Dealing with Sensor Interoperability using Quality Estimates:

The UAM experience at BMEC 2007

Dr. Julian Fierrez
Universidad Autonoma de Madrid, SPAIN
(Visiting researcher at Michigan State University, USA)

(with contributions from Fernando Alonso-Fernandez, Daniel Ramos, Javier Galbally, and Javier Ortega-Garcia)

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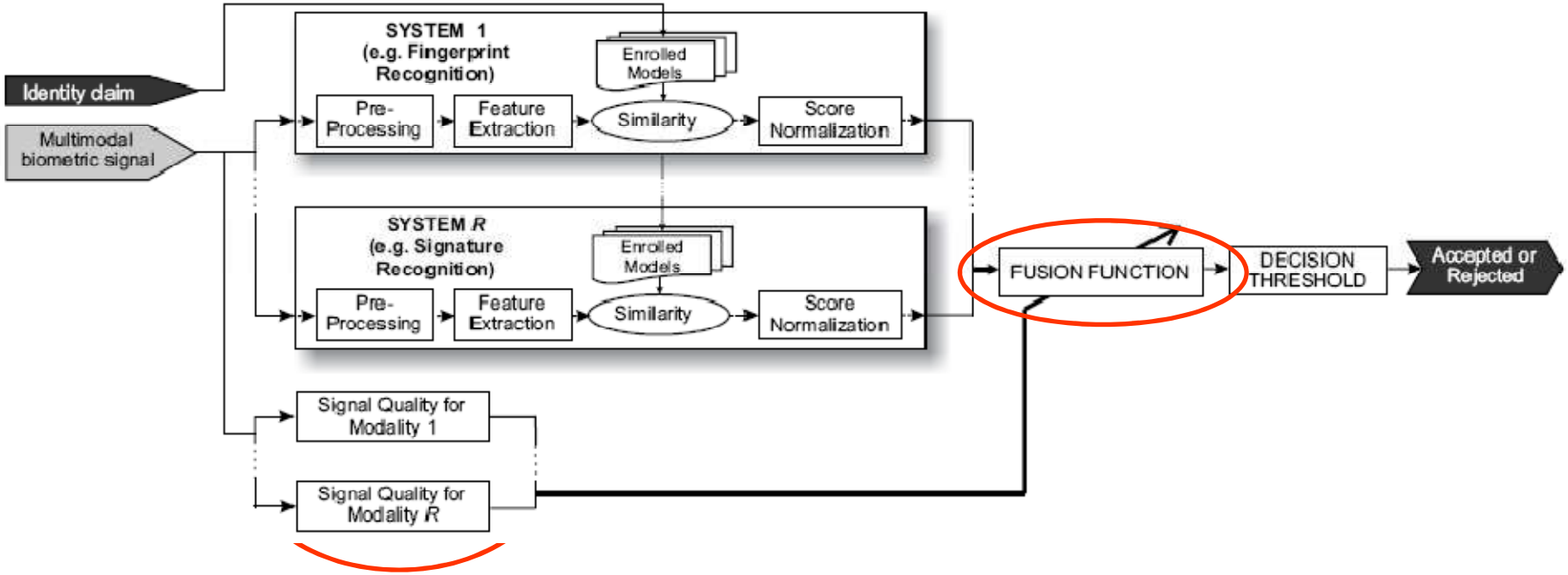
What we will not see…

QUALITY-BASED FUSION

- NIST BQW I (Fierrez et al.), NIST BQW II (Kryszczuk)
- NIST Biometric Quality Homepage Reading Materials



QUALITY MEASURES

- Fingerprint Survey to appear in *IEEE Trans. IFS*, 2007 or 2008

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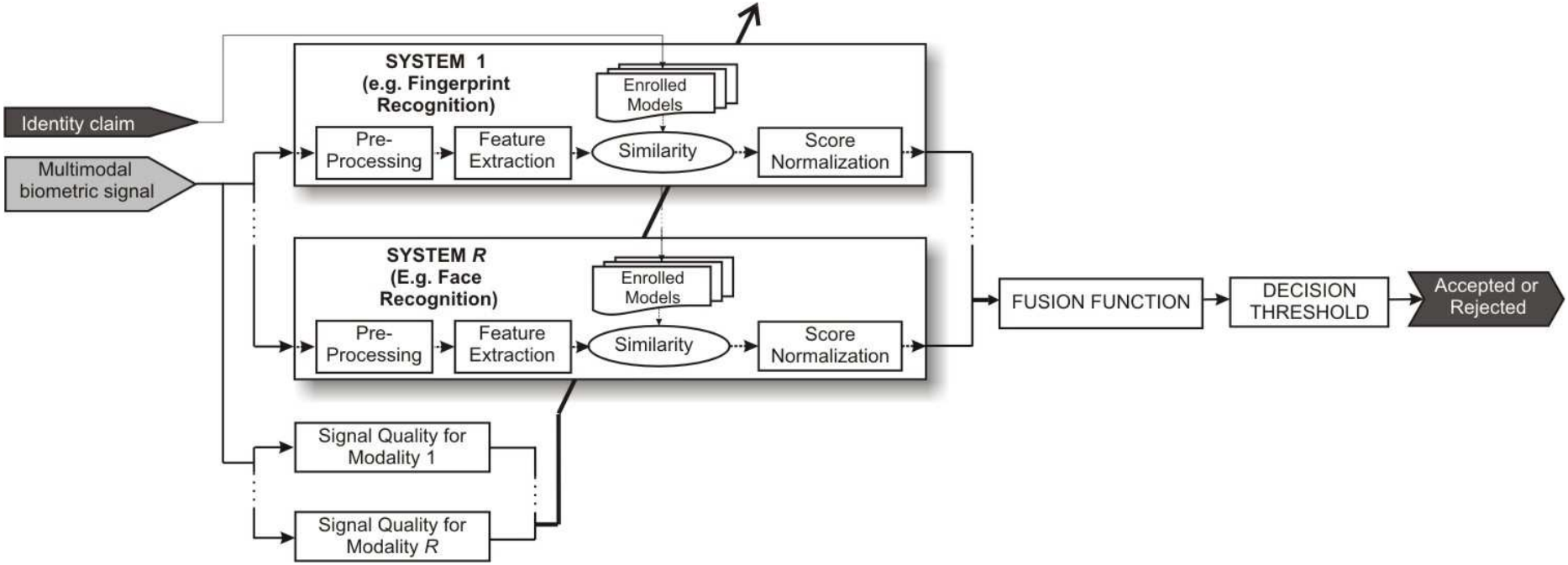
What we will see...

