

# 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)

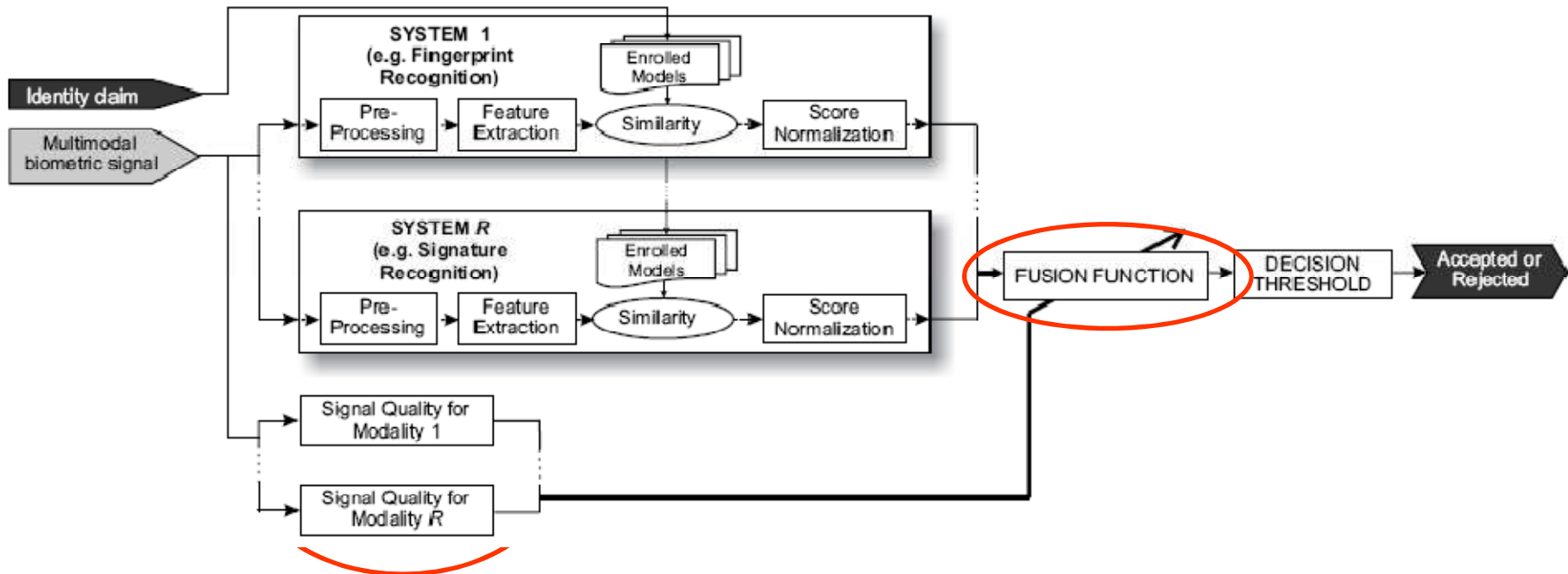
(with contributions from Fernando Alonso-Fernandez, Daniel Ramos,  
Javier Galbally, and Javier Ortega-Garcia)



