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Non-Cooperative Biometric Recognition: Issues and Trends

June 1st, 2011. Faculty of Engineering, Oporto .

- Overview
  - Part I – Biometric Recognition
    - Biometric Traits
    - Typical Cohesive Perspective
    - Performance Measures
  - Part II – Non-Cooperative Recognition
    - Goal and Scope
    - State-of-the-Art
  - Part III – Issues / Trends
    - Negative Recognition
    - Questionable Observers

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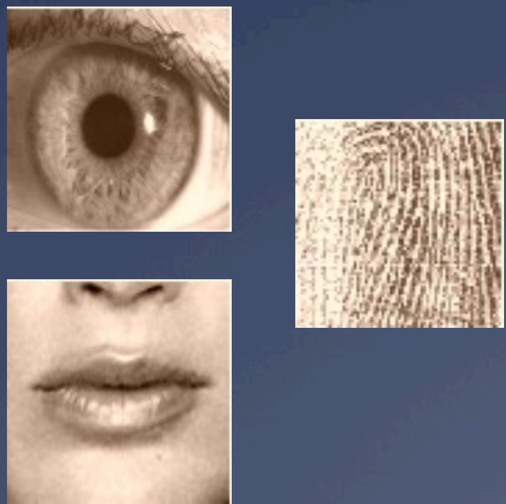
- **Biometrics**
  - ***"Biometrics consists of methods for uniquely recognizing humans based upon one or more intrinsic physical or behavioral traits". (Wikipedia)***
    - **Main properties: Universality, uniqueness, permanence and collectability**
    - **Complementary properties: performance, acceptability and circumvention**



→ Automated Data Analysis

12.612	0.1721	215.19
0.1219	1.1913	0.1283
146.19	1677.1	210.14
2161.9	0.1812	0.8283

Biometric Signature

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* **Biometric Recognition Systems are currently used for different purposes with highly satisfactory results.**
  * **Refugee control, Access to Physical Resources, Airports…**

(http://fingerprint-security.net/)


(http://www.lockheedmartin.com)


(http://www.engadget.com/)

"Considering the recent mandates of several governments for the nationwide use of biometrics (…) Pattern recognition systems have never been tried at such large scales nor have they dealt with such a wide use of sensitive personal Information. As pattern recognition researchers, it is a great opportunity and challenge for us to make a difference in our society (…)" A.K. Jain; "Biometrics: A Grand Challenge", ICPR 2004.

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Biometric Traits:

- Different types of traits were proposed to perform recognition:
  - Fingerprint, Face, Iris, Retina, Voice, Ear, Gait, Keystroke and Signature Dynamics, Odor, Hand and Finger Geometry, Vascular Structure, DNA

Trait	Unicidade	Universalidade	Permanência	Collectabilidade	Desempenho	Aceitabilidade	Circunvenção
DNA	87%	95%	94%	19%	19%	15%	55%
Orelha	46%	58%	85%	50%	53%	100%	50%
Face	44%	92%	50%	84%	25%	99%	37%
Termograma Facial	95%	100%	25%	100%	69%	85%	100%
Geometria Dedos	23%	58%	70%	75%	47%	70%	50%
Impressão Digital	78%	47%	91%	62%	98%	49%	71%
Passo	25%	50%	25%	100%	21%	100%	50%
Geometria Mão	54%	57%	54%	78%	50%	67%	59%
Estrut. Venosa	57%	52%	53%	52%	50%	56%	97%
Íris	96%	93%	97%	62%	98%	50%	95%
Forma Teclar	17%	23%	28%	56%	25%	67%	50%
Cheiro	70%	89%	85%	25%	21%	50%	37%
Impressão Mão	96%	50%	100%	50%	97%	50%	50%
Retina	94%	86%	66%	29%	98%	23%	100%
Assinatura	35%	39%	34%	83%	23%	97%	33%
Voz	39%	49%	31%	59%	23%	99%	33%

- Values averaged from 10 different sources (available at: http://www.di.ubi.pt/~hugomcp/doc/TesePhD_HugoMCP.pdf)

