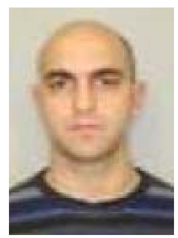
Benchmarking Quality-dependent and Cost-sensitive Multimodal Biometric Fusion Algorithms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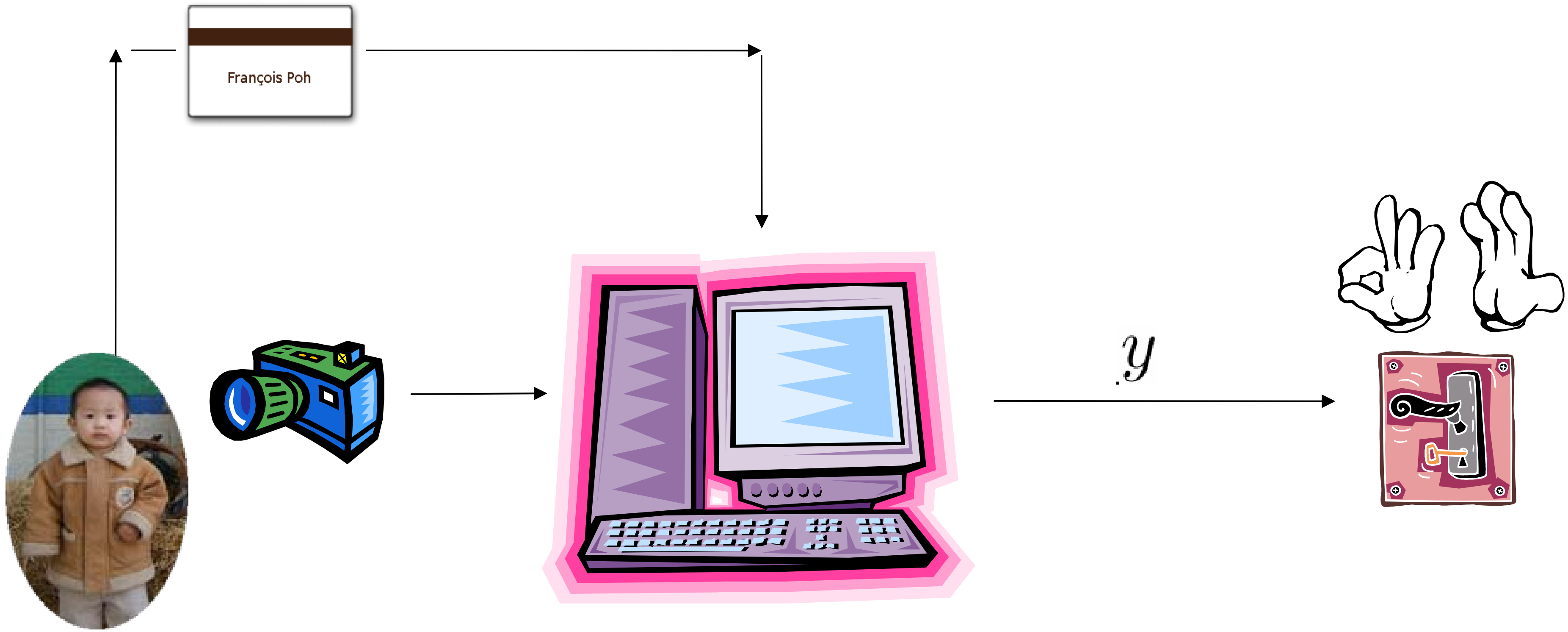
Biometric Authentication: The Access Control Scenario



