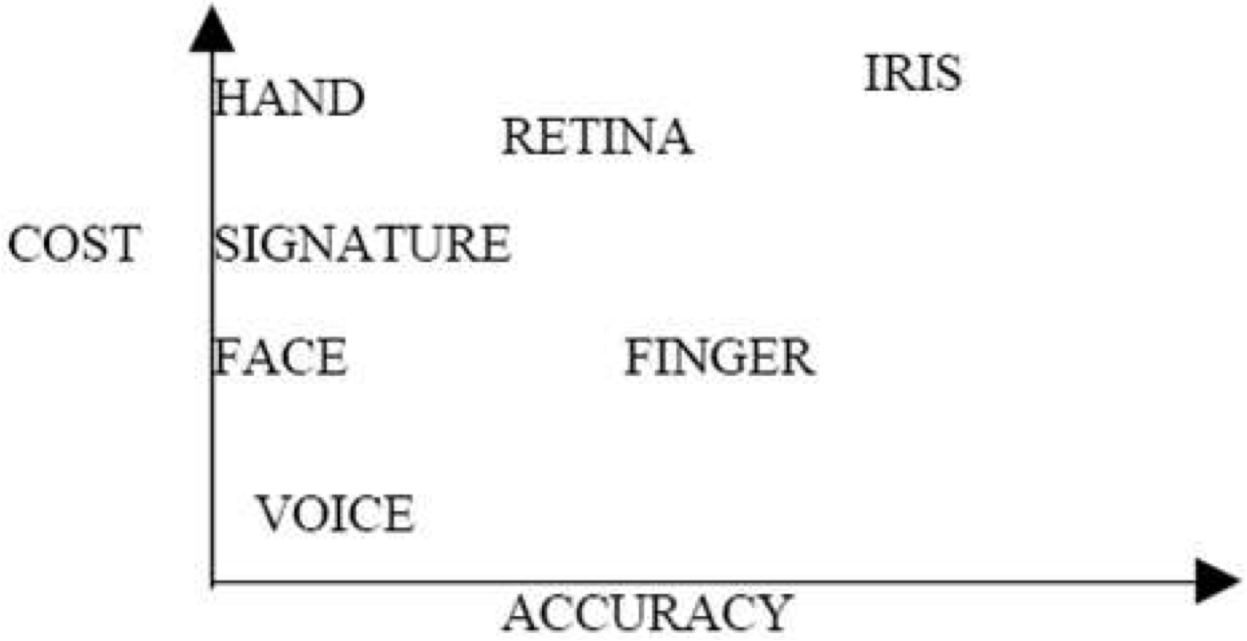


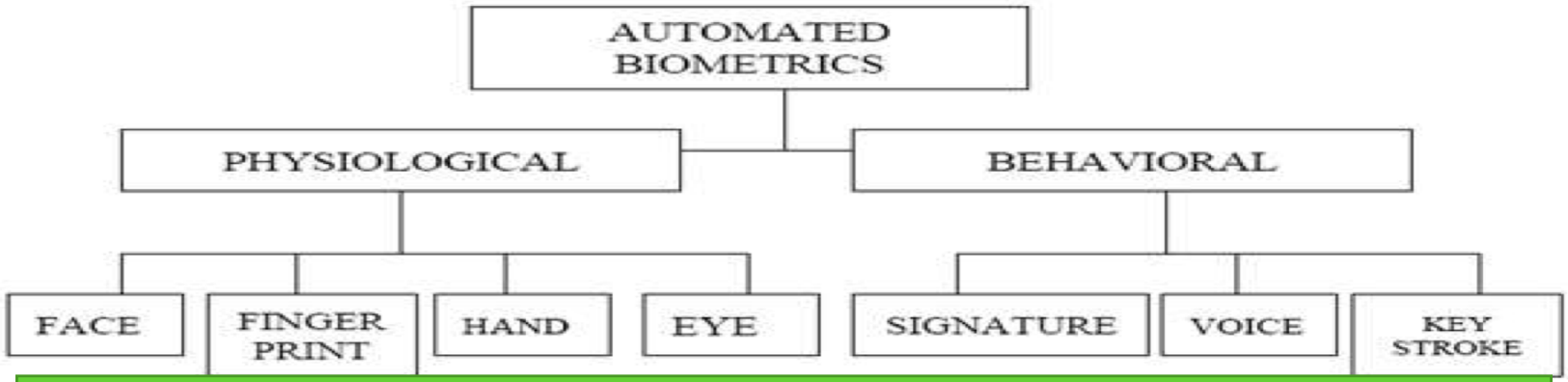


Introduction

- Some defence against the use of fake eyes and irises
  - changing ambient lighting during the identification such that the pupillary reflex can be verified and the iris image be recorded at several different pupil diameters
  - analysing the 2D spatial frequency spectrum of the iris image for the peaks caused by the printer dither patterns found on commercially available fake-iris contact lenses
  - analysing the temporal frequency spectrum of the image for the peaks caused by computer displays
  - … (https://en.wikipedia.org/wiki/Iris_recognition)