BIOSECURE MULTIMODAL BIOMETRIC DATABASE

- Face, fingerprint, iris, voice, signature, hand; around 1000 subjects
- Enables research on individual modalities (Q measures), and fusion
- Biosecure Multimodal Evaluation Campaign (BMEC 2007)

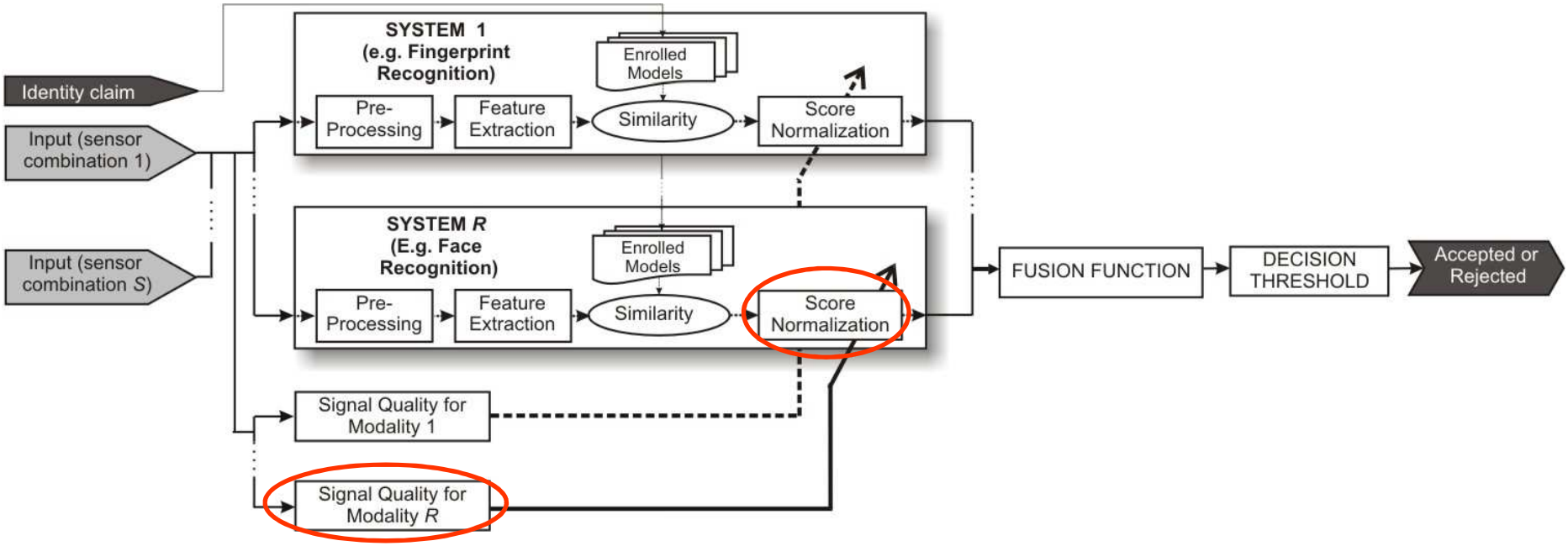
QUALITY-BASED CONDITIONAL PROCESSING (Benini, NIST BQW II)



...more specifically

QUALITY-BASED CONDITIONAL PROCESSING (Benini, NIST BQW II)

- Dealing with sensor interoperability using quality vectors (Lazarick, NIST BQW II)



OVERVIEW

BIOSECURE MULTIMODAL BIOMETRIC DATABASE

- Internet Dataset: voice, face
- Desktop Dataset: voice, face, iris, fingerprint, signature, hand
- Mobile Dataset: voice, face fingerprint, signature

BIOSECURE MULTIMODAL EVALUATION CAMPAIGN

- **Mobile:** talking face, signature, fingerprint
- **Access control:** still face, fingerprint, iris