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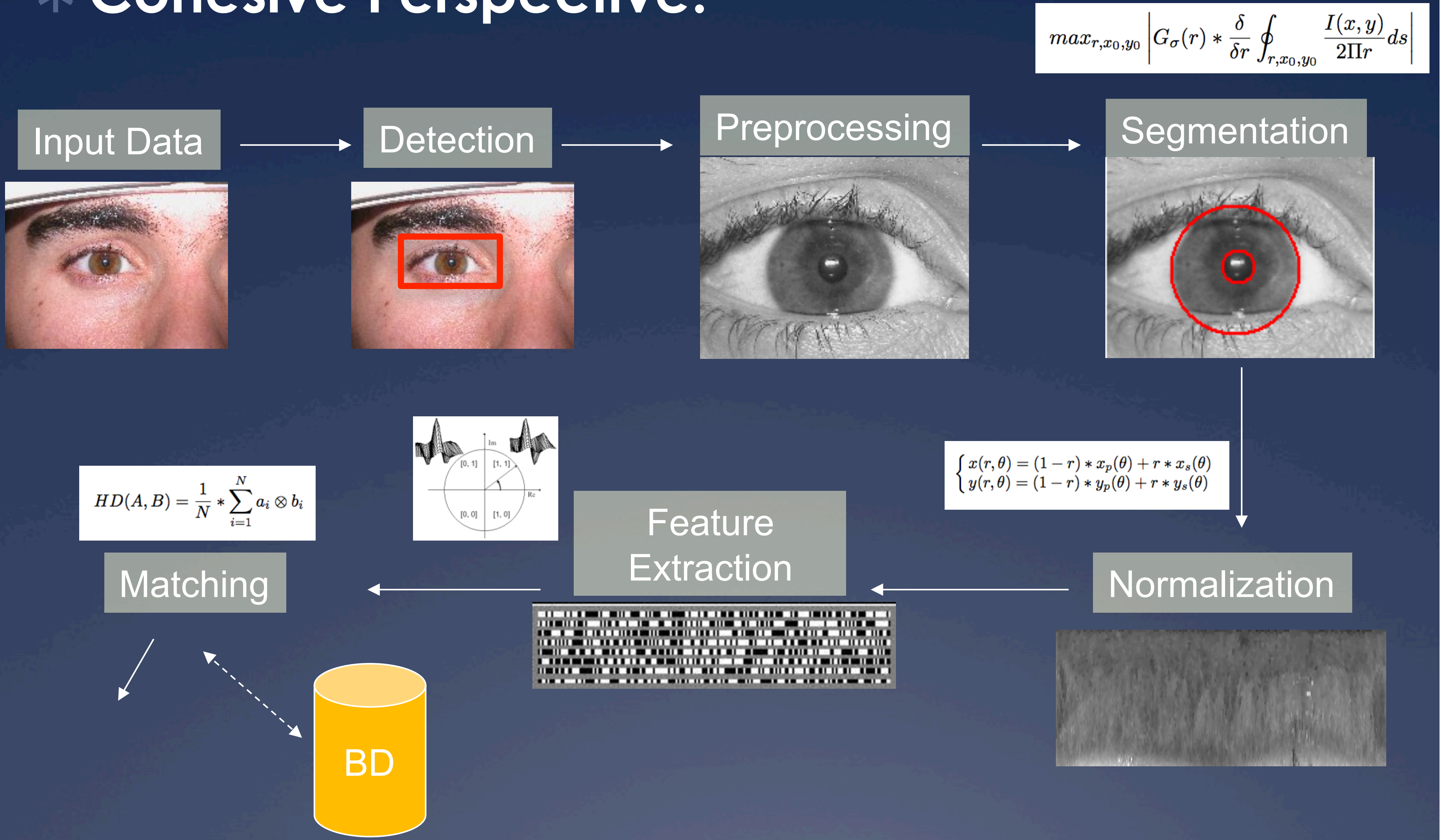
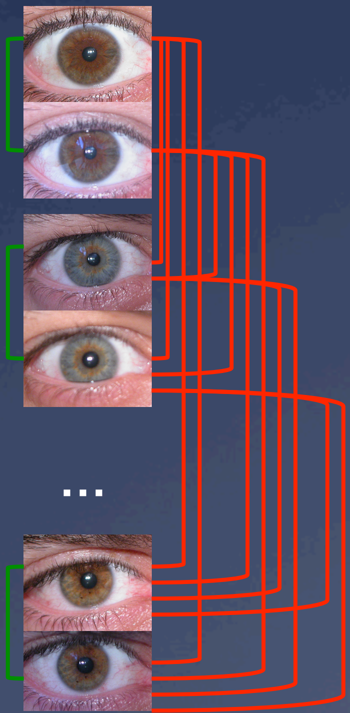
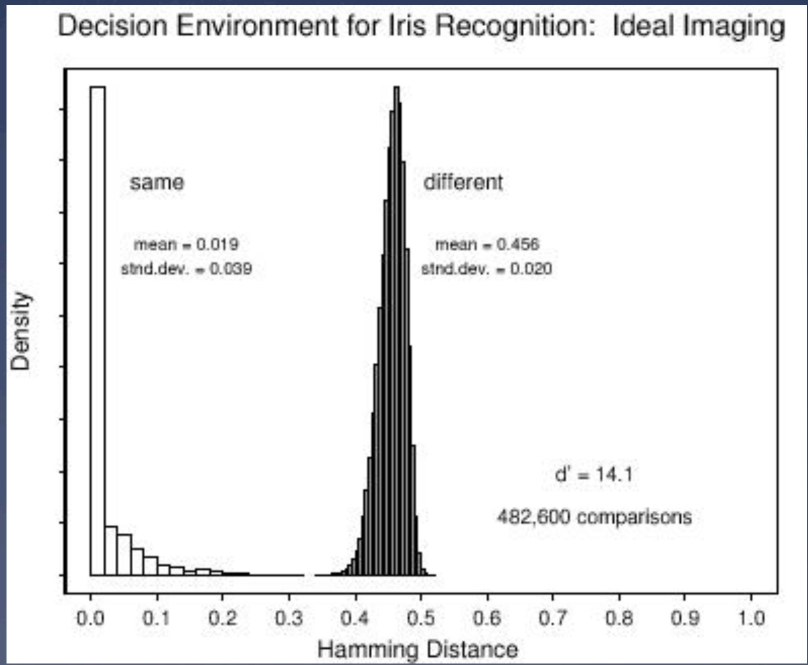
Cohesive Perspective:



Decision Environment

- Given "k" instances (k small) of "n" classes (n very large), robust classification should be achieved.
- The problem is regarded as binary, by simply considering comparisons between images of the same (genuine) / and different eyes (impostors).





(http://www.cl.cam.ac.uk/~jgd1000/decidability.html)

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Performance Measures

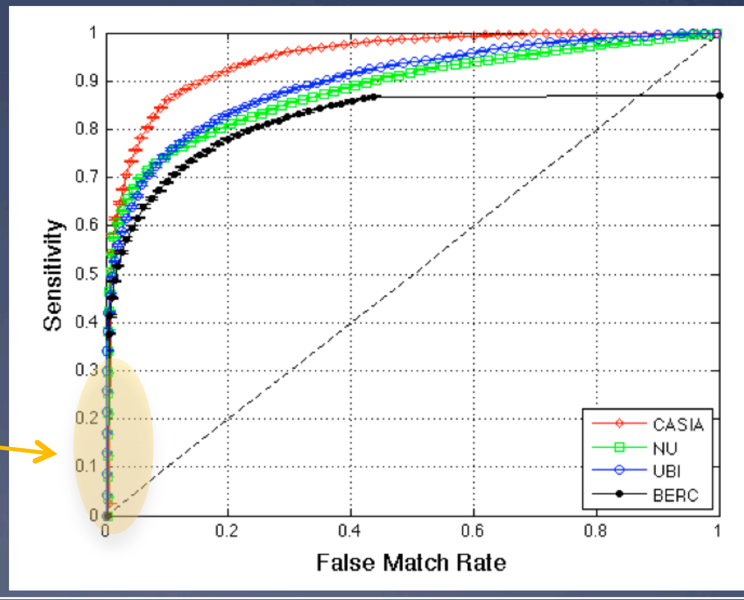
- Traditionally used in Pattern Recognition systems: ROC, DET, EER, AUC.
- Identification Mode:
  - Rank-n, Accumulated Rank-n
- Decidability

$$d' = \frac{|\mu_E - \mu_I|}{\sqrt{\frac{\sigma_I^2+\sigma_E^2}{2}}},$$

- FRR @ FAR= δ ,

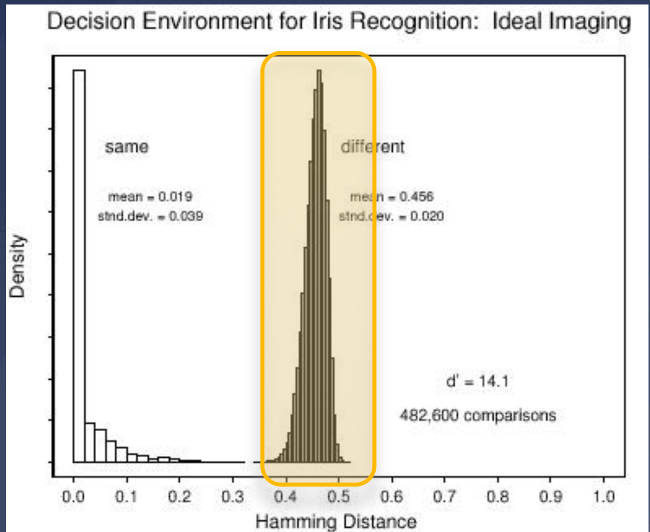
  (δ very small)