Introduction

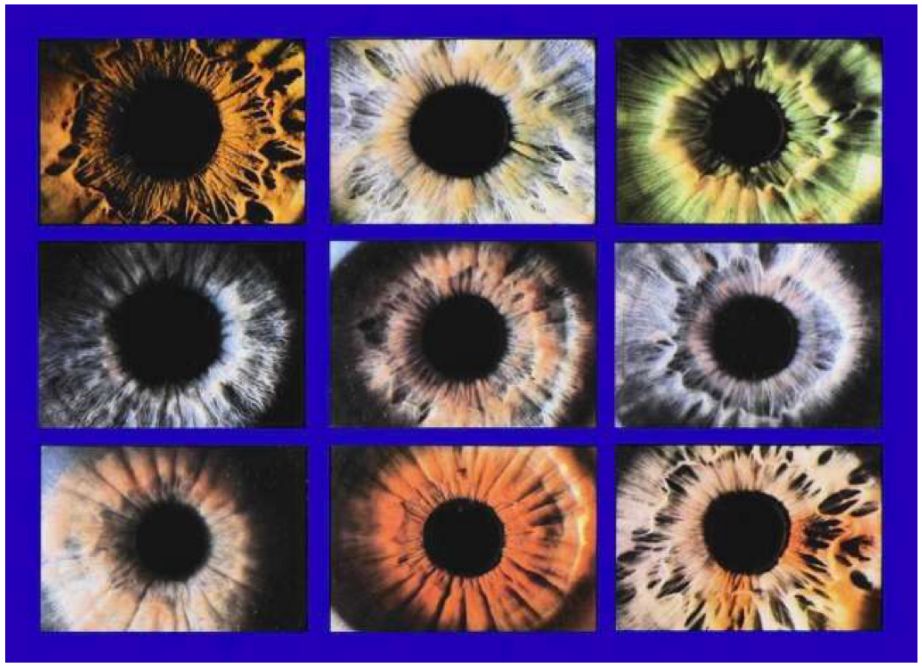


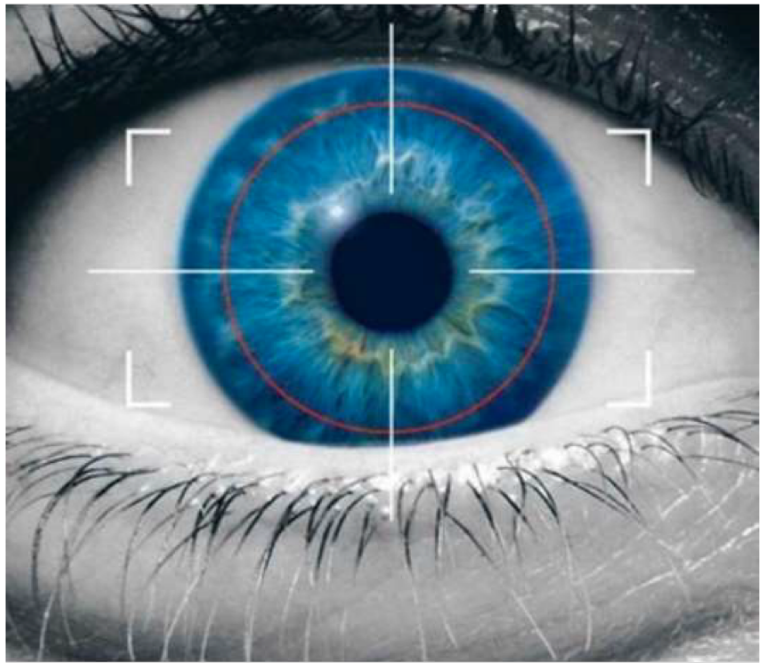


IRIS and automated biometric recognition

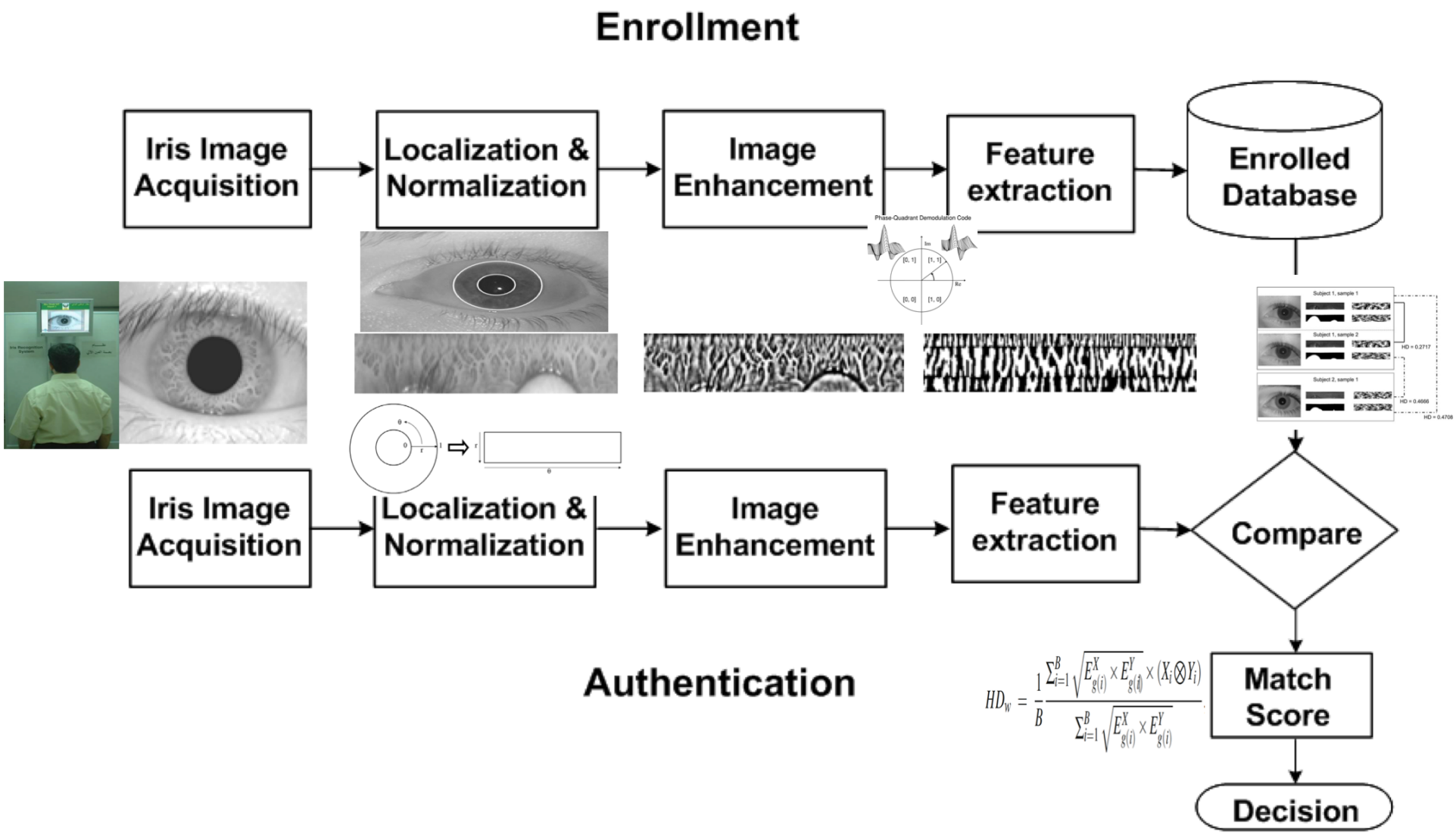
Introduction

- Probability of matching of two irises is $1/10^{78}$
- Right eye differs from left eye
- Twins have different iris texture
- Iris pattern remains unchanged long time