  Cost-Based

  Quality-Based **Protocol, UAM Approach, Results**

The Biosecure Multimodal Biometric Database

Biosecure Multimodal Database

DATASETS:

- **DS1 (Internet): Voice, face**
- **DS2 (Desktop): Voice, face, signature, fingerprint, iris, hand**
- **DS3 (Mobile): Voice, face, signature, fingerprint**

STATISTICS:

- 11 acquisition sites across Europe
- 2 acquisition sessions for each DS (2 months between them)
- Subjects (aprox.): 1000 DS1, 700 DS2, 700 DS3 (400 common)

AVAILABILITY:

- Through the Biosecure Association (more information to appear in 2008 at http://www.biosecure.info)

Internet Dataset (DS1)

DS1: Voice, face

- PC-based, on-line, unsupervised (Internet)
- Equipment: low-cost webcam and bluetooth microphone

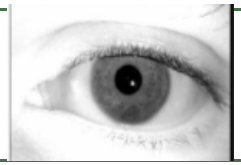
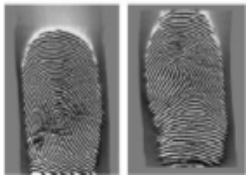
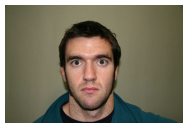
Internet Dataset (DS1): Contents

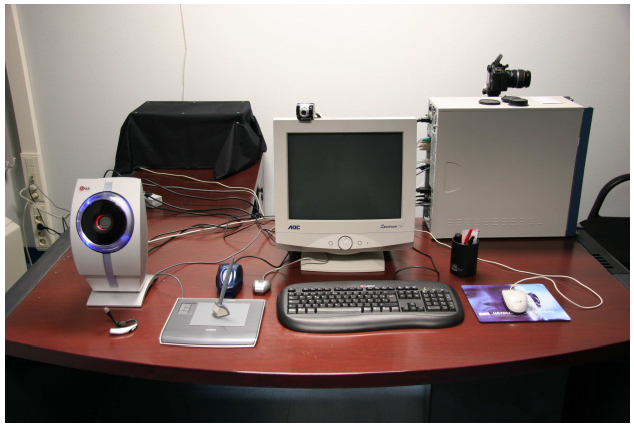
• Acquisition protocol (per session, total duration per session around 20 minutes, ***COMMON to the 3 DSs***):

Mode ID	Sample ID	Data Type	Contents
I	1-2	Image	2 still frontal face images
C	1-2	AV	2 repetitions of a 4-digit PIN code (the same between DSs) from a set of 100 different PINs in English
C	3-4	AV	2 repetitions of a 4-digit PIN code (different to C1-2, the same between DSs) from a set of 10 different PINs in native language
D	1	AV	Digits from 0 to 9 in English
S	1-2	AV	2 different phonetically rich sentences in English (different between DSs)
S	3-4	AV	2 different phonetically rich sentences in native language (different to S1-2, different between DSs)

Desktop Dataset (DS2)

DS2: Voice, face, signature, fingerprint, iris, hand

PHILIPS SPC 900NC + PLANTRONICS Voyager 510		 
LG IrisAccess EOU3000		
BIOMETRIKA FX2000		
YUBEE (Atmel FingerChip)		
WACOM Intuos A6 + Inking Pen		
CANON EOS 30D + Ring Flash		 



Desktop Dataset (DS2): Contents

- Per session, total duration per session around 20 minutes:

Mode	Sample	Data Type	Sensor	Contents
SI	**1-5**	**Signatures**	**Tablet**	**5 genuine of donor *n***
SI	**6-10**	**Signatures**	**Tablet**	**5 dynamic imitations of donor *n* – 1 (*n*–3 session 2)**
SI	**11-15**	**Signatures**	**Tablet**	**5 genuine of donor *n***
SI	**16-20**	**Signatures**	**Tablet**	**5 dynamic imitations of donor *n* – 2 (*n*–4 session 2)**
SI	**21-25**	**Signatures**	**Tablet**	**5 genuine of donor *n***
COMMON – AUDIO / VIDEO (simultaneosly with the webcam and the bluetooth earbud)				
IR	**1-4**	**Iris images**	**Iris cam**	**(Right eye Left eye) x 2 times**
FO	**1-12**	**Fingerprints**	**Optical**	**(R_thumb R_index R_middle L_thumb L_index L_middle) x 2**
FT	**1-12**	**Fingerprints**	**Thermal**	**(R_thumb R_index R_middle L_thumb L_index L_middle) x 2**
HA	**1-8**	**Hand**	**Camera**	**(Right hand x 2 times Left hand x 2 times) without flash (THE SAME) with flash**
FA	**1-4**	**Face**	**Camera**	**2 photos without flash 2 photos with flash (ISO-like conditions)**

Mobile Dataset (DS3)