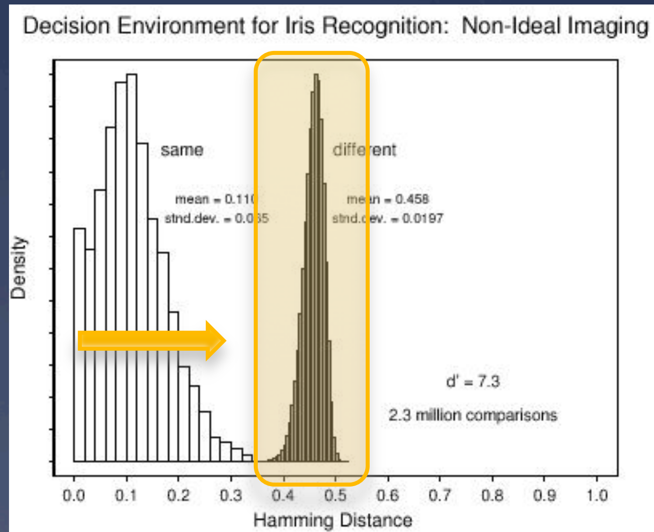
ROI



Degradations in Performance

- Current biometric systems achieve remarkable performance when analyzing good quality data.
- Performance significantly decreases when data is degraded, due to problems in the acquisition process.





(http://www.cl.cam.ac.uk/~jgd1000/decidability.html)

… and gets much worse on *real-world* data

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Main Goal

- To develop an automaton able to robustly recognize human beings, without requiring them any cooperation in the acquisition process.
  - Perhaps contrary to usual belief, such automata are still confined to science Fiction.

(http://www.prisonplanet.com/)

  - Book “*Nineteen Eighty-Four*” by George Orwell (1948) gave birth to the idea of “*Big Brother*”.

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Why use the iris?

1. Naturally protected internal organ;
2. Supports contactless data acquisition;
3. Uses the lowest and middle-low frequency components to perform recognition.
4. Its regular shape turns easier its detection and segmentation;
5. Its planar shape turns easier to compensate for off-angle acquisition.

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* **Why use visible light imagery?**
  1. Systems require high illumination levels, sufficient to maximize the signal-to-noise ratio in the sensor;
  2. Acquiring data from largest distances, acceptable depth-of- fields demand higher f-numbers for the optical system (corresponding directly - squared - with the amount of light required);
  3. The motion factor demands very short exposure times, which again will require too high levels of light;
  4. Excessively strong illumination cause permanent eye damage. The NIR wavelength is particularly hazardous:
     1. Eye does not instinctively respond with its natural mechanisms (aversion, blinking, and pupil contraction).

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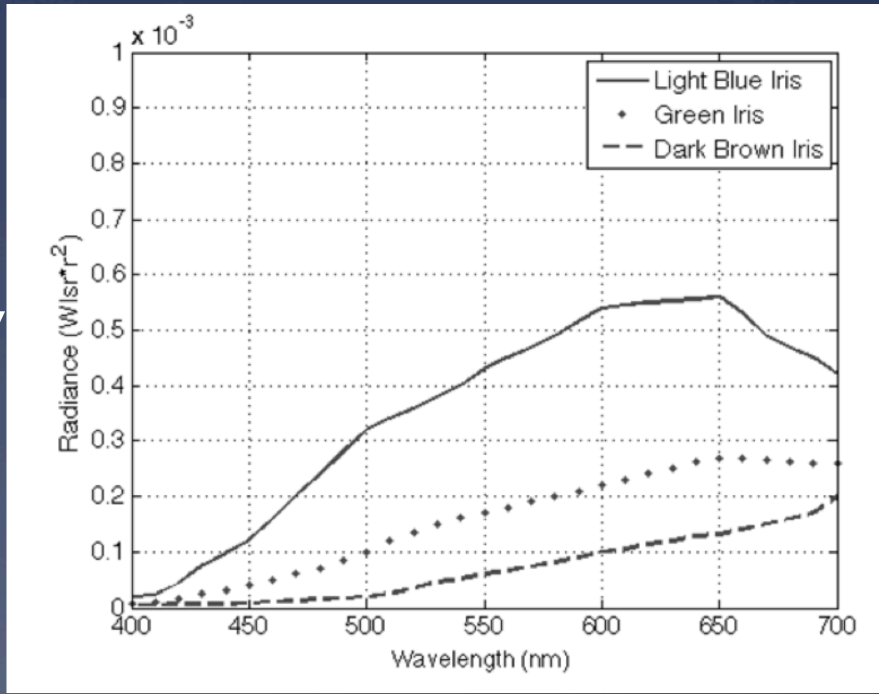
- **Iris Recognition at Visible Wavelengths (VW)**
  - **The pigmentation of the human iris consists mainly of two molecules: brown-black Eumelanin (over 90 percent) and yellow-reddish Pheomelanin.**
  - **Eumelanin has most of its radiative fluorescence under the VW, which enables to capture much more detail, but also more noisy artifacts (specular and diffuse reflections and shadows);**
  - **The spectral radiance of the iris in respect of the levels of its pigmentation varies much more significantly in the VW than in the NIR.**
  - **Glossy reflections occlude portions of the iris ring.**



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* Acquisition Framework (Project BIOREC: PTDC/EIA/69106/2006