# 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

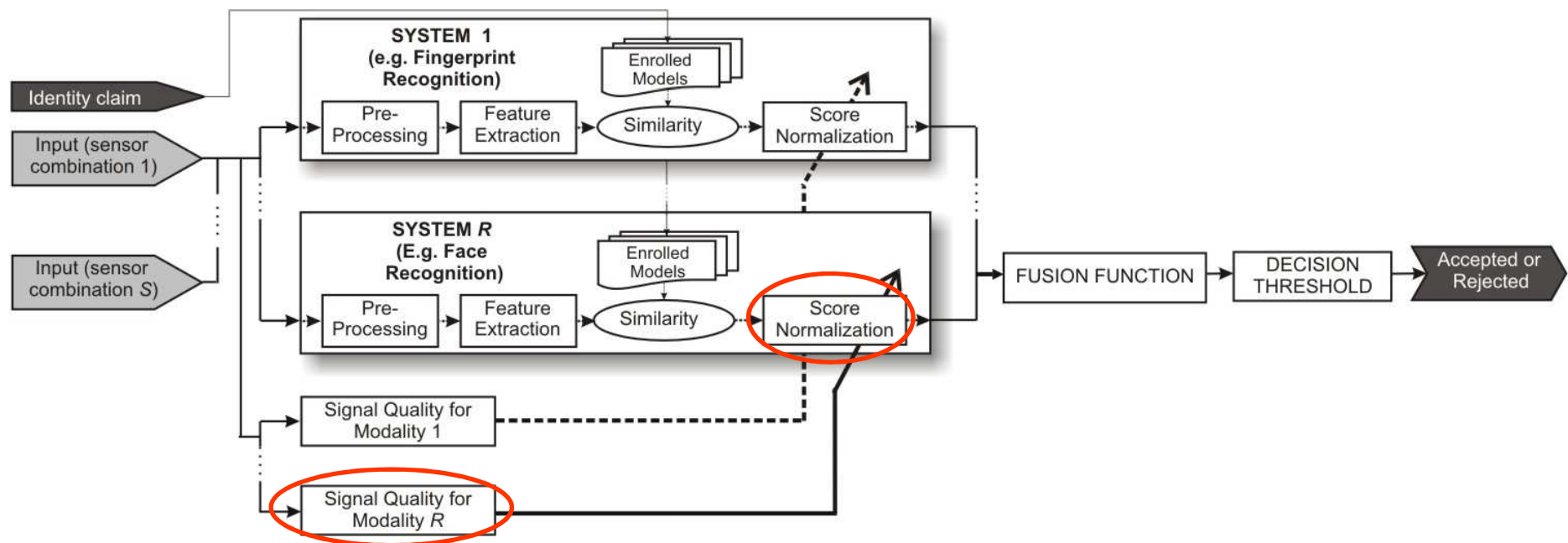
- Fingerprint      Survey to appear in *IEEE Trans. IFS*, 2007 or 2008



# ...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

- n PC-based, on-line, unsupervised (Internet)
- n 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**

<p><b>PHILIPS SPC 900NC + PLANTRONICS Voyager 510</b></p>		
<p><b>LG IrisAccess EQU3000</b></p>		
<p><b>BIOMETRIKA FX2000</b></p>		
<p><b>YUBEE (Atmel FingerChip)</b></p>		
<p><b>WACOM Intuos A6 + Inking Pen</b></p>		
<p><b>CANON EOS 30D + Ring Flash</b></p>		



# 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 $n$
<b>COMMON – AUDIO / VIDEO (simultaneously with the webcam and the bluetooth earbud)</b>				
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)

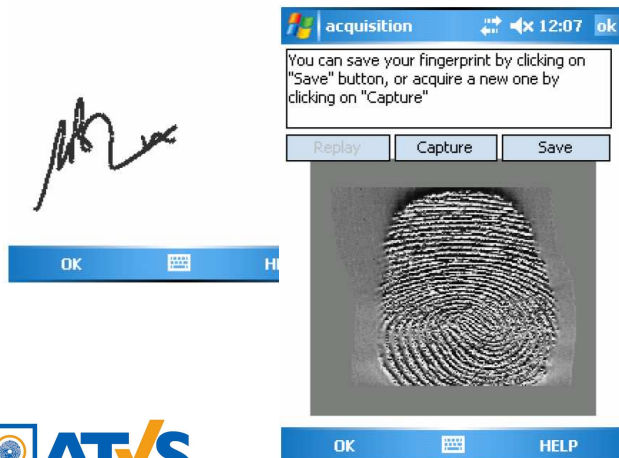
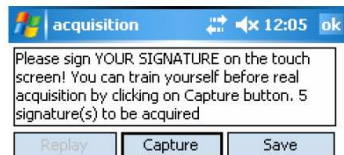
# Mobile Dataset (DS3)