DS3: Voice, face, signature, fingerprint

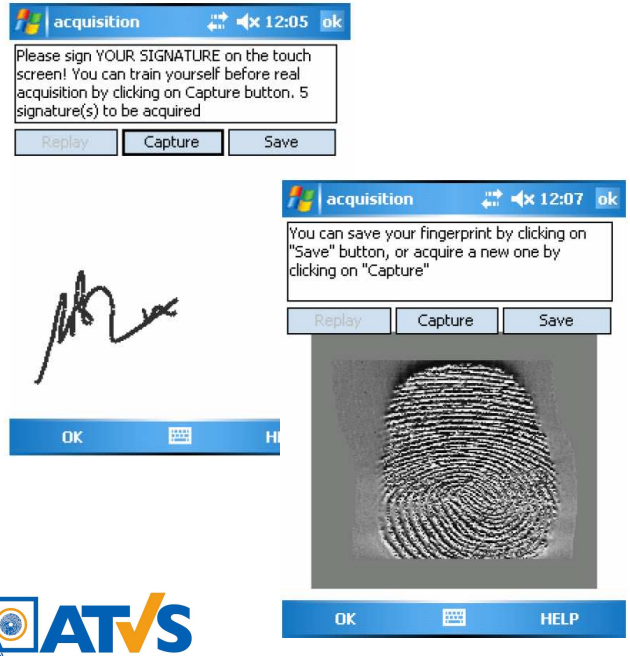
- Equipment: mobile devices (PDA and Ultra-Mobile PC)
- Indoor and outdoor conditions

HP iPAQ hx2790

Fingerprint and Signature

SAMSUNG Q1 + WebCam

Face and Voice



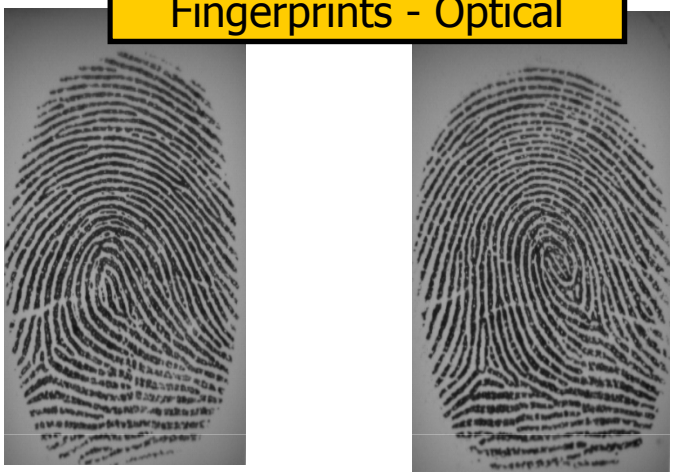
Mobile Dataset (DS3): Contents

- Per session, total duration per session around 20 minutes:

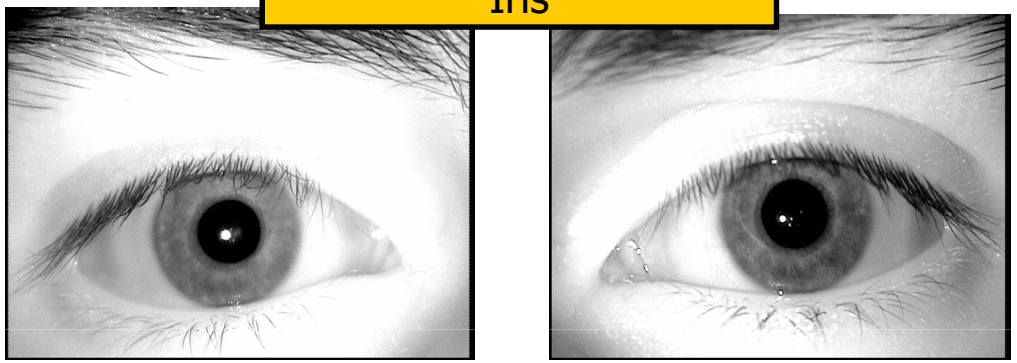
Mode ID	Place	Sample ID	Data Type	Sensor	Contents
SI	**Indoor *(standing)***	**1-5**	**Sign**	**iPAQ**	**5 signatures of donor *n***
SI	**Indoor *(standing)***	**6-10**	**Sign**	**iPAQ**	**5 dynamic imitations of donor *n* – 1 (*n*–3 *session 2*)**
SI	**Indoor *(standing)***	**11-15**	**Sign**	**iPAQ**	**5 signatures of donor *n***
SI	**Indoor *(standing)***	**16-20**	**Sign**	**iPAQ**	**5 dynamic imitations of donor *n* – 2 (*n*–4 *session 2*)**
SI	**Indoor *(standing)***	**21-25**	**Sign**	**iPAQ**	**5 signatures of donor *n***
FT	**Indoor *(standing)***	**1-12**	**Finger**	**iPAQ**	**(R_thumb R_index R_middle L_thumb L_index L_middle) x 2**
***COMMON* – AUDIO / VIDEO (Q1 + WebCam) – INDOOR**					
***COMMON* – AUDIO / VIDEO (Q1 + WebCam) – OUTDOOR**					