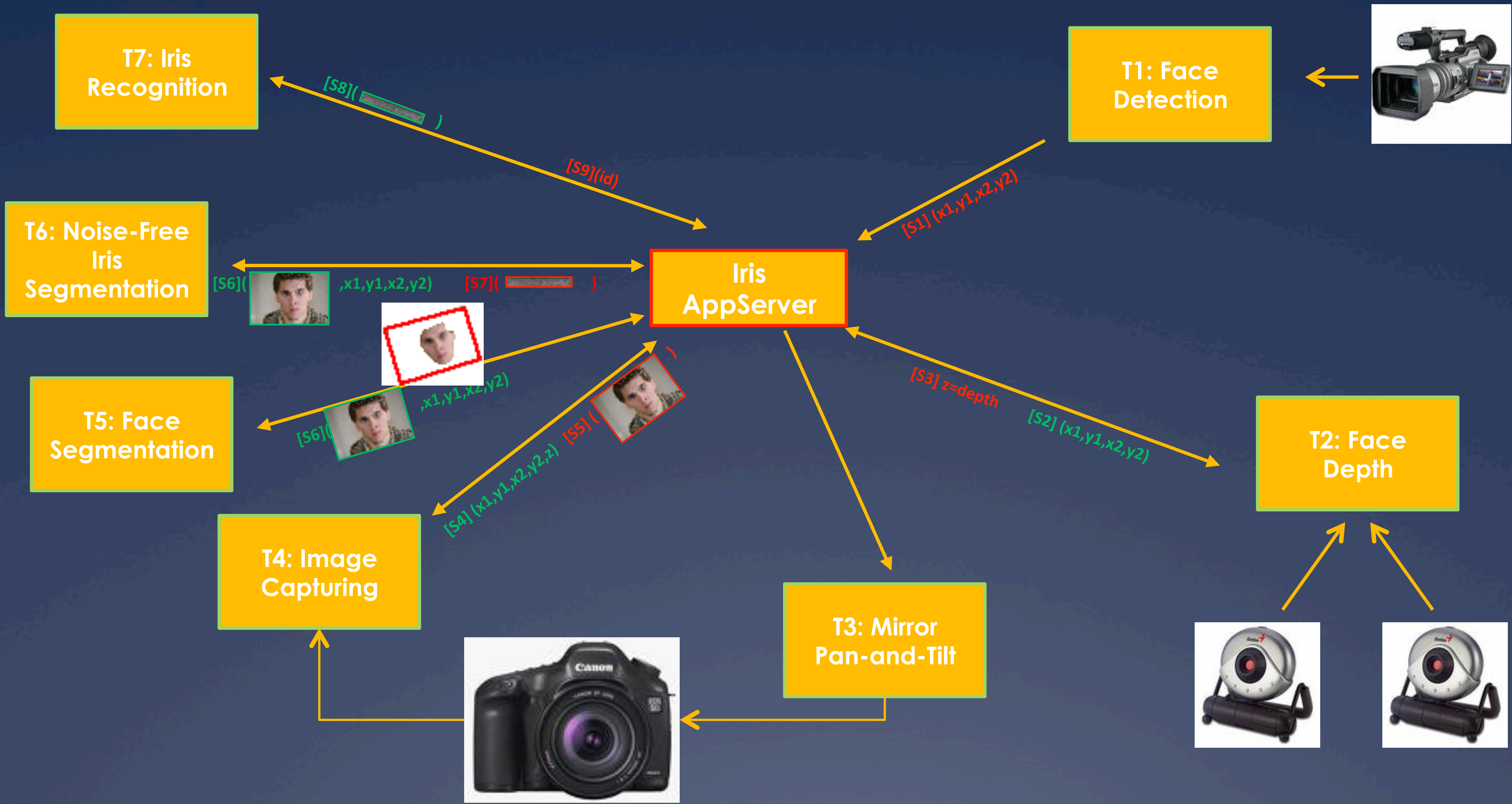

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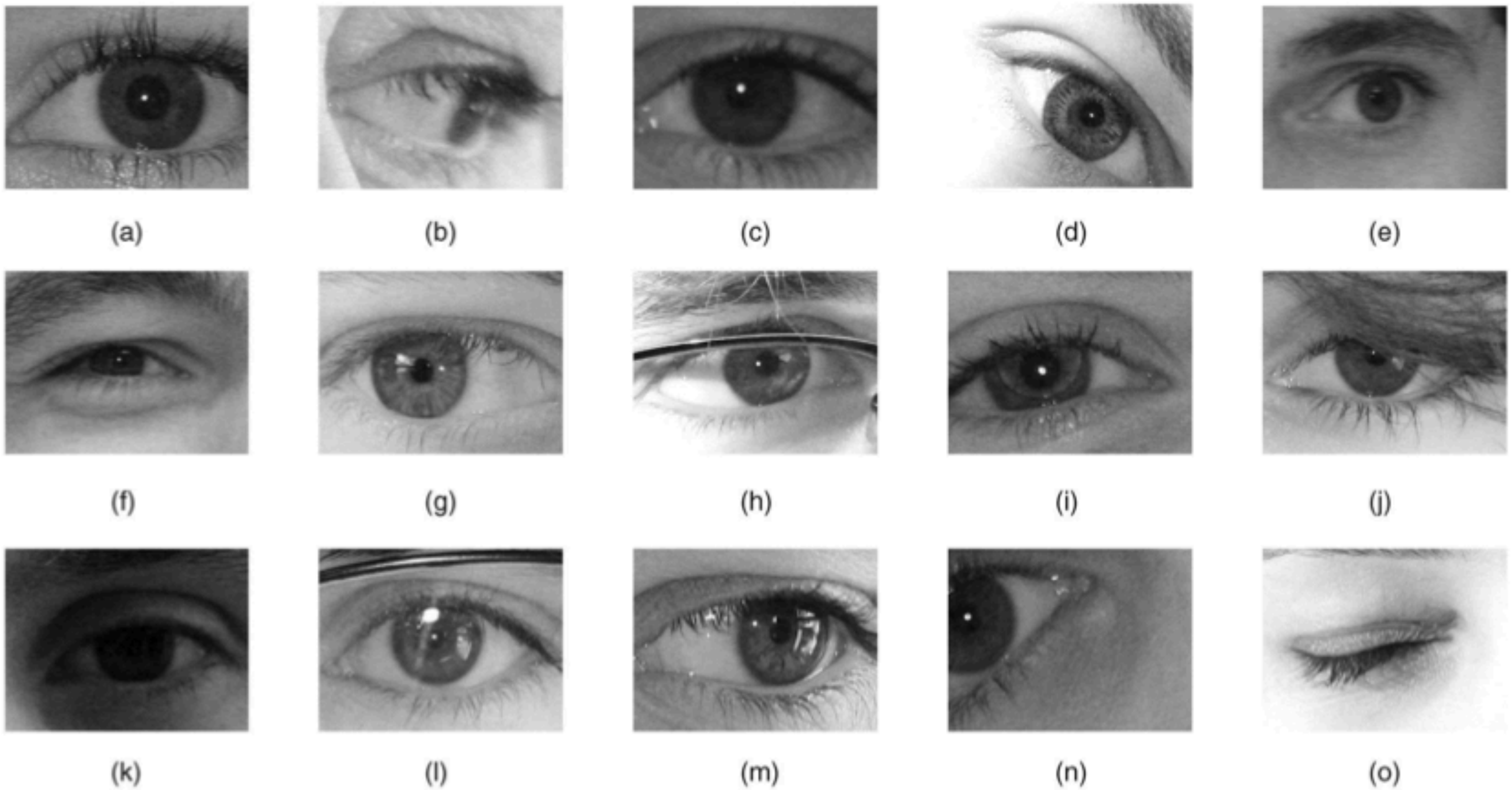
Image Degradation Factors

Resultant of Uncontrolled Acquisition Setups and Dynamic Lighting Conditions



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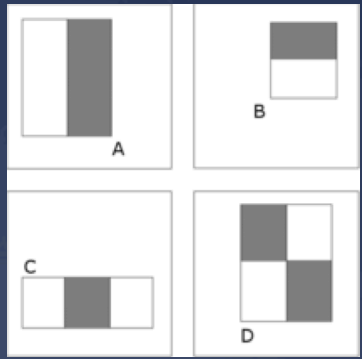
Detection of Eyes (Periocular Region)

- P. Viola and M. Jones. "Robust real-time object detection", IJCV, 57(2):137–154, 2004.
- It enables real-time processing.
- Used in the detection of both the facial and periocular regions.
- Based in the notion of integral-image, a *Haar*-based feature that is possible to extract in a single image scan.



- According to an Adaboost-like learning strategy, builds a strong classifier from orthogonal weak single features classifiers.