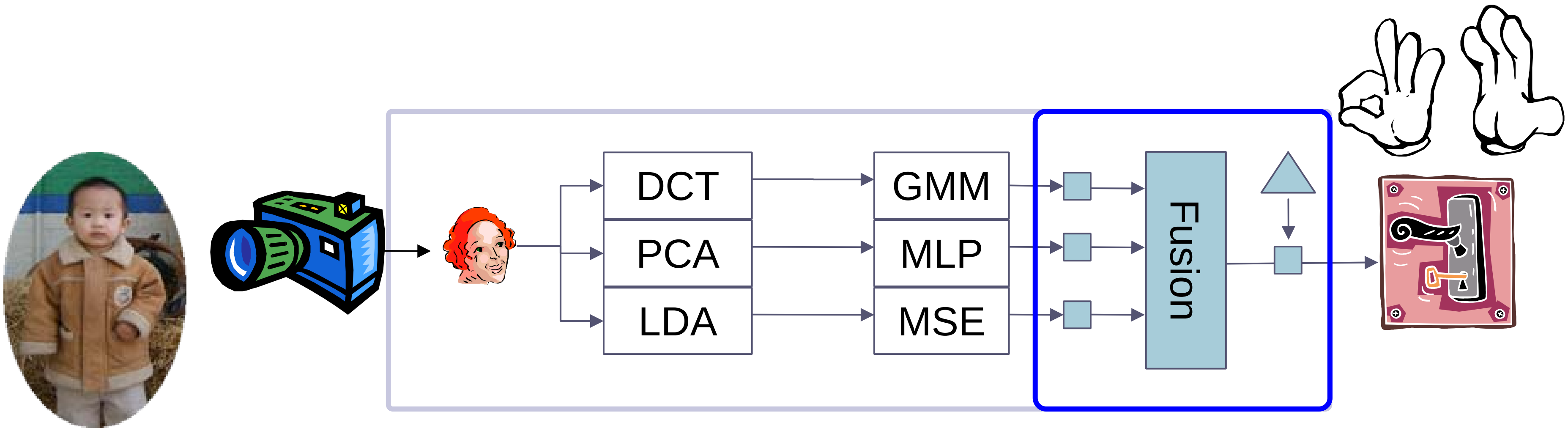
500 users

$$\text{decision}(\mathbf{x}) = \begin{cases} \textit{accept} & \text{if } f(\mathbf{x}) > \Delta \\ \textit{reject} & \text{otherwise} \end{cases}$$