Biosecure Multimodal Database: Examples

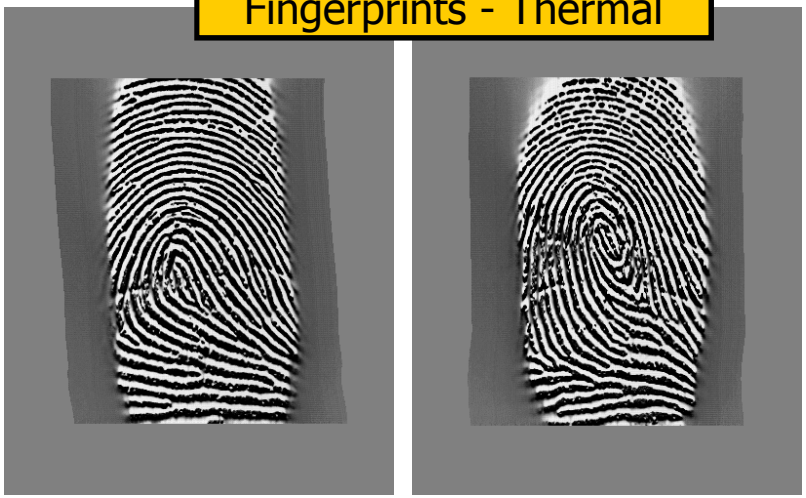
Fingerprints - Optical

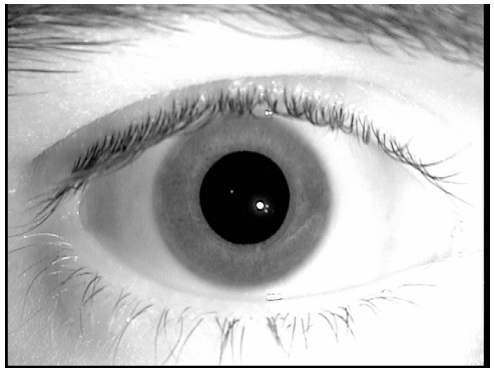


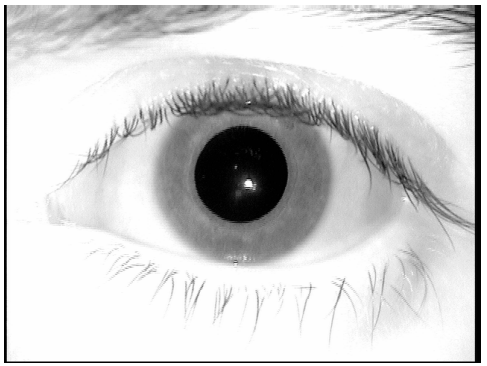
Iris



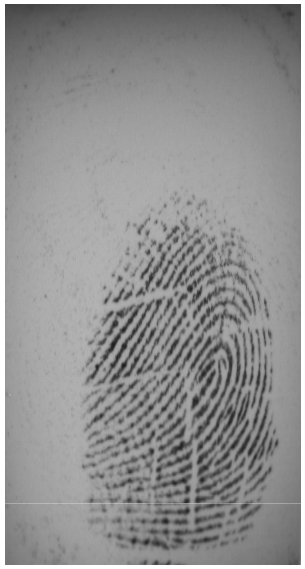
Fingerprints - Thermal



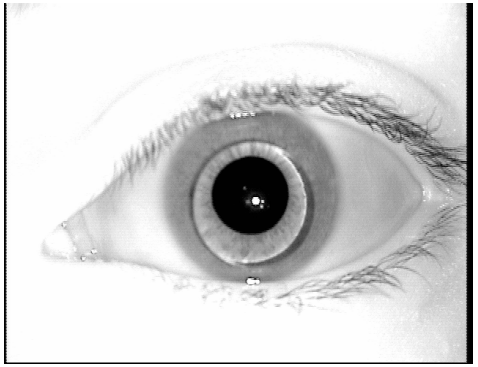




Biosecure Multimodal Database: Low Q Examples







The Biosecure Multimodal Evaluation Campaign (BMEC 2007)

Biosecure MEC 2007

"Mobile" scenario (DS3): talking faces, signature, fingerprint

Objective: to test the robustness of mono and multimodal systems

The participants were provided with **raw** data (monomodal) and development **scores** (multimodal)

"Access control" scenario (DS2): face, fingerprint, iris

Score fusion, 2 different tasks:

- **Quality-based evaluation:** aimed at achieving the best verification performance using score fusion algorithms
- **Cost-based evaluation:** aimed at minimizing a criterion combining verification error rates with the cost of deployment (the use of each biometric trait is associated with a given cost)

The participants were provided with development **scores** and biometric data **quality** information for each trait

17 laboratories, 50 different systems submitted

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Quality-based Evaluation (I)

Objectives:

- To achieve the best possible verification performance using fusion algorithms
- To test the capability of a fusion algorithm to cope with query biometric signals originated from different devices (sensor interoperability)
- To exploit the information on biometric quality during the fusion process (quality estimates are provided by the organizers)
- To cope with missing values of the component monomodal systems (if a system fails in score or quality computation, a special output is generated)

Quality-based Evaluation (II)

Traits and devices:

Mode	Data type	Sensor	Contents
fnf1	Face still	Digital camera (high resolution)	Frontal face images
fa1		Webcam (low resolution)	
fo1, fo2, fo3	Fingerprint	Optical	1 right thumb, 2 right index
ft1, ft2, ft3		Thermal	3 right middle finger