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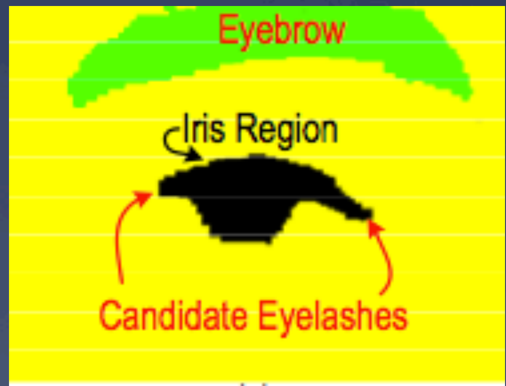
Segmentation of VW Degraded Data

- Z. He et al. "Towards Accurate and Fast Iris Segmentation for Iris Biometrics", IEEE-TPAMI, 31:9, 1670-1684.
- Most mis-localizations occur on non-iris regions due to the high local contrast.
- Pixel-clustering produces more homogenous data.



- Both the pupillary and scleric boundaries are segmented with higher degrees-of-freedom (off-angle acquisition)
  - Use of Active Contours

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- Examples of Segmented VW Degraded Images
  - Most of the times, state-of-the-art methods achieve results that can be considered satisfactory.

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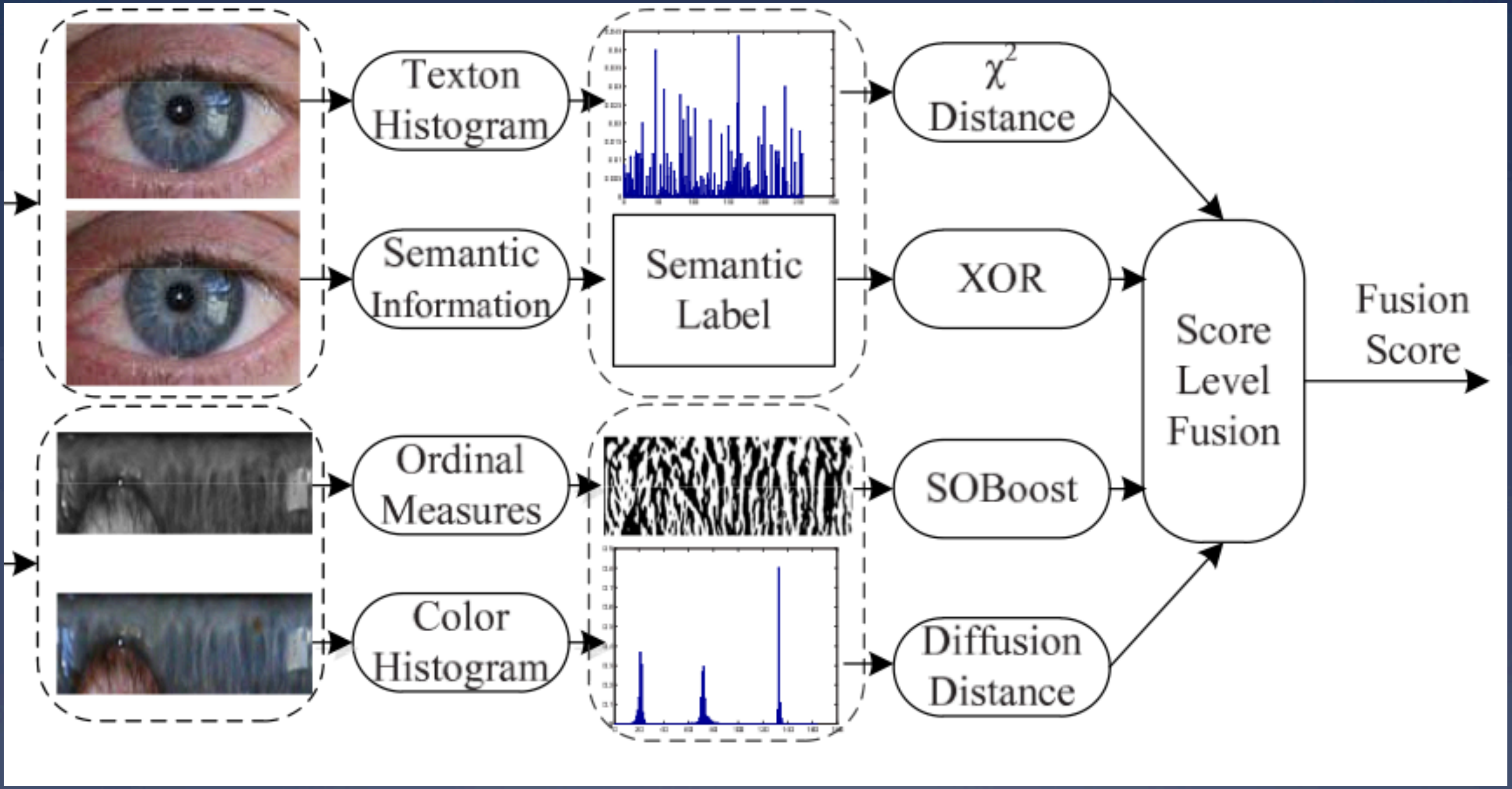
Feature Extraction on VW Degraded Data

- *Tan et al. Noisy Iris Image Matching by Using Multiple Cues, PRL (to appear).*
- *Cohesive Perspective:*



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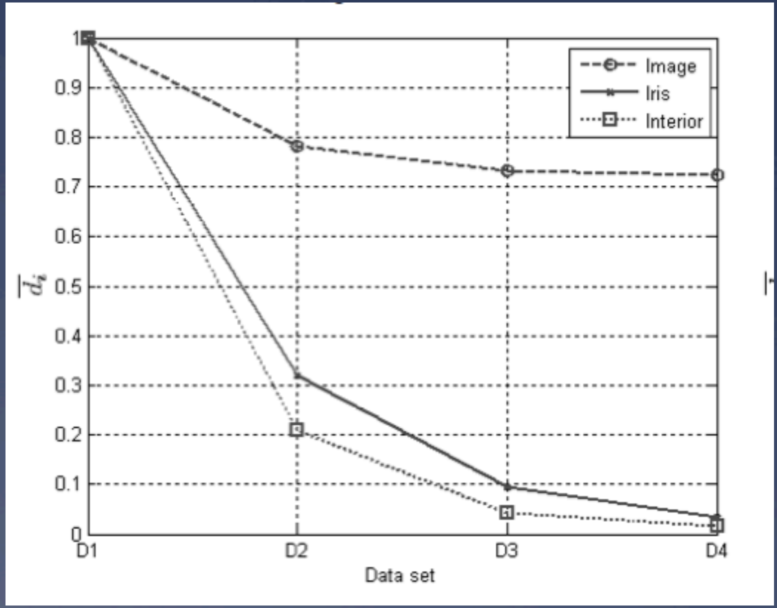
Quality Assessment of VW Degraded Data