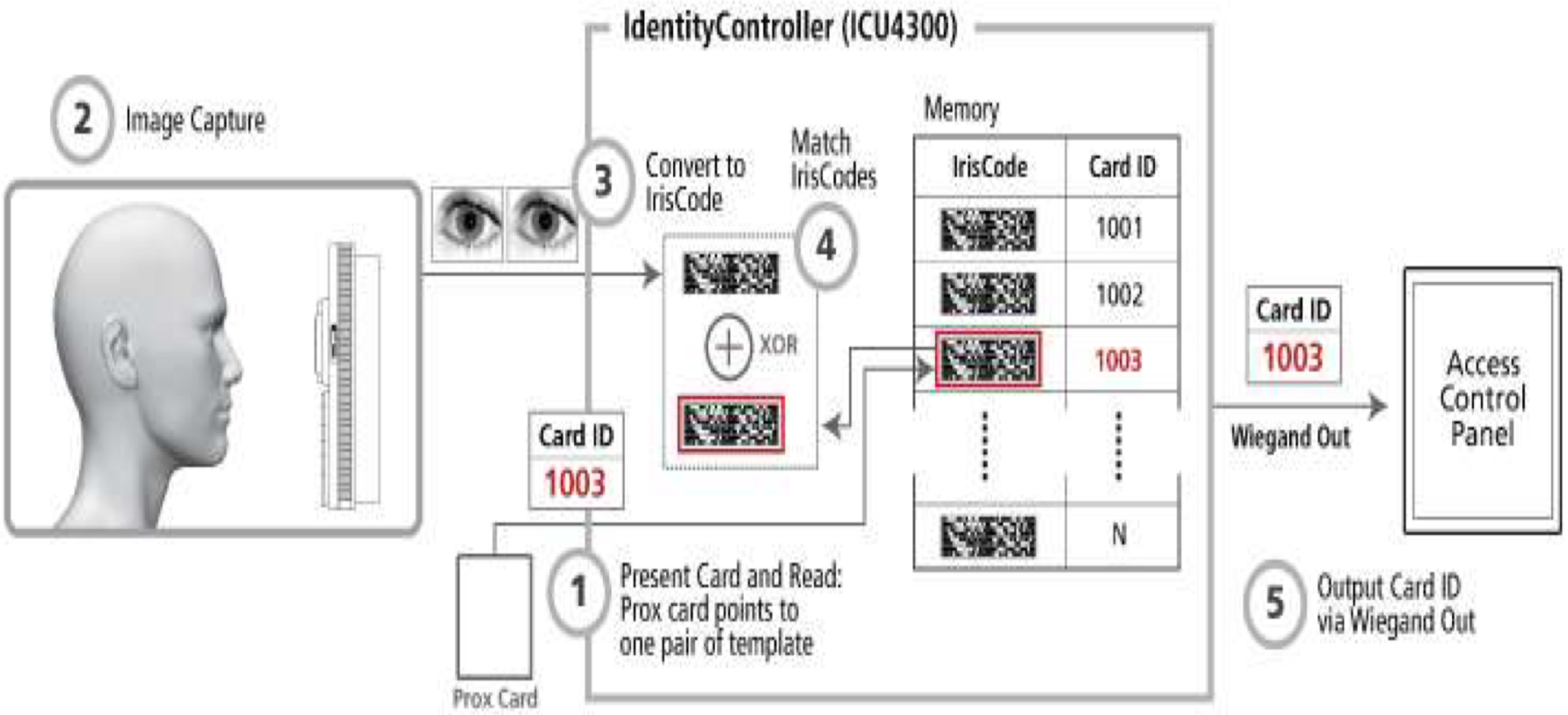


Introduction: System design



Introduction: System design

- An identification system in practice



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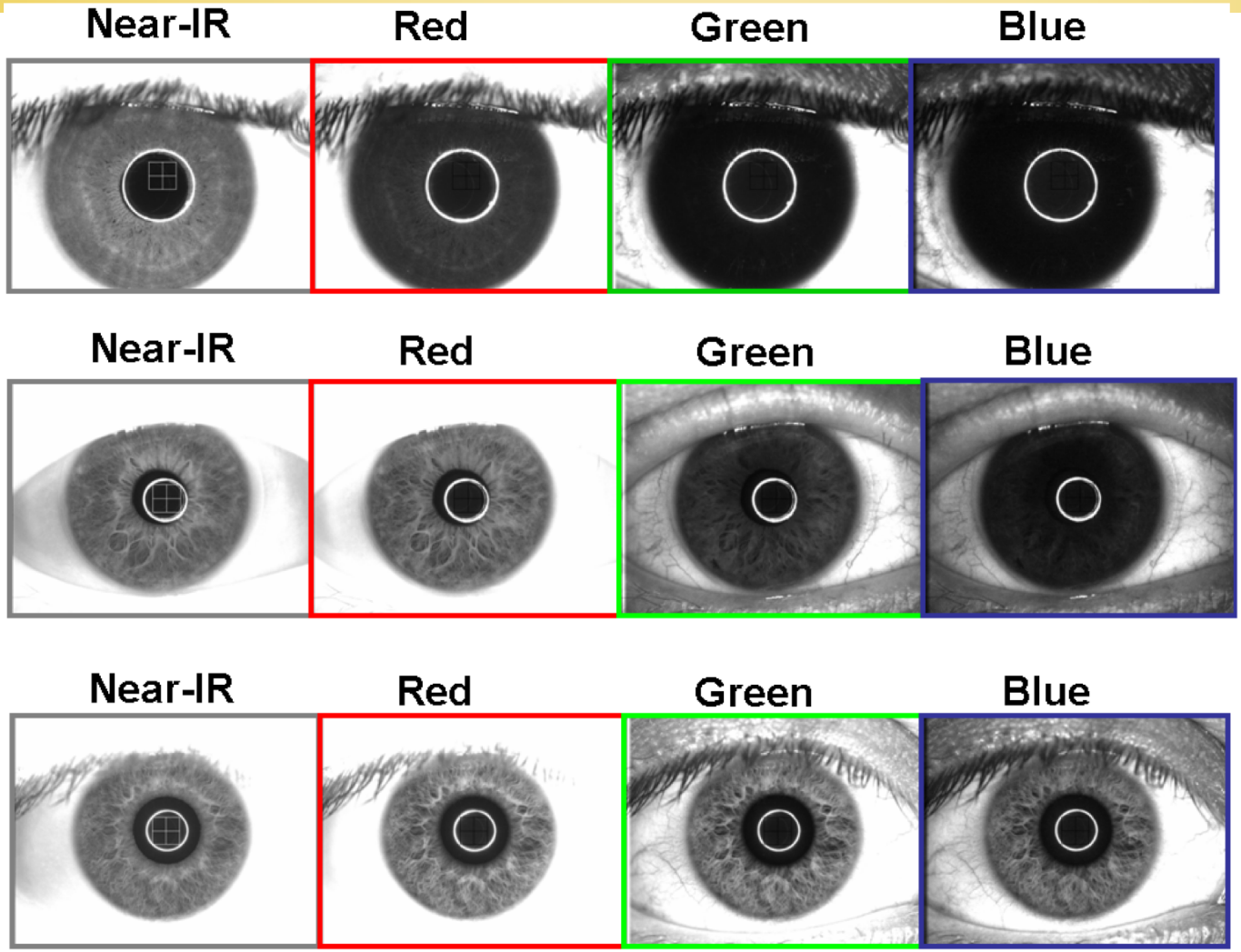
Iris image acquisition

- An eye image is obtained using a sensor sensitive to the near-infrared (NIR) portion of the electromagnetic spectrum: 700nm - 900nm range of the IR spectral band
- Due to the absorption characteristics of the melanin found in the iris, color images of dark-colored irides do not clearly reveal the rich texture of the iris
- NIR light cannot be perceived by the human eye→ the image acquisition process is non-intrusive

Coal mine in China

UAE

Iris image acquisition



The texture revealed in three different irides when they are observed in the NIR, red, green, and blue channels