## 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:

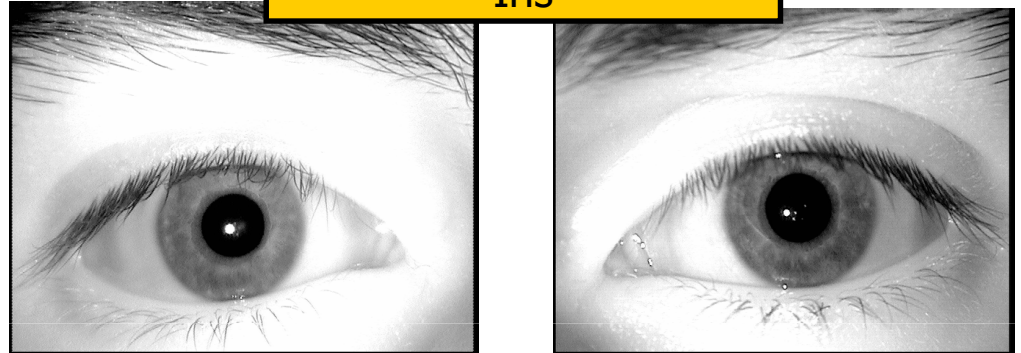
Mode ID	Place	Sample ID	Data Type	Sensor	Contents
SI	Indoor (standing)	1-5	Sign	iPAQ	5 signatures of donor $n$
SI	Indoor (standing)	6-10	Sign	iPAQ	5 dynamic imitations of donor $n - 1$ ( $n-3$ session 2)
SI	Indoor (standing)	11-15	Sign	iPAQ	5 signatures of donor $n$
SI	Indoor (standing)	16-20	Sign	iPAQ	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
<b>COMMON – AUDIO / VIDEO (Q1 + WebCam) – INDOOR</b>					
<b>COMMON – AUDIO / VIDEO (Q1 + WebCam) – OUTDOOR</b>					

# Biosecure Multimodal Database: Examples

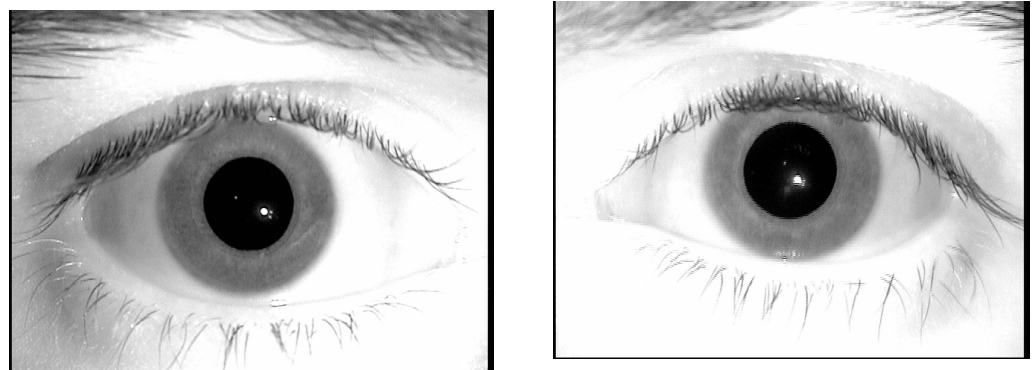
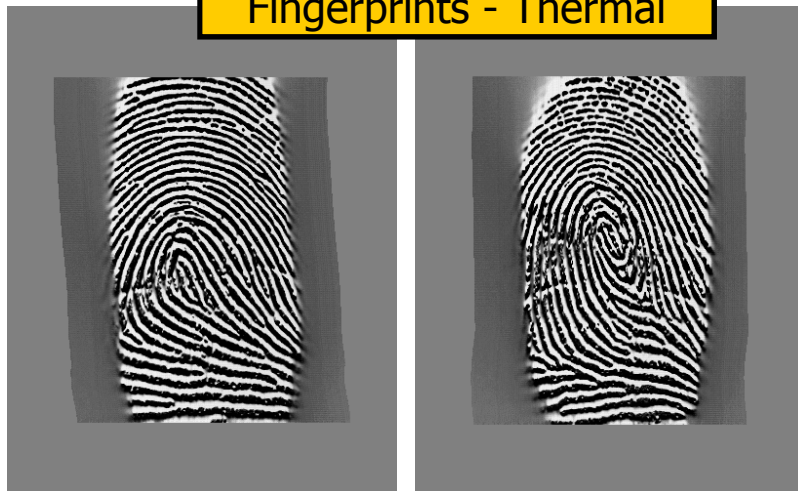
Fingerprints - Optical