- H. Proença. "Quality Assessment of Degraded Iris Images Acquired in the Visible Wavelength", IEEE-TIFS, 6(1), 82-95.
- Focus Assessment:
  - Assessed by measuring the amount of high frequencies, i.e., the power of the convolution between I and a high-pass kernel H:

$$\alpha_f = \int_x \int_y |I * H|^2 dx dy$$

  - Problem: Eyebrows, Eyelashes



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Quality Assessment of VW Degraded Data

Motion Assessment

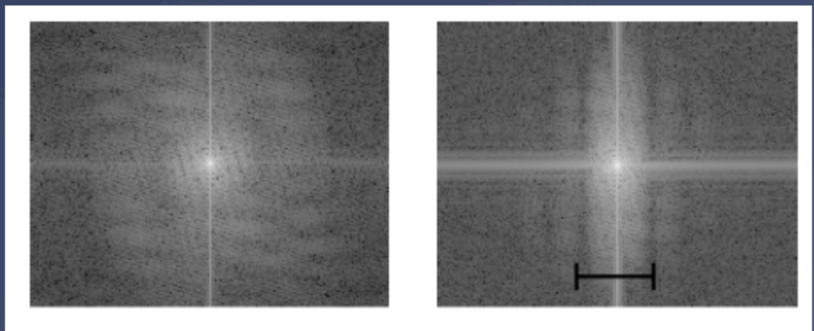
- The primary direction of motion is deemed to be the one that minimizes the power of the derivatives of along a particular direction.

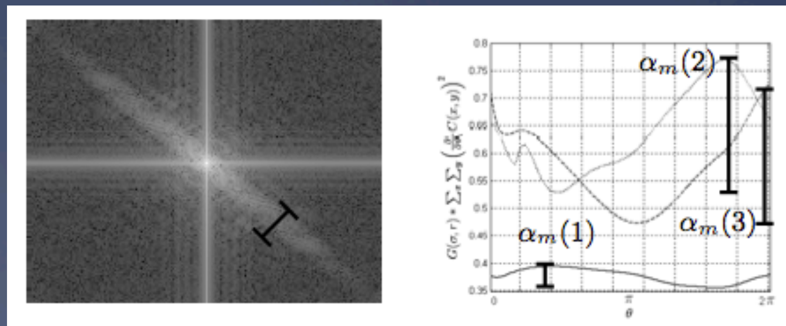
$$\theta_m = \arg\min_{\theta_i} G(\sigma, r) * \sum_x \sum_y \left(\frac{\partial}{\partial \theta_i} C(x,y)\right)^2$$

- The amount of motion is deemed to be in direct correspondence to the amplitude of this signal:

$$\alpha_m = \max_{\theta_i} \sum_x \sum_y \left(\frac{\partial}{\partial \theta_i} C(x,y)\right)^2 - \min_{\theta_i} \sum_x \sum_y \left(\frac{\partial}{\partial \theta_i} C(x,y)\right)^2$$

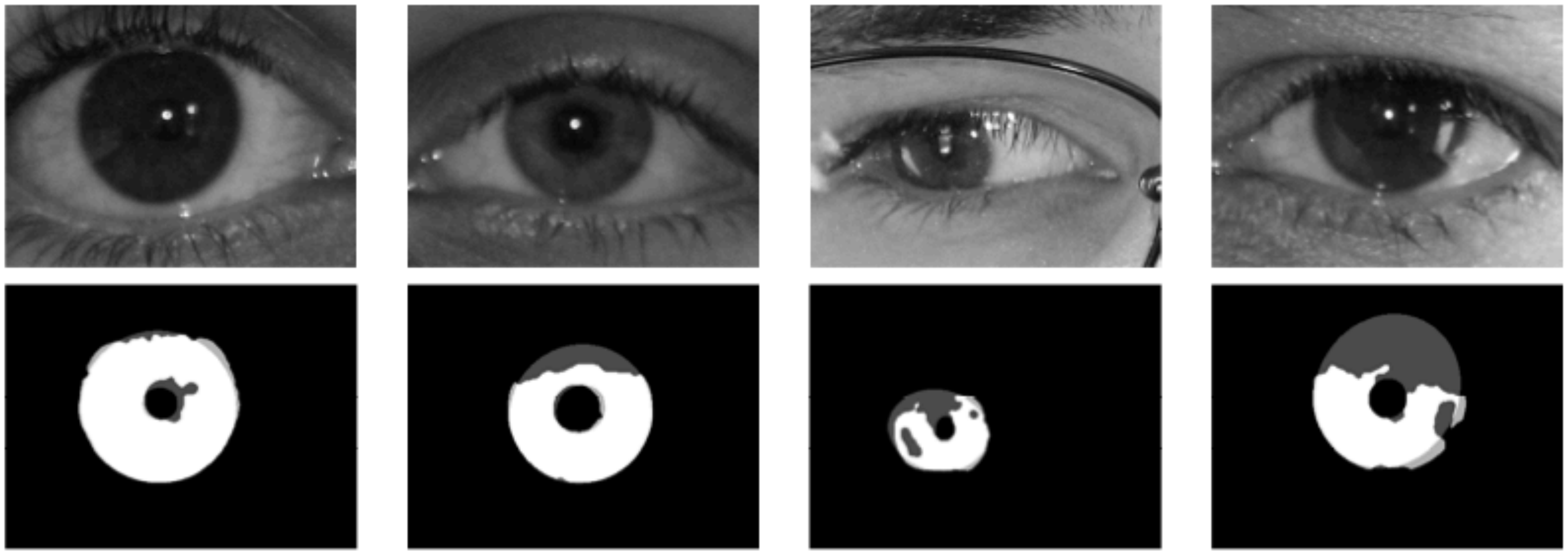
- Example:





Quality Assessment of VW Degraded Data

- Occlusions Assessment
  - The proportion between the region defined by the *biological iris boundaries* and the area of the segmented noise-free iris constitutes a strong estimator for occlusions.