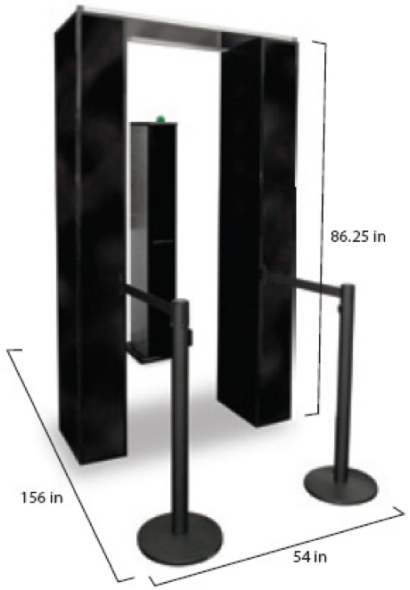
Iris image acquisition

Panasonic BM-ET 330: both eye images possible

LG IrisAccess 4000

Oki IrisPass

Iris On the Move (IOM) system



IOM PassPort

Examples of commercialized iris image acquisition devices

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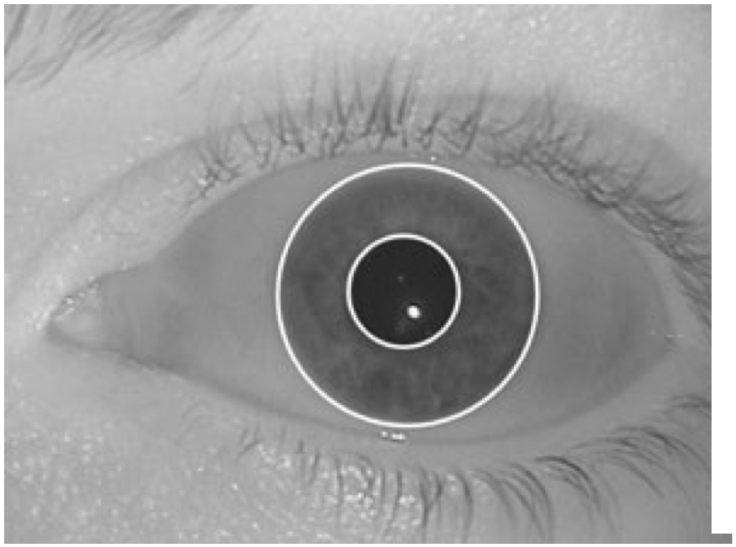
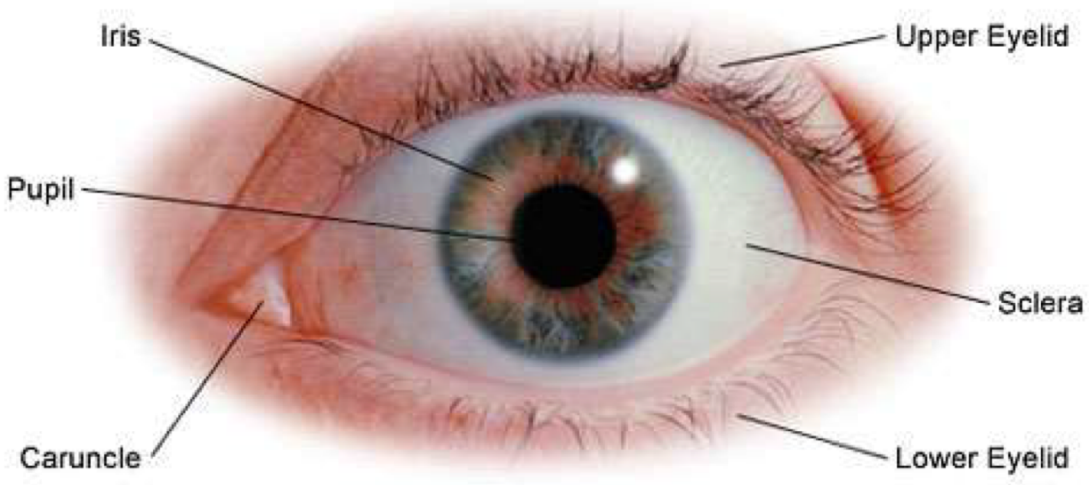
Iris feature extraction: segmetation, normalization, encoding

- An eye image includes the iris, pupil, eyelids, eyelashes, and sclera
- Process of locating and isolating the iris from such an image is known as iris localization or segmentation



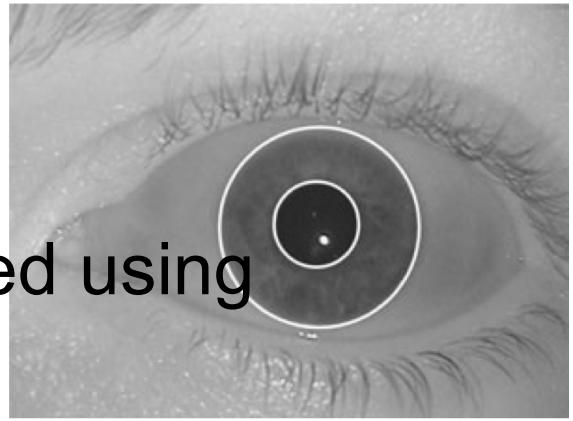


Iris feature extraction: segmetation, normalization, encoding

- Iris segmentation is not an easy task:
  - iris texture exhibits a great degree of irregularity and varies substantially across eyes
  - viewed as a stochastic texture containing numerous “edge”-like-features that are randomly distributed on its anterior surface
  - simple image models cannot be used to describe its content, thereby precluding the use of appearance-based schemes for iris segmentation
  - incorrectly estimating internal/external boundaries can result in the over- or under-segmentation of the iris entity
  - The iris texture may be partially occluded by eyelashes (cf. fig)

Iris feature extraction: segmetation, normalization, encoding

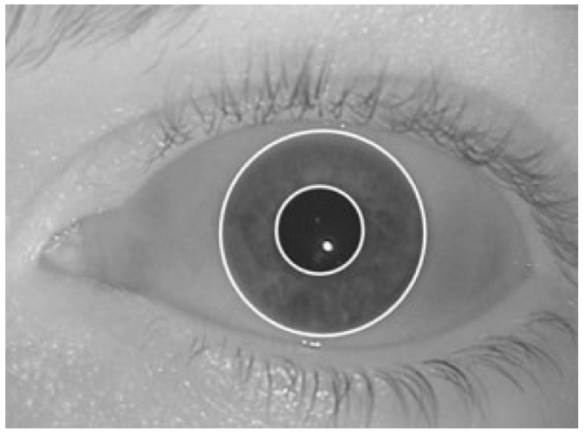
- The contrast in image intensity between the pupil and the iris offers a good cue for identifying the pupillary boundary
- Similarly to detect the limbus boundary between the iris and the sclera
- Assumes:
  - both boundaries can be approximated using circles
  - magnitude of the edge pixels contributing to these boundaries is stronger than those pertaining to other circular contours in the image



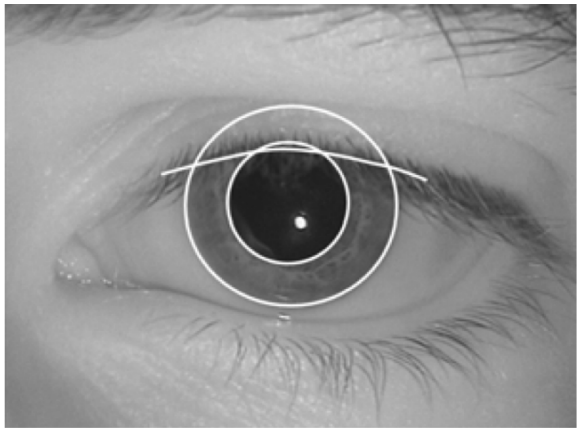
Iris feature extraction: segmetation, normalization, encoding

Iris segmentation using the integro-differential operator (cf. 4.4.1 [2])

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



An eye image in which the pupillary and limbus boundaries are not interrupted by the eyelids

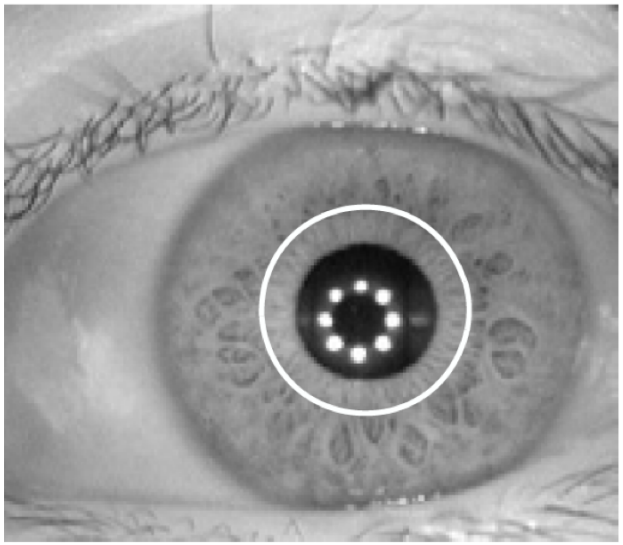


A post-processing scheme is required to detect the eyelids and extract the iris pixels from the annular region defined by the two circular contours