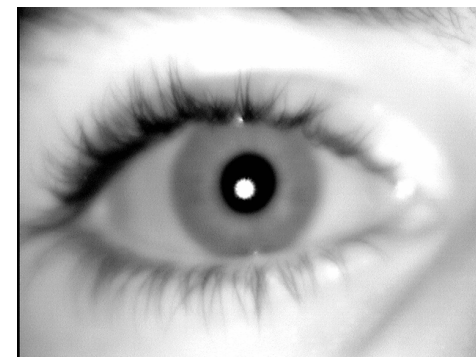
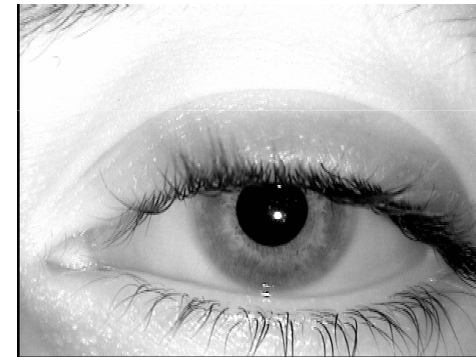
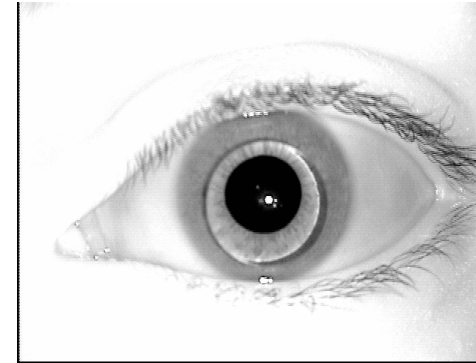
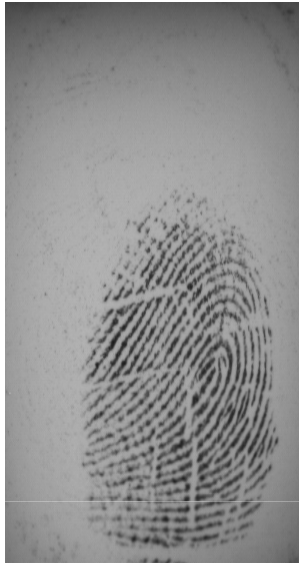
Iris



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**

# 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 3 right middle finger
ft1, ft2, ft3		Thermal	

## 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:

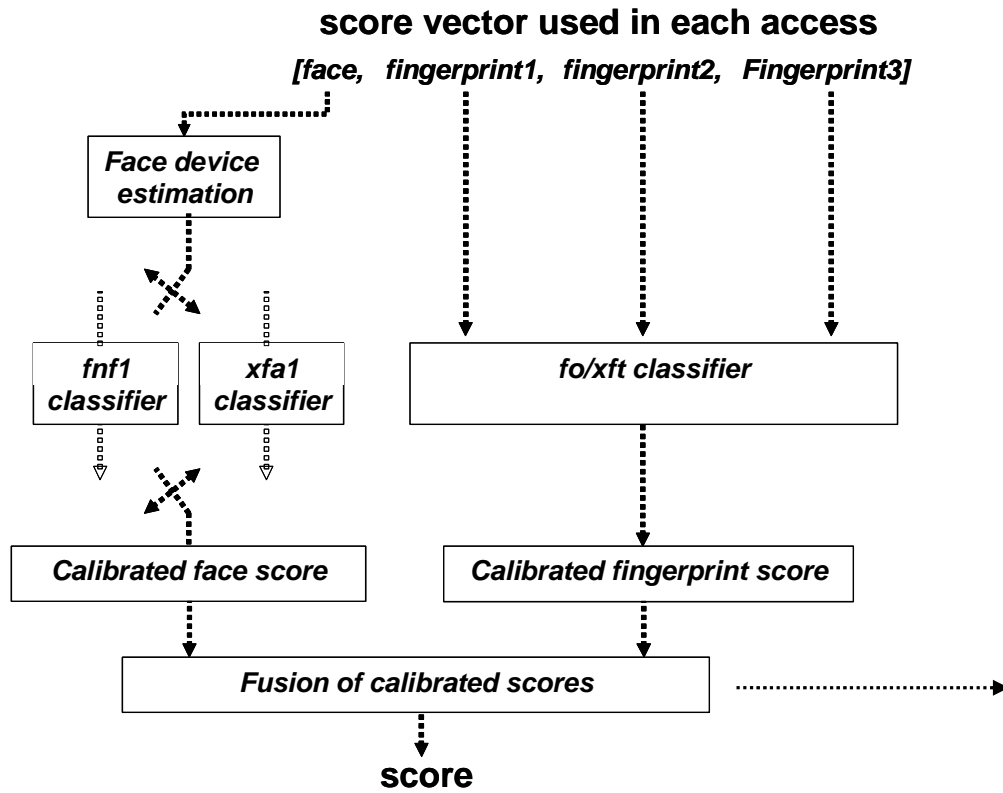
- **FACE:** all quality measures provided (14)
- **FINGERPRINT:** a set of 8 parameters computed combining  $Q_{\text{query}}$  and  $Q_{\text{template}}$  from the three fingerprint scores (difference, maximum  $Q_{\text{query}}$ , minimum  $Q_{\text{query}}$ , average  $Q_{\text{query}}$ , etc.)