$\alpha_o = 0.032$ $\alpha_o = 0.178$ $\alpha_o = 0.345$ $\alpha_o = 0.485$

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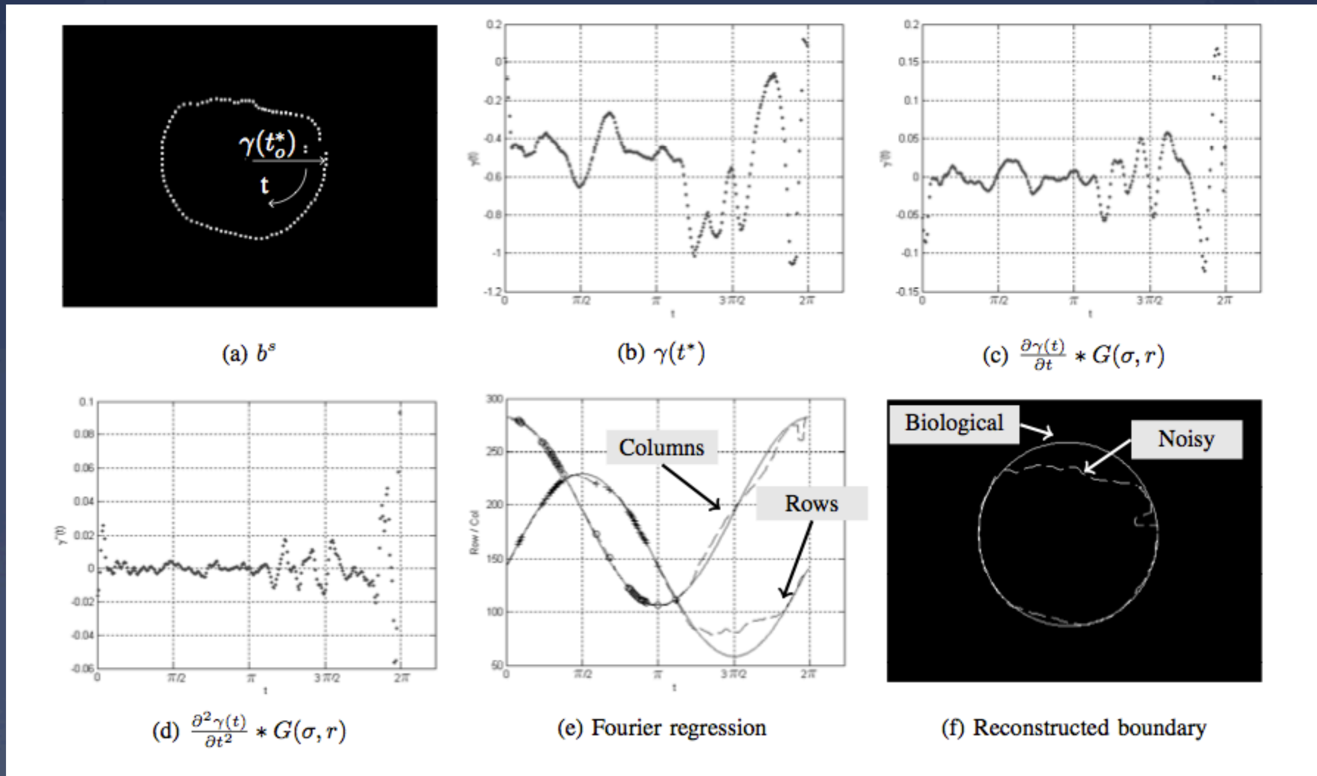
Quality Assessment of VW Degraded Data

- We started by the description of each boundary by a shape descriptor (cumulative angular descriptor), obtained its first and second derivatives) and built an objective function.
- The first quartile of pixels (25% of the whole boundary) were used in a Fourier regression process that reconstructs the whole boundary.



(a) b^s (b) $\gamma(t^*)$ (c) $\frac{\partial \gamma(t)}{\partial t} * G(\sigma, r)$

(d) $\frac{\partial^2 \gamma(t)}{\partial t^2} * G(\sigma, r)$ (e) Fourier regression (f) Reconstructed boundary

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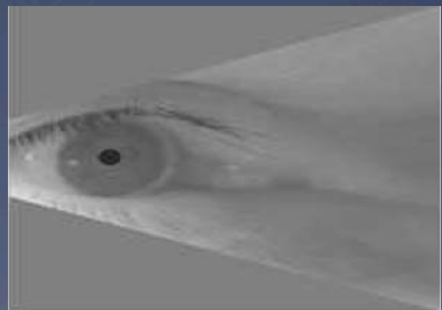
Quality Assessment of VW Degraded Data

- **N. Kalka et al. Estimating and Fusing Quality Factors for Iris Biometric. IEEE TSMC:A, 40(3), 509-524.**
- **Projected an integro-differential operator at multiple yaw and pitch angles:**
- **Applied a set of affine transforms, so to maximize the circularity of the detected boundary:**

$$J(\psi,\varphi) = \max_{r,x_0,y_0} \left| G_\sigma(r) * \frac{\partial}{\partial r} \oint_C \frac{I(x',y' : \psi,\varphi)}{2\pi r} \mathrm{d}s \right|$$



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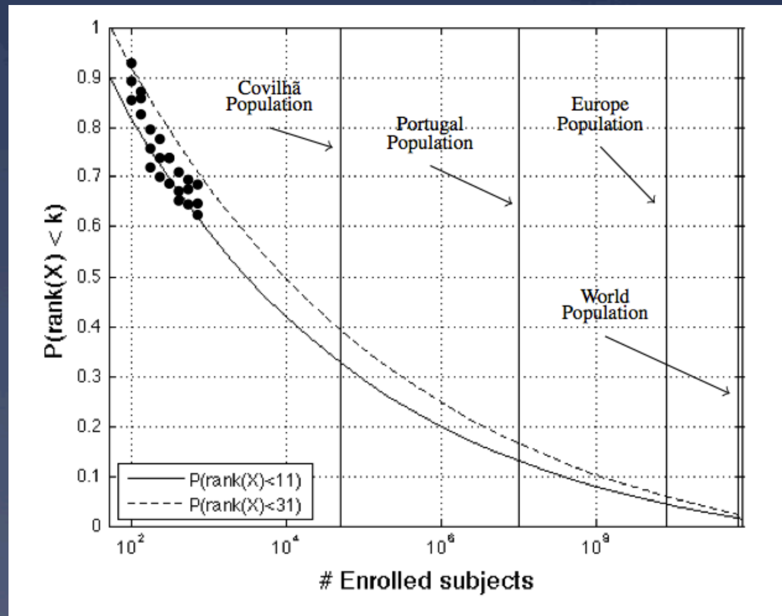
State-of-the-Art Performance

- Best results
  - Using iris + periocular information (d’=2.57)
  - Using exclusively iris (d’=1.82)

- Probability that a given query returns up to rank-10 i.e., the system returns the true identity in the first 10 Results, with respect to the dimension of the Universe.