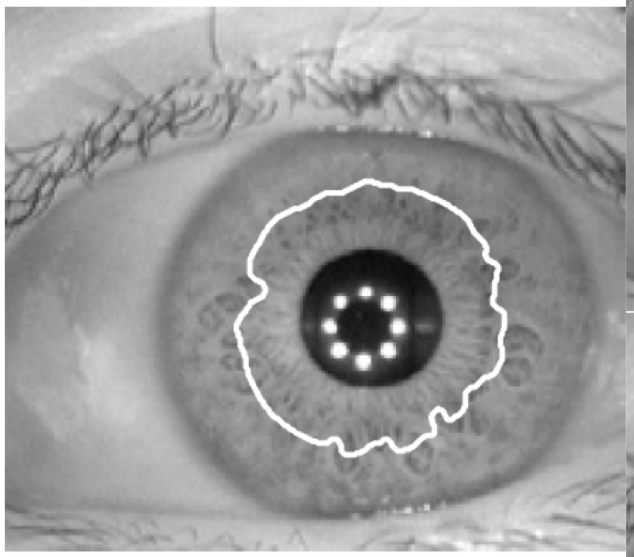
Iris feature extraction: segmetation, normalization, encoding

Segmentation using Geodesic Active Contours (GAC) (cf. 4.4.2 [2])

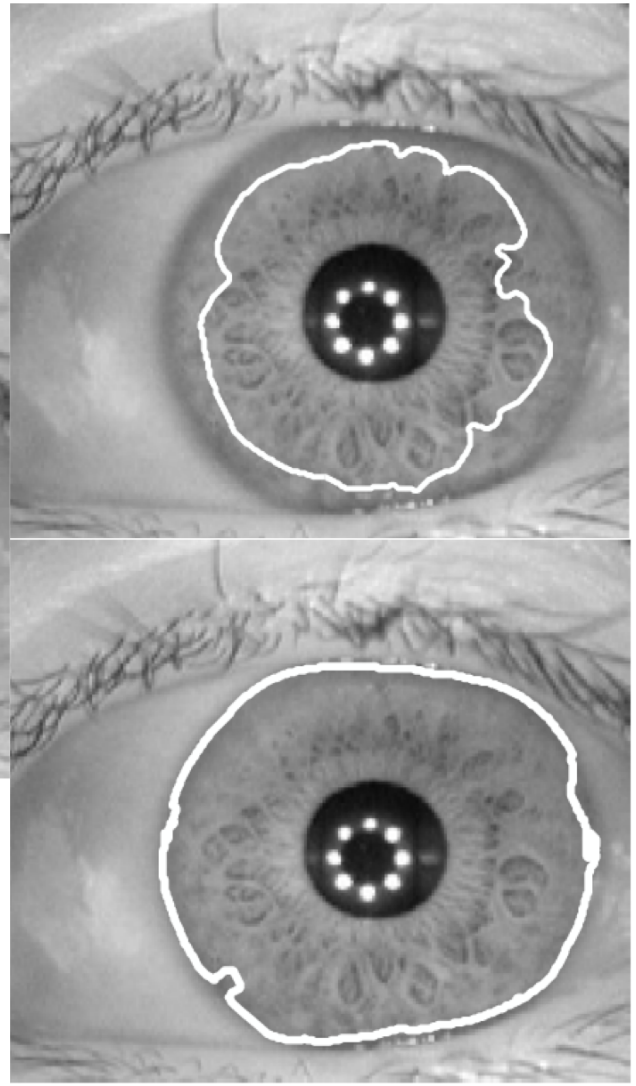
to detect the outer boundary of the iris