Possible mixtures for each access:

Mixture	Modalities	Face	Fingerprint
1	(fnf1/fo1/fo2/fo3)	Good quality	Good quality
2	(fnf1/xft1/xft2/xft3)	Good quality	Bad quality
3	(xfa1/fo1/fo2/fo3)	Bad quality	Good quality
4	(xfa1/xft1/xft2/xft3)	Bad quality	Bad quality

- 1 face score, 3 fingerprint scores per access
- xft/xfa: template image is acquired using the good quality sensor and query image is acquired using the bad quality sensor
- All fingerprints are acquired with the same device for each access

Quality-based Evaluation (III)

Face quality measures (14 in total):

- Face detection reliability, Brightness, Contrast, Focus, Bits per pixel, Spatial resolution, Illumination, Uniform Background, Background Brightness, Reflection, Glasses, Rotation in plane, Rotation in Depth, and Frontalness

Fingerprint quality measure (only one):

- Based on local gradient (minutiae extractability)

Reference systems for matching:

- Face: Omniperception's Affinity SDK, LDA-based matcher
- Fingerprint: NIST fingerprint system

Protocol:

- DEVELOPMENT: aprox. 50 subjects
- EVALUATION: aprox. 150 subjects

UAM Approach for the Quality-Based Evaluation*

* Fernando Alonso-Fernandez, Julian Fierrez, Daniel Ramos, and Javier Ortega-Garcia, "**Dealing with sensor interoperability in multi-biometrics: The UPM experience at the Biosecure Multimodal Evaluation 2007** ", to appear in *SPIE Defense & Security Symposium, Proc. Biometric Technology For Human Identification V*, Orlando, 2008.

UAM Fusion Algorithm (I)

Method for device estimation using quality:

Use of a linear discriminant function with multivariate normal densities for each class (device1, device2) based on the available Q measures:

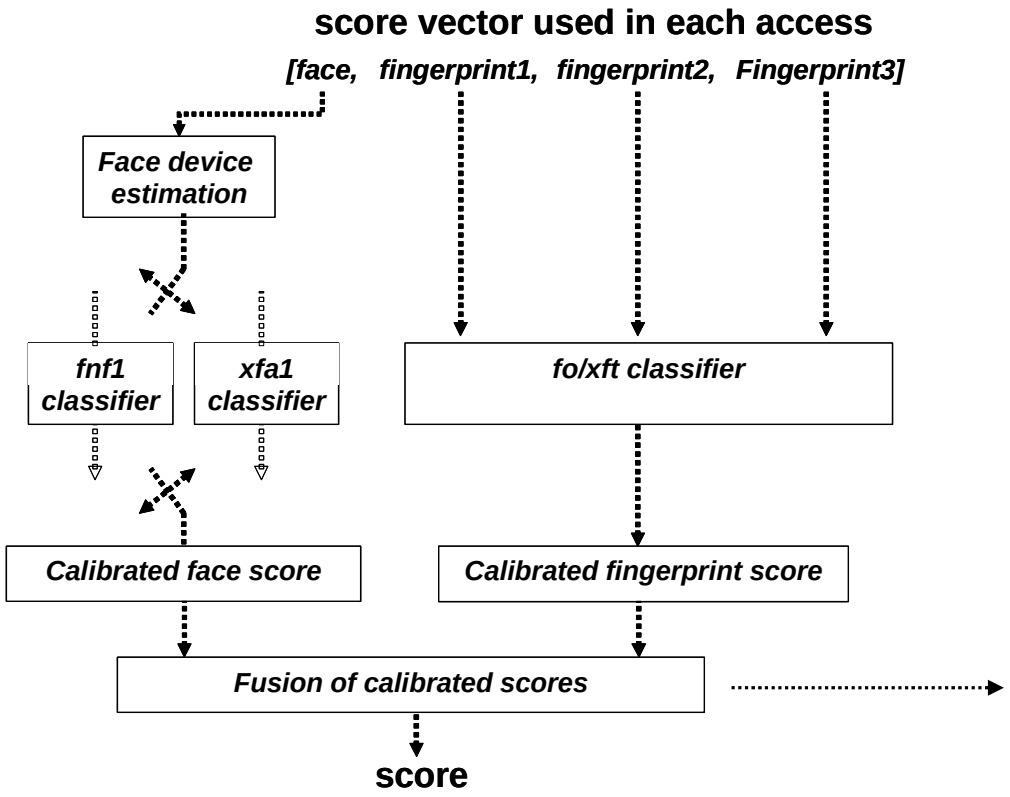
- **FACE:** all quality measures provided (14)
- **FINGERPRINT:** a set of 8 parameters computed combining Q_{query} and $Q_{template}$ from the three fingerprint scores (difference, maximum Q_{query}, minimum Q_{query}, average Q_{query}, etc.)