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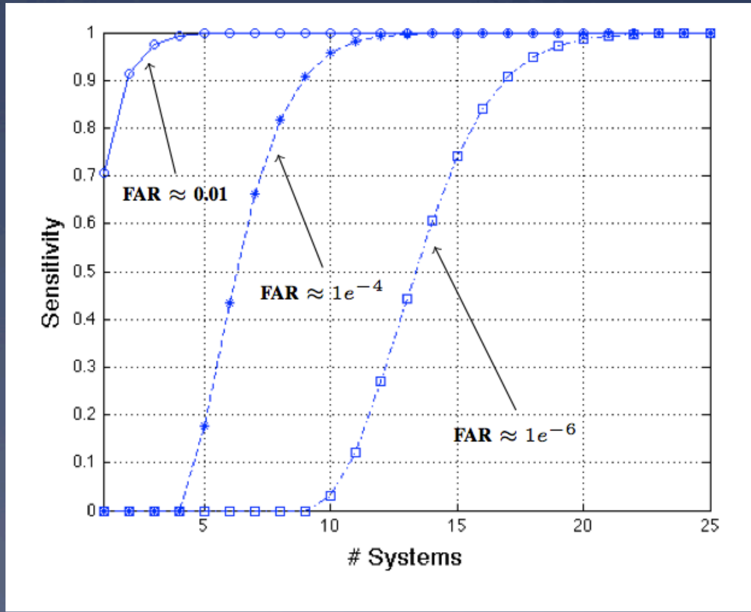
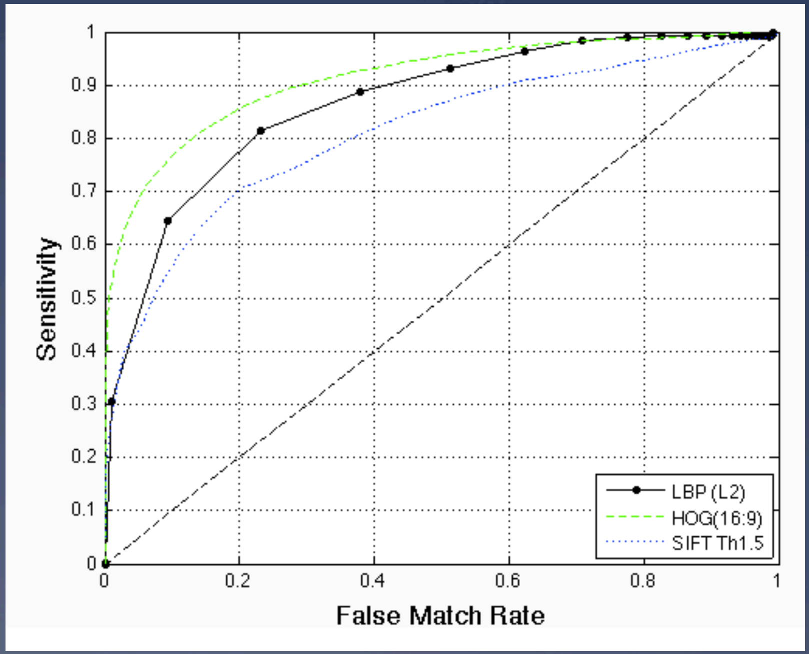
- Suppose that we are able to install several consecutive recognition systems.
  - Working on purposely different conditions, so to minimize correlation.
    - Lighting conditions
      - Different types of illuminants
    - Acquisition perspectives and distances
    - Analyzing different regions
    - Using different algorithms
  - Number of independent systems required, with respect to different performance levels:



Periocular Biometric Recognition

- Park *et* al. Periocular Biometrics in the Visible Spectrum," IEEE-TIFS, 6 (1), 96 – 106.
- Periocular biometric refers to the facial region in the immediate vicinity of the eye.
- Acquisition of the periocular data is expected to require less cooperation and permits a larger stand-off distance than other ocular biometrics.
- Few published works



- Based in:
  - SIFT
  - Local Binary Patterns
  - Histograms Oriented Gradients

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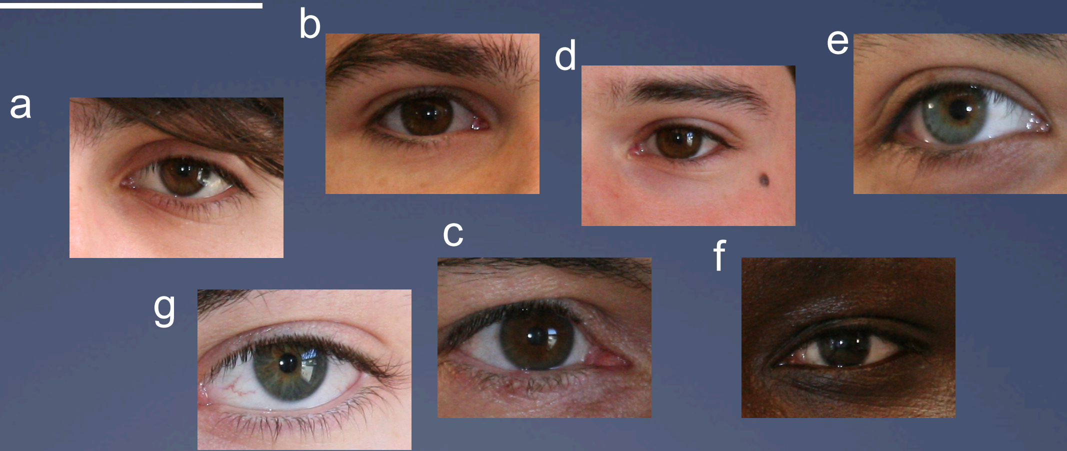
- **Negative Biometric Recognition (NECOVID: PTDC/EIA-EIA/103945/2008)**
  - Check that an individual is not among a group of people already known to the system.
  - Although the quality of data may deny positive recognition, in most cases is possible to confirm that data is not correspondent to a subset of the enrolled templates, which most of the everyday situations is the essential.

?



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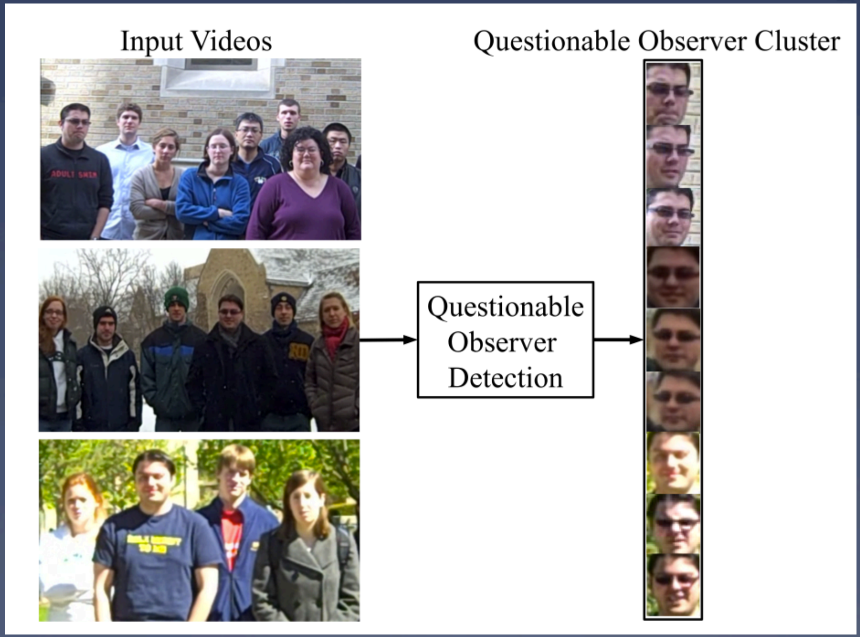
Questionable Observers

- J. Barr *et* al. "Detecting Questionable Observers Using Face Track Clustering", in Proceedings of the 2011 IEEE Workshop on Applications of Computer Vision (WACV), 182-184.
- Given a collection of videos of crowds, determine which individuals appear unusually often across the set of videos:



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