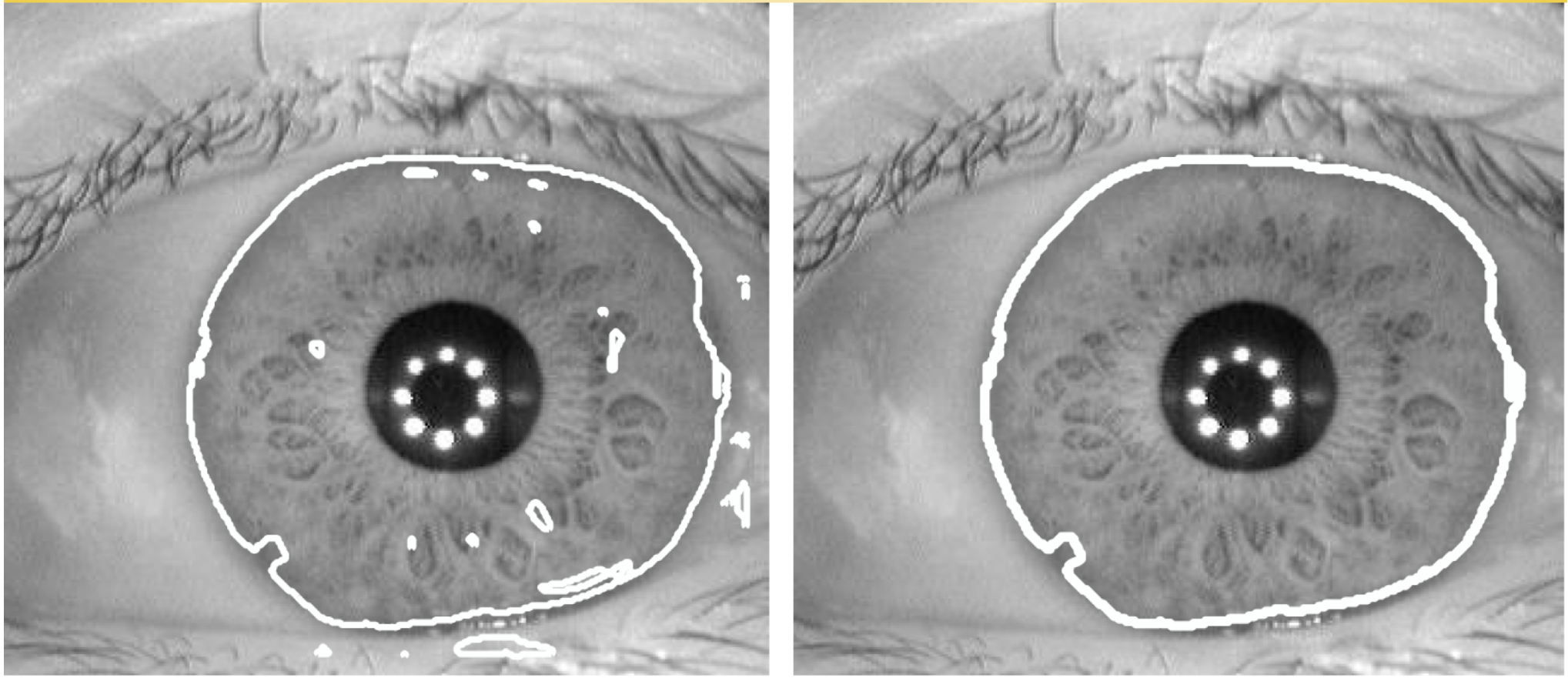
Initial contour



After a number of iterations



Iris feature extraction: segmetation, normalization, encoding



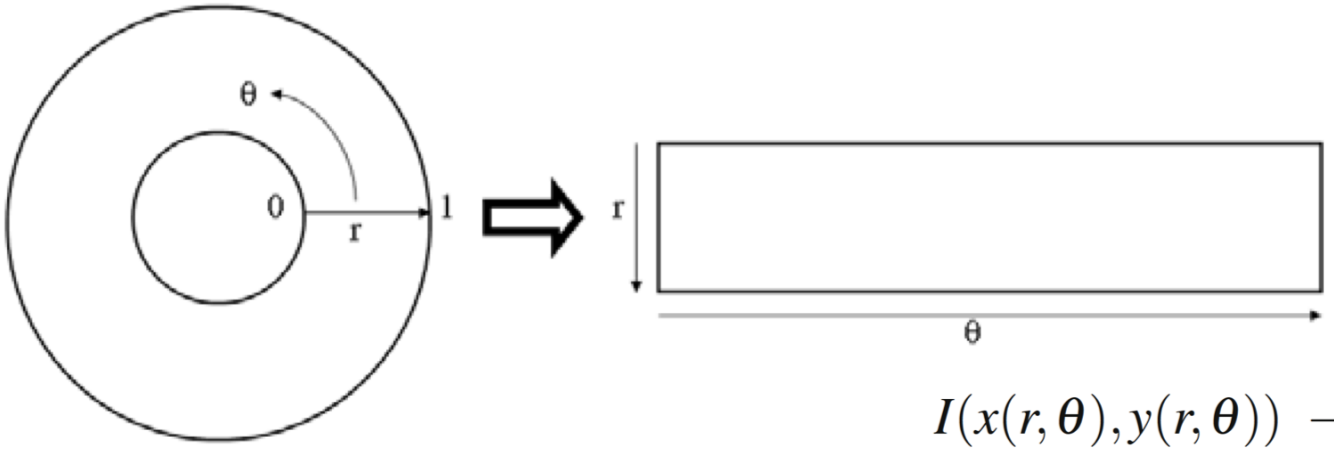
The final contour obtained when segmenting the iris using the GAC scheme: example of a geodesic contour splitting at various local minima, and final contour corresponds to the true limbus boundary

Iris feature extraction: segmetation, normalization, encoding

- The amount of iris texture can be impacted by the dilation and contraction of the pupil in response to ambient illumination (and other factors)
  - size of the iris increases as the pupil contracts in response to bright light and decreases when the pupil dilates in low light
- To address these variations in size, the segmented iris is unwrapped and converted from cartesian coordinates to a normalized pseudo-polar coordinate system
- Daugmans rubber sheet model

Iris feature extraction: segmetation, normalization, encoding

- Normalization routine converts the pixel coordinates in the annular region between the pupillary and limbus boundaries to polar coordinates
- This addresses the problem of variations in pupil size across multiple images



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

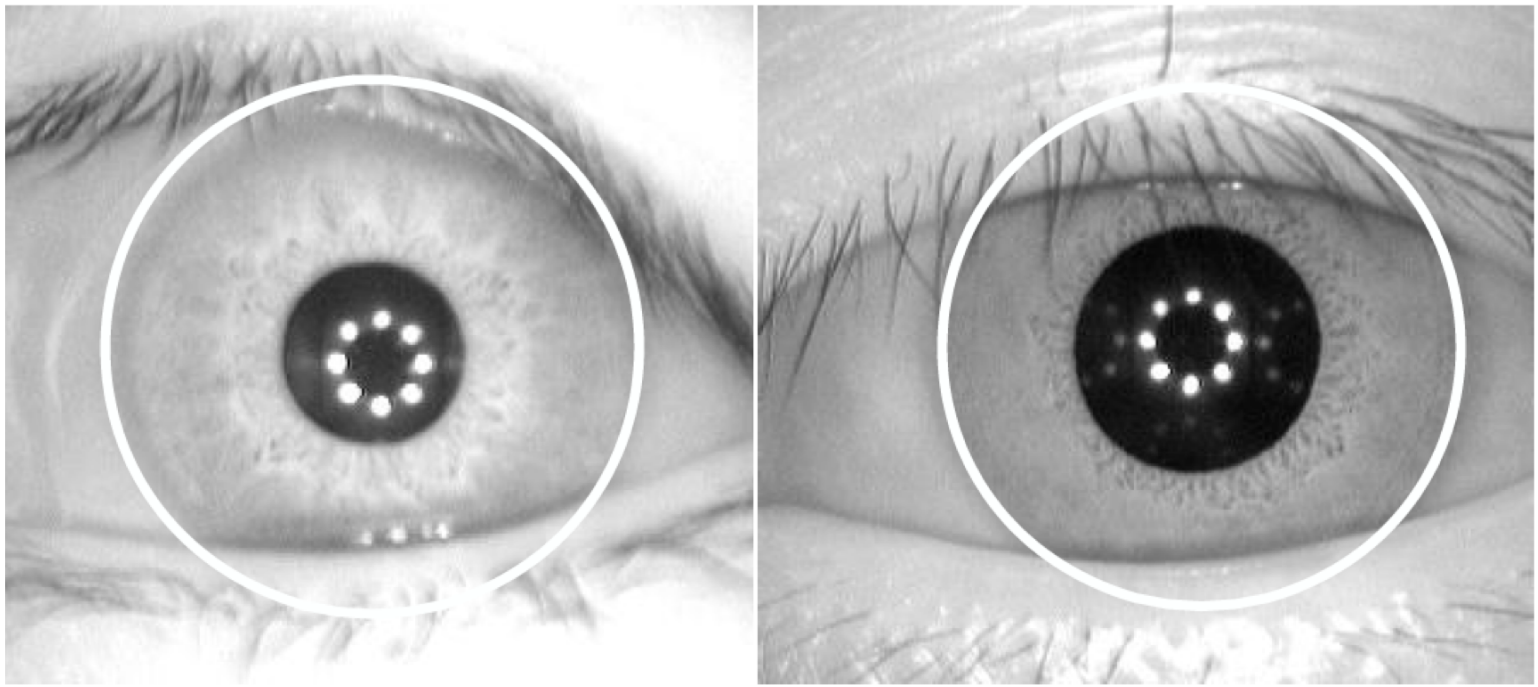
where xp,yp and xl ,yl are the coordinates of points sampled from the pupillary and limbus boundaries, respectively

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

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

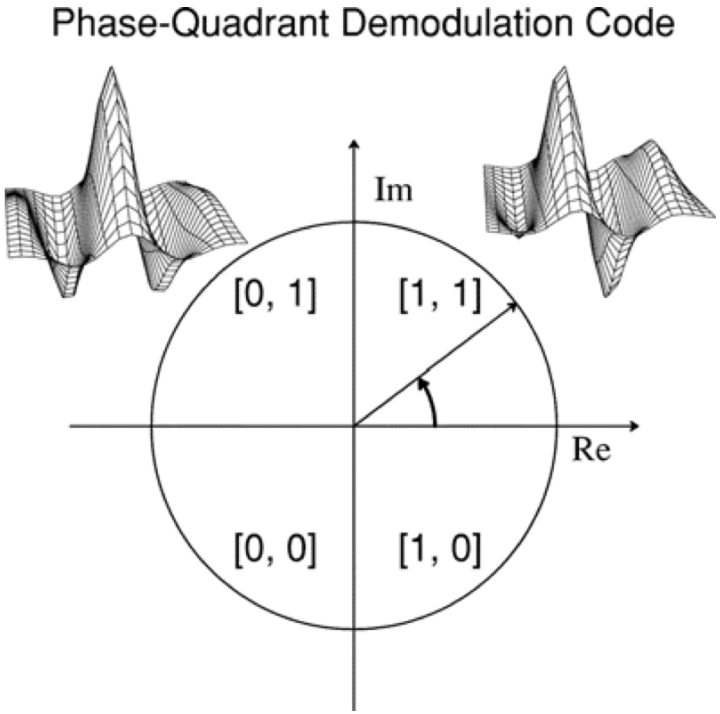
Iris feature extraction: segmetation, normalization, encoding

- When GAC is used to localize the outer iris boundary:
  - the irregular boundary deduced using active contours is converted to a circular boundary
  - pixels included within the circular boundary, but excluded by the irregular boundary are considered to be non-iris pixels and excluded by the mask



Iris feature extraction: segmetation, normalization, encoding

- Process of extracting a numerical feature set from the iris is called iris encoding (i.e. feature extraction)
- 2-dimensional Gabor wavelet is usually convolved with the unwrapped iris image: Gabor wavelets filter out structures at different scales and orientations
- The response of this operation is a binary output referred to as iris code (amplitude information may vary wrt. image quality so ignored)