Results of device estimation using quality:

Good estimation of the **face device (<1% error),** poor estimation of the **fingerprint device (~15% error)**

UAM Fusion Algorithm (II)

Fusion architecture:



Log-likelihood ratios

>0 accept

<0 reject

We choose the score which **stronger** supports the acceptance or rejection decision:

$$\pm \max\left(|s_{face}|, |s_{finger}|\right)$$

If a modality is missing, we just consider the other one

UAM Fusion Algorithm (III)

Linear Logistic Regression fusion: $f = a_0 + a_1 s_1 + \cdots + a_N s_N$

$\mathbf{s} = (s_1, \ldots, s_N)$ scores of individual systems

$\{a_0, a_1, \cdots, a_N\}$ weights trained by linear logistic regression*, solving (conjugate gradient algorithm):

$$\arg \min_{a_0,\ldots,a_N} = \frac{1}{N_u} \sum_{N_u} \log(1 + \mathrm{e}^{-f_u}) + \frac{1}{N_i} \sum_{N_i} \log(1 + \mathrm{e}^{-f_i})$$

N_u, N_i: number of user and impostor training scores
f_u, f_i: fused user and impostor training scores

Score normalization property: fused scores log-likelihood ratios (LLR):

$$f \approx \log\left(\frac{p(\mathbf{s} \mid genuine)}{p(\mathbf{s} \mid impostor)}\right)$$

when $N = 1$ score normalization of a given system

* N. Brümer et al., "**Fusion of heterogeneous speaker recognition systems in the STBU submission for the NIST speaker recognition evaluation 2006**", IEEE Trans. on Audio, Speech and Lang. Proc. 15(7), 2007.

Quality-based Evaluation Results

Training Results (pre-eval)

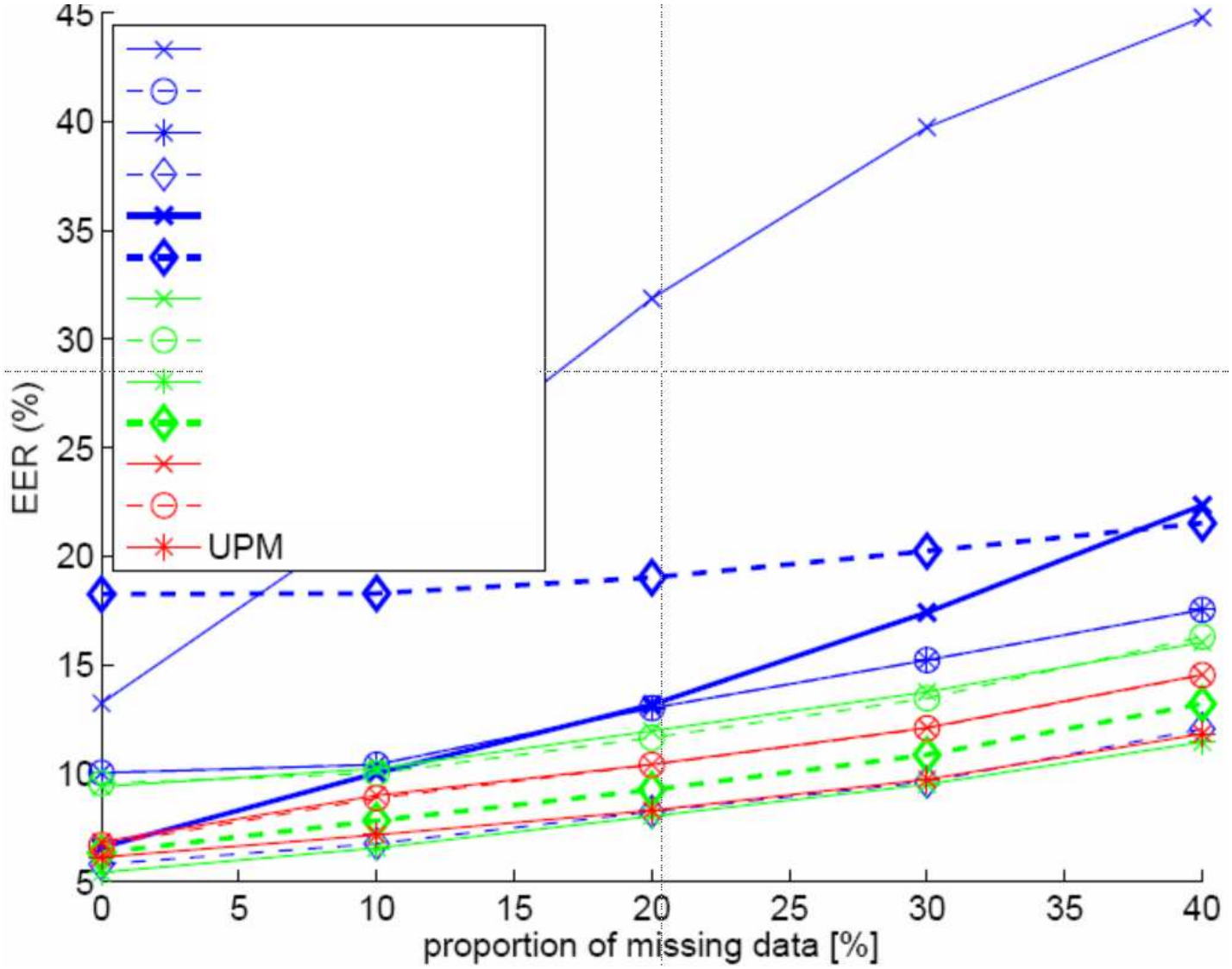
Comparison with simple fusion rules:

- Overall performance of the proposed LLR fusion is 59% better than the best simple fusion rule

Mixture	Modalities	LLR fusion	Arithmetic mean	MIN	MAX	Geometric mean
1	(fnf1/fo1/fo2/fo3)	3.92%	2.94%	8.56%	1.82%	3.92%
2	(fnf1/xft1/xft2/xft3)	4.90%	5.88%	10.00%	14.29%	5.88%
3	(xfa1/fo1/fo2/fo3)	0.98%	1.32%	6.75%	0.57%	2.93%
4	(xfa1/xft1/xft2/xft3)	4.90%	7.84%	13.72%	17.25%	7.84%
ALL		**3.09%**	**5.19%**	**9.31%**	**9.14%**	**4.90%**

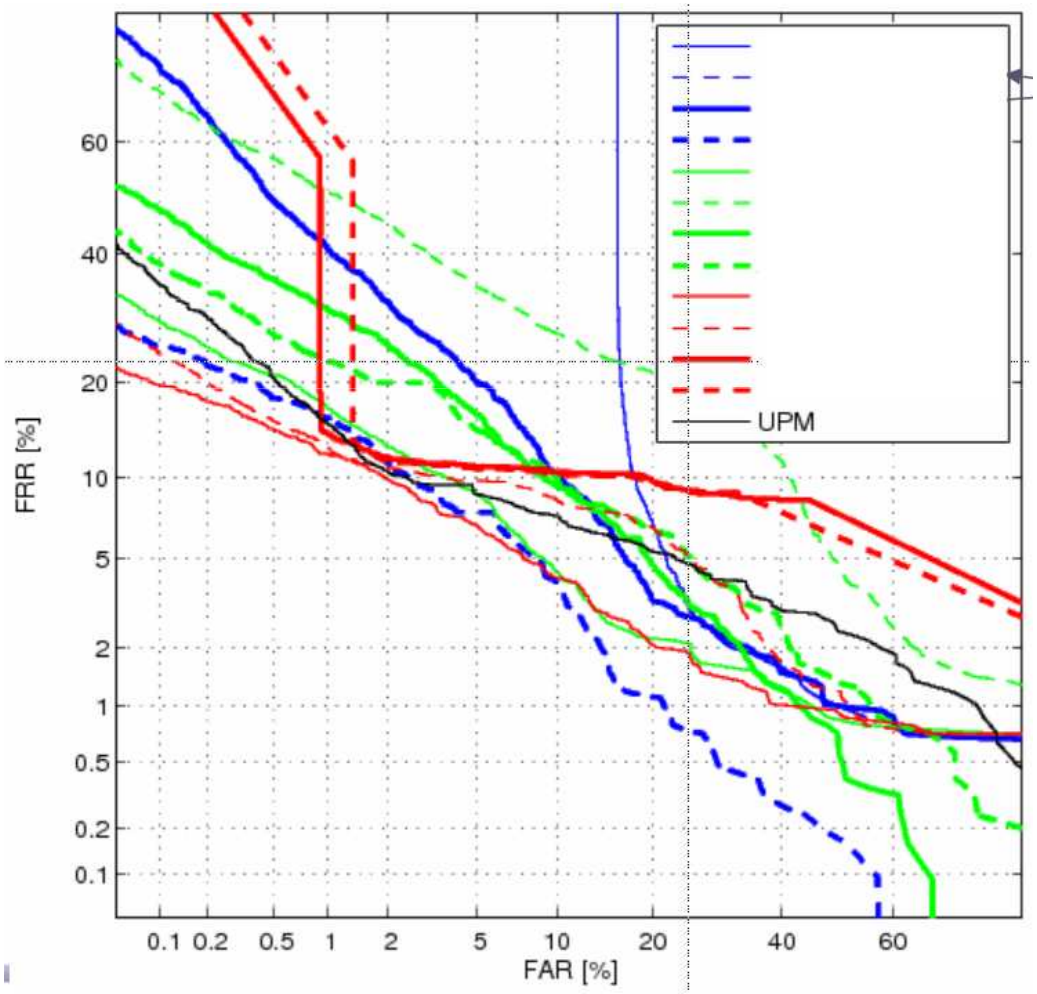
Evaluation Results (I)

Fusion performance (EER)



Evaluation Results (II)

Fusion performance (DET curve)



Detailed results to appear at: http://www.biosecure.info

SUMMARY

- The Biosecure Multimodal Biometric Database:
  - Voice + face + iris + fingerprint + hand + signature
  - Internet (1000 subjects), Desktop (700), Mobile (700)
  - 400 subjects common to the 3 Datasets
- The Biosecure Multimodal Evaluation Campaign 2007:
  - Mobile scenario
  - Access Control scenario:
    - Cost-Based task
    - Quality-Based task: Protocol, UAM Approach, Results
- Integrated framework for score fusion and normalization based on Linear Logistic Regression
- Example of quality-based conditional processing: Q vectors used to predict the query sensor
  - Good estimation (face): sensor-dependent processing (score norm.)
  - Poor estimation (fingerprint): sensor-independent processing

Dealing with Sensor Interoperability using Quality Estimates:

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