## 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:

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

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

# UAM Fusion Algorithm (III)

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

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

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

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

$N_u, N_i$ : 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):

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

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

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# Quality-based Evaluation Results

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# Training Results (pre-eval)

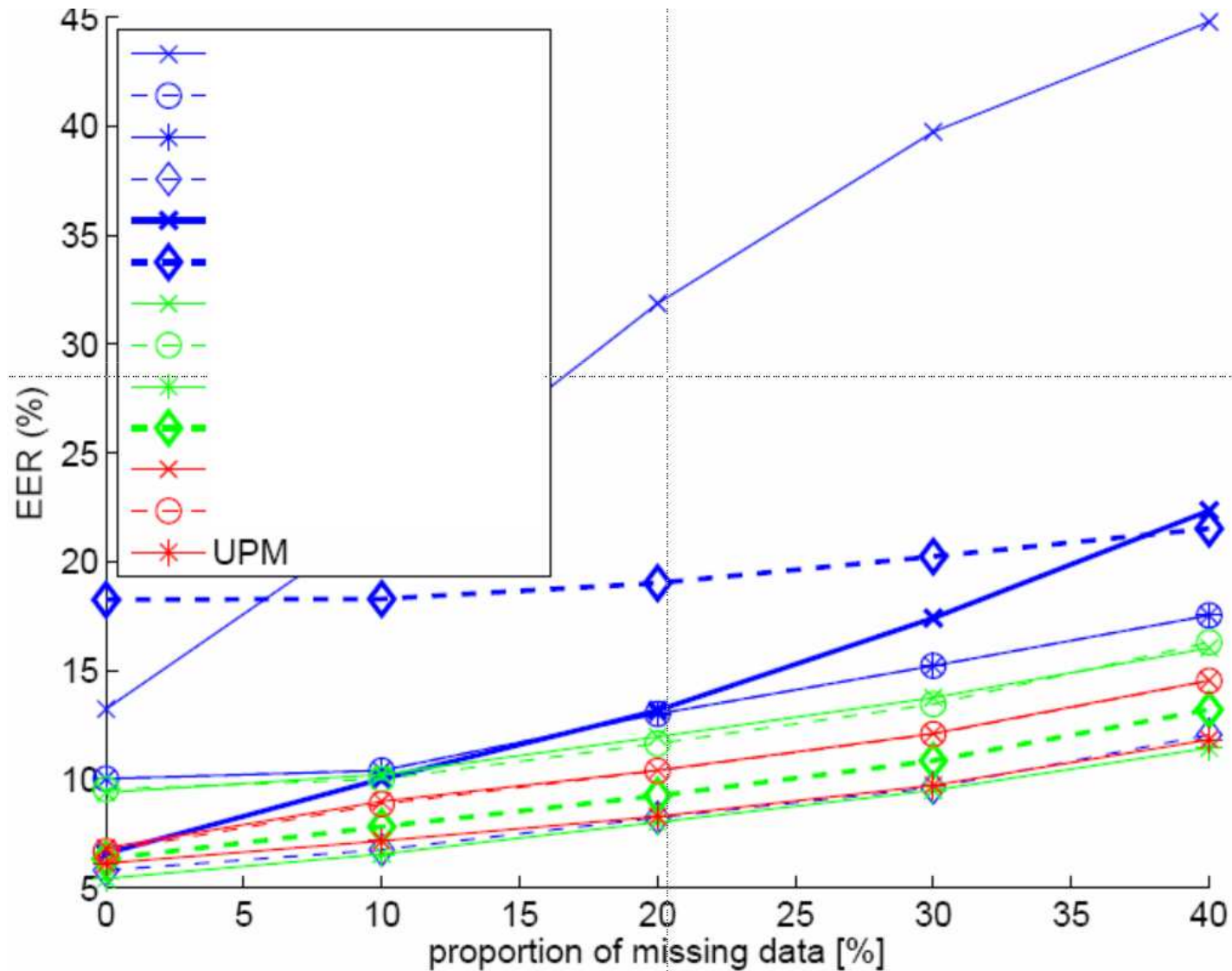
## Comparison with simple fusion rules:

- 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%
<b>ALL</b>		<b>3.09%</b>	<b>5.19%</b>	<b>9.31%</b>	<b>9.14%</b>	<b>4.90%</b>

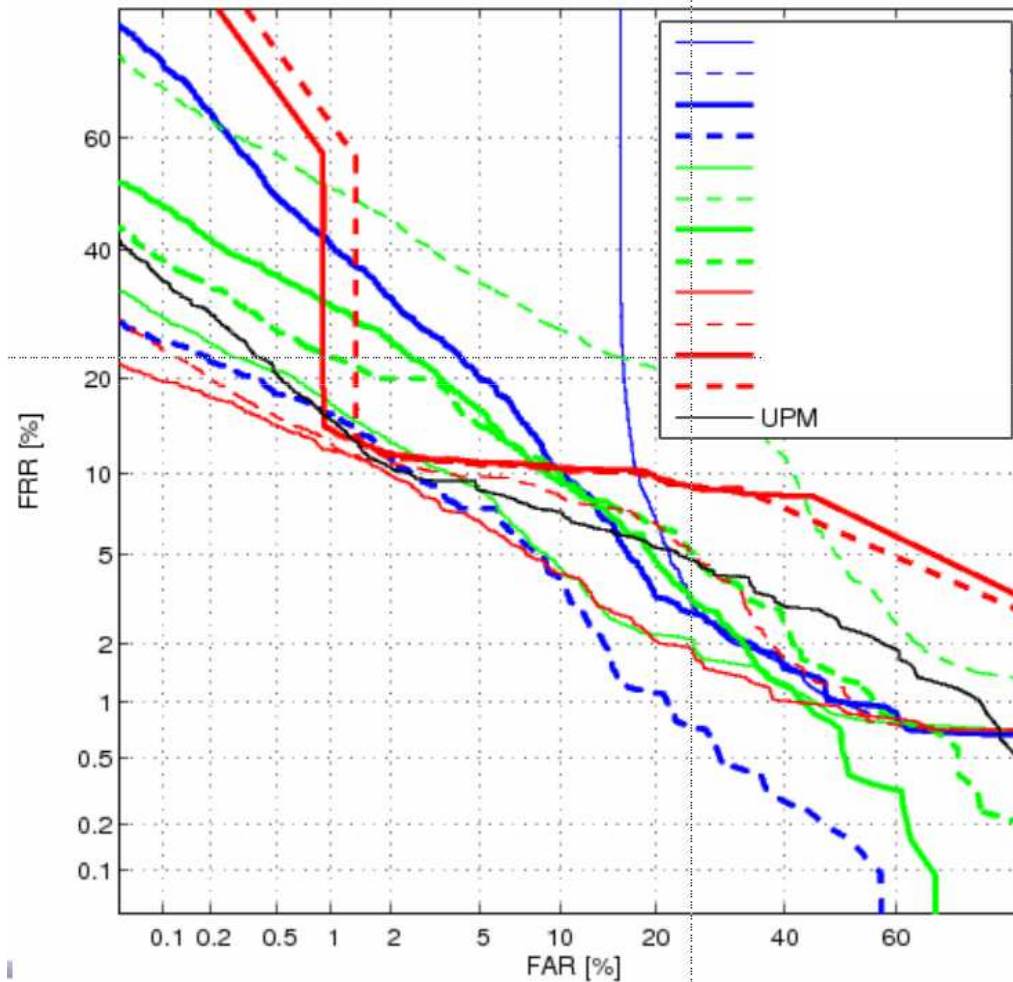
# Evaluation Results (I)

## Fusion performance (EER)



# Evaluation Results (II)

## Fusion performance (DET curve)



# 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

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