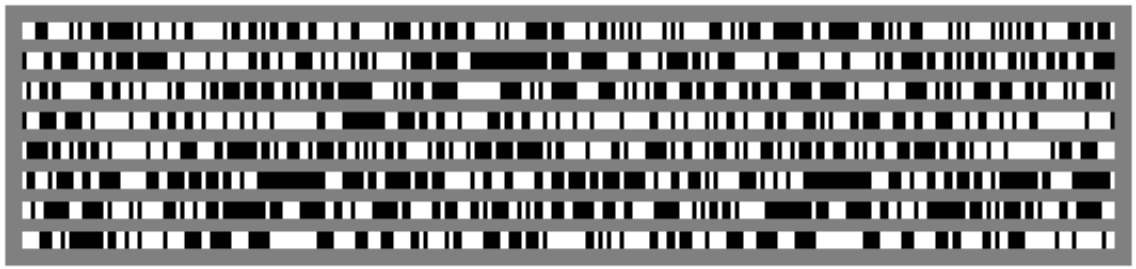


An illustration of the phase demodulation and quantization process used to encode the iris

The phasor response at each pixel in the normalized iris is quantized into two bits of information.

Iris feature extraction: segmetation, normalization, encoding

- Total 512 bytes code
  - 2048 bits or 256 bytes code initially
  - Rest 256 bytes contain other image informations like mask, eyelash occlusions, etc.



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Iris matching

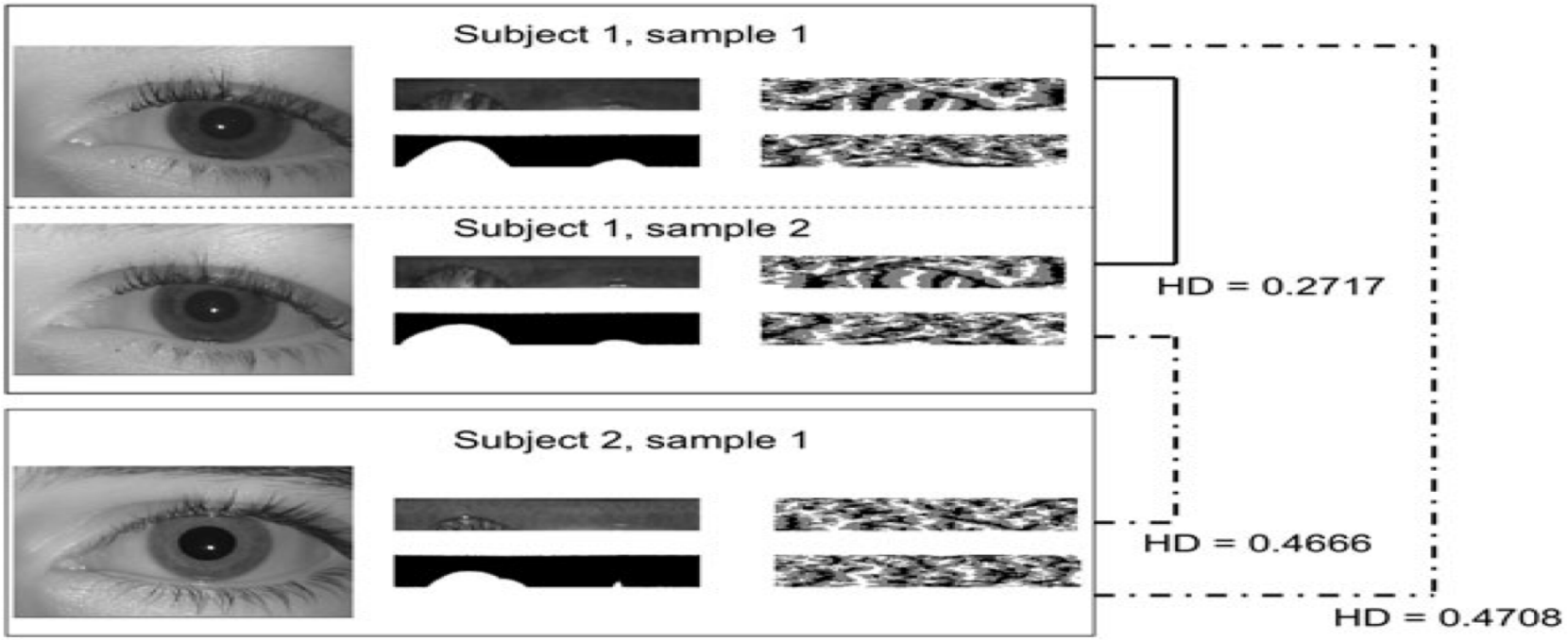
- The Hamming Distance (HD) between two iris codes is computed as:

$$HD = \frac{\| (IrisCodeA \oplus IrisCodeB) \cap MaskA \cap MaskB \|}{\| MaskA \cap MaskB \|}$$

  - Masking every iris code with its respective mask to disregard noisy regions
  - The normalized HD between two iris codes is used as a measure of the dissimilarity

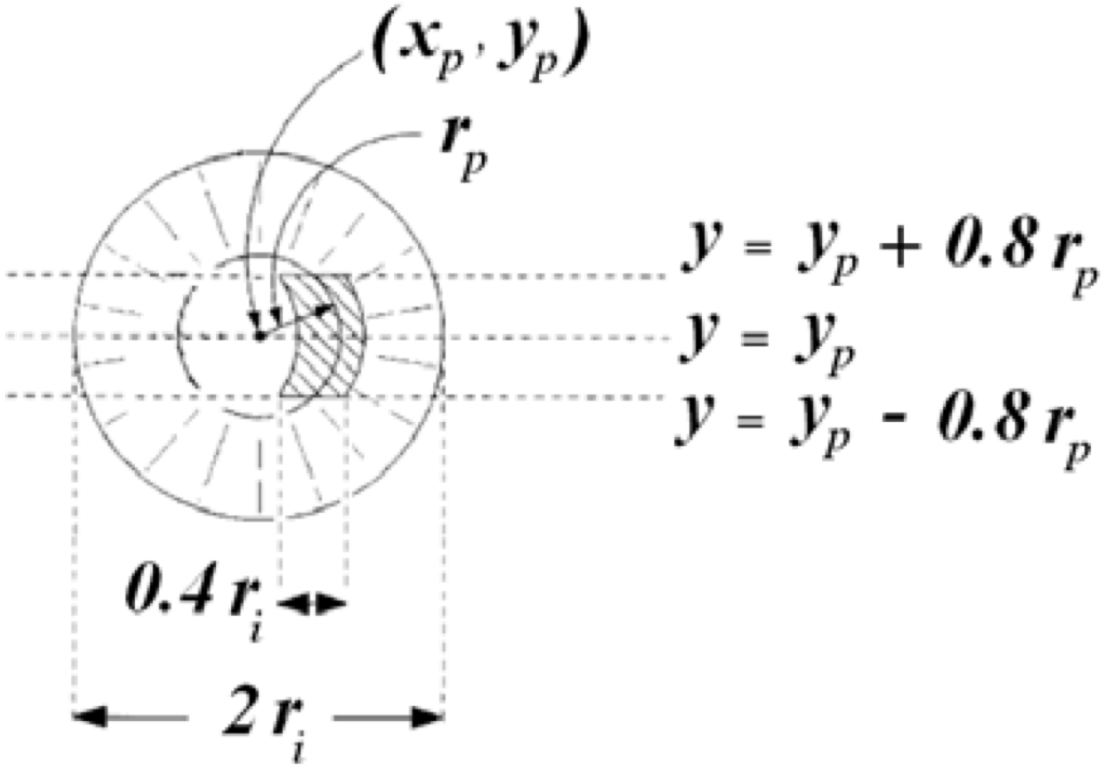
Iris matching

- 3 images of the eye from 2 different subjects
- Segmentation: extract the iris, convert to a rectangular entity via Daugman's rubber sheet model
  - also results in a binary mask: 1/0 indicates an non-iris pixel
- Normalized iris: using Gabor wavelets and the resulting phasor response is quantized into an iris code
- HD between two iris codes of the same iris is expected to be smaller



Iris matching: Quality measure

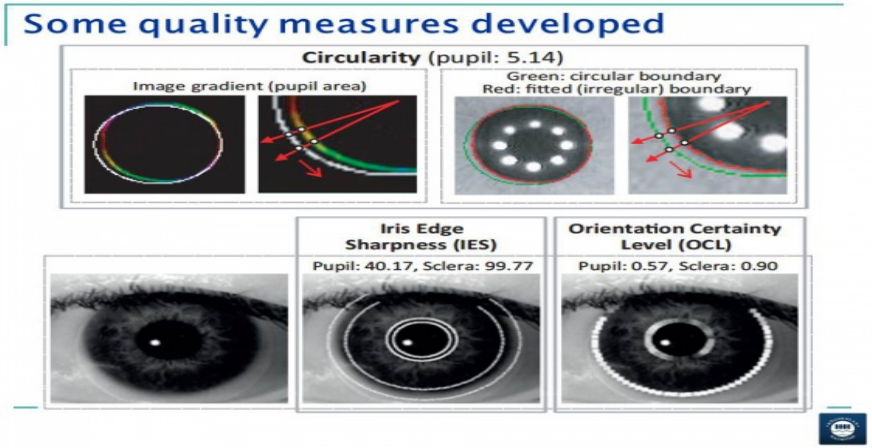
- Only the rich textural information of the iris between the pupillary and limbus boundaries is used for recognition
- So, quality evaluation is typically based on factors that degrade or reduce the size of the iris region
  - Examining the sharpness of a portion between the pupil and iris



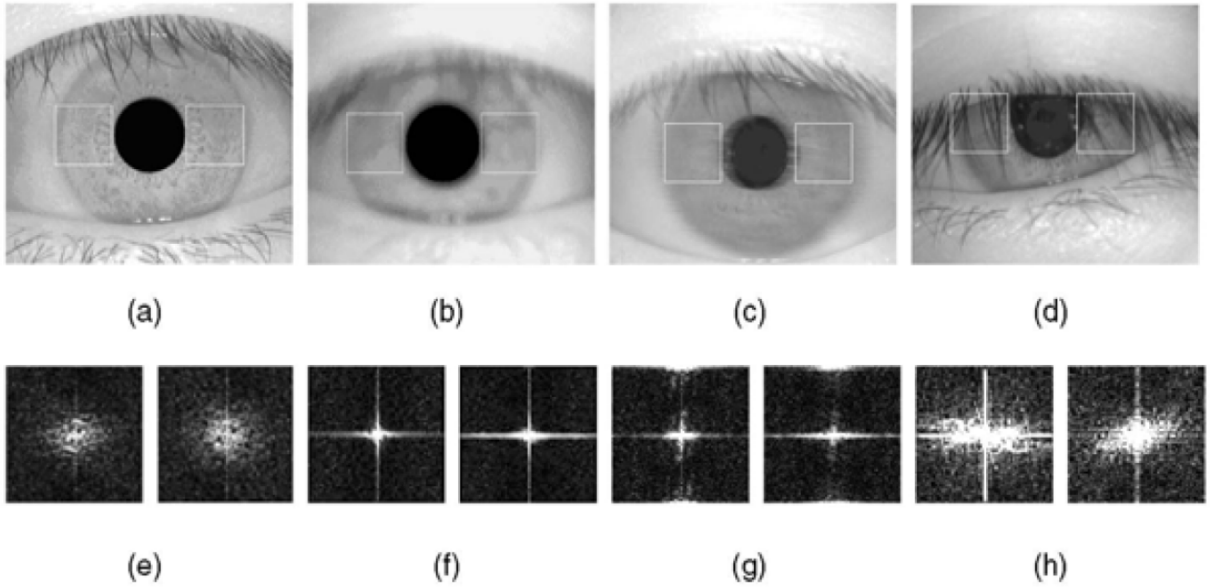
If the sharpness measure is above a threshold value of 0. 5, the image is considered to be well focused and, therefore, of good quality

Iris matching: Quality measure

- Quality evaluation is typically based on factors that degrade or reduce the size of the iris region (cont.)
  - Quantifying the energy of high spatial frequencies over the entire image: determine the sharpness over the whole image using 2D Fourier analysis in order to eliminate optically defocused images
  - Analyzing the Fourier spectra of local iris regions: detect poor quality images caused by factors such as (a) out-of-focus blur, (b) motion blur, and (c) occlusion due to the eyelashes, and/or eyelids
  - Measuring the energy from 2D wavelets at local concentric bands of iris



Iris matching: Quality measure



(a) Good quality

Poor quality iris images: (b) out-of-focus, (c) motion blur, and (d) occlusion

(e), (f), (g), and (h) show the Fourier spectra of the selected two local iris regions of size 64°ø64 (highlighted by the white boxes)

$$HD_w = \frac{1}{B} \frac{\sum_{i=1}^{B} \sqrt{E_{g(i)}^X \times E_{g(i)}^Y} \times (X_i \otimes Y_i)}{\sum_{i=1}^{B} \sqrt{E_{g(i)}^X \times E_{g(i)}^Y}}$$

- Result: new/modified HD calculation
- Iris image quality assessment is an area of continuing research
  - Initial research has shown the benefits of incorporating iris quality, but its assessment and use in a real-time environment is still an open challenge

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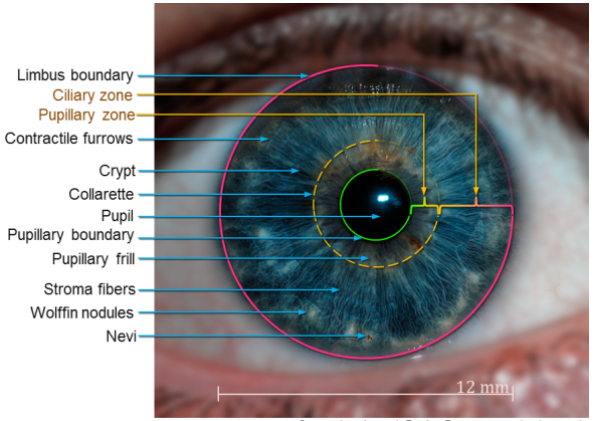
Error Probabilities

HD Criterion	Odds of False Accept	Odds of False Reject
0.28	1 in 10^{12}	1 in 11,400
0.29	1 in 10^{11}	1 in 22,700
0.30	1 in 6.2 billion	1 in 46,000
0.31	1 in 665 million	1 in 95,000
0.32	1 in 81 million	1 in 201,000
0.33	1 in 11.1 million	1 in 433,000
0.34	1 in 1.7 million	1 in 950,000
0.342 Cross-over	1 in 1.2 million	1 in 1.2 million
0.35	1 in 295,000	1 in 2.12 million
0.36	1 in 57,000	1 in 4.84 million
0.37	1 in 12,300	1 in 11.3 million

Summary

- No effective theoretical models exist for quantifying the iris's individuality yet
- Again, concerns about the iris template's security and the retention of its owner's privacy



Source (eye image): Dr. Jan Drewes. www.jandrewes.de

Q&A

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