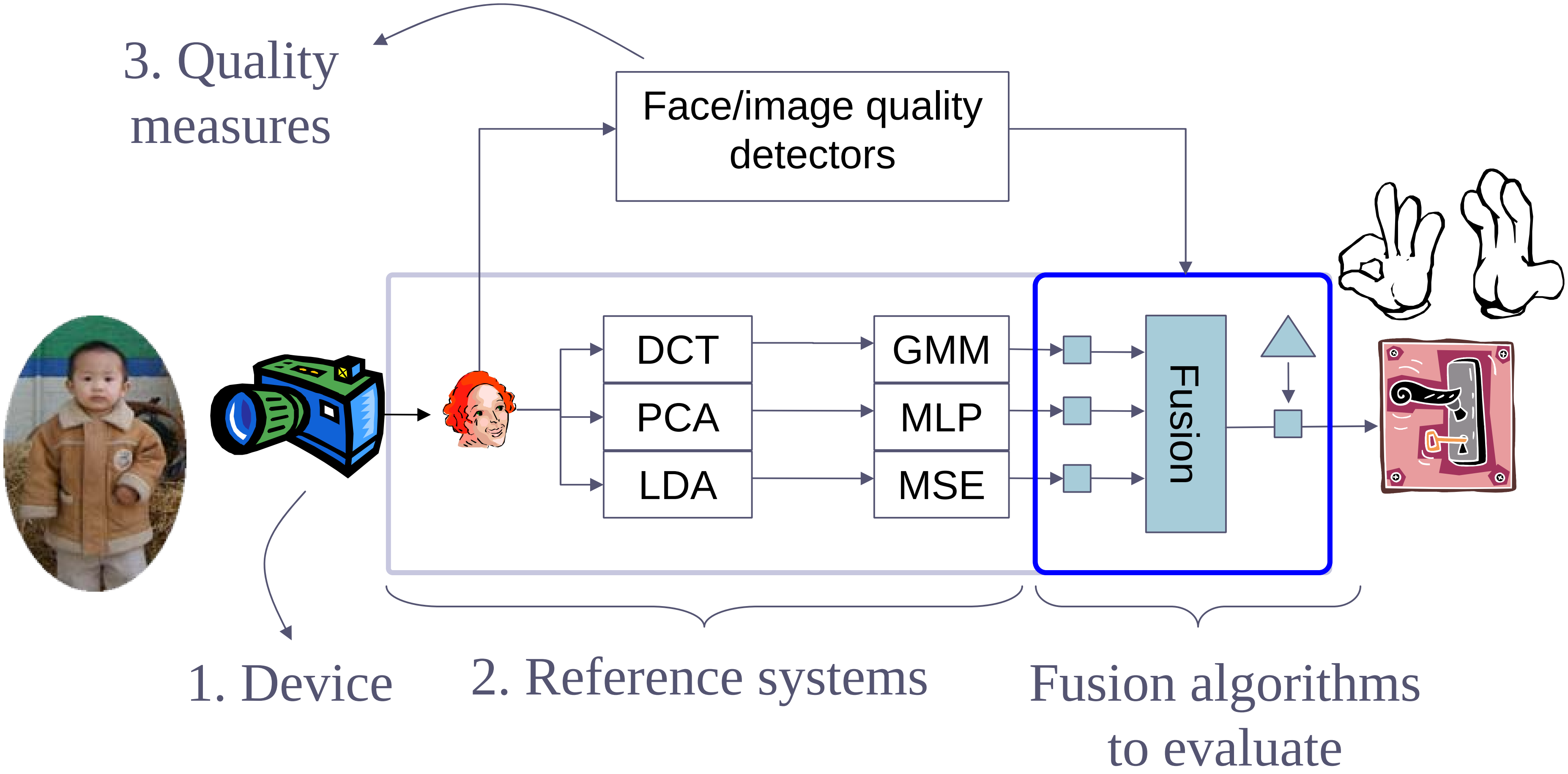
Motivations

- How well can a multimodal biometric system cope with missing information?
- How well can *automatically derived* quality measures improve the fusion system performance?
- How well can a multimodal system perform given restricted computation and in the presence of hardware/software failures?
  - Failure to enrol and failure to match
- What if the device used during authentication is different from that used during enrollment? [device mismatch]
- Principally interested in performance improvement due to the use of quaulity measures in fusion
  - w.r.t the baseline system
  - w.r.t. a fusion system without given any quality measure
- Not particularly concerned with state-of-the-art performance
  - Simulate failures by masking the data!

Conventional Fusion Algorithms



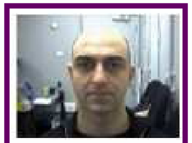
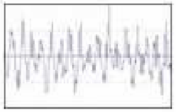
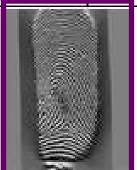
Quality-dependent Fusion Algorithms



Score/Quality Measures Generation Principles

- Use baseline systems
  - standard algorithms
  - LDA for face, NIST's fingerprint matcher, Daugman's algo. for iris
- Fully automatic segmentation and matching
  - If a system cannot process a query, e.g., due to failure to segment or failure to match, output a dummy match score '-999'
- Automatically computed quality measures
  - If a quality detector fails, output a dummy '-999' instead
- Consequence: Algorithms have to deal with missing observations/values

Capturing Devices

CAPTURING DEVICE		MODALITY	SAMPLE IMAGES
WACOM INTUOS 3 A6 Tablet + Inking Pen		SIGNATURE	
Phillips SPC 900NC web camera +	 	AUDIO+VIDEO	 
Thermal sensor (acquired by sweeping)		FINGERPRINT	
Optical sensor		FINGERPRINT	
LG3000 iris capturing system		IRIS	
CANON EOS 30D Digital Camera		FACE + HAND *HIGH QUALITY*	 

Legend:

Used in the evaluation

Biosecure project

Face Quality Measures

- Face
  - Frontal quality
  - Illumination
  - Rotation
  - Reflection
  - Spatial resolution (between eyes)
  - Color bit per pixel
  - Focus
  - Brightness
  - Background informity
  - Glasses

Well illuminated

Glass=89%

Illum.=100%

Side illuminated

Glass=15%

Illum=56%

Quality measures for iris

Quality measures for fingerprint

Low vs High Quality Face Images

webcam

Digital camera

Note: quality (e.g., image resolution), dependents on the device and its operational settings (e.g., white balance adjustment).

Intra-site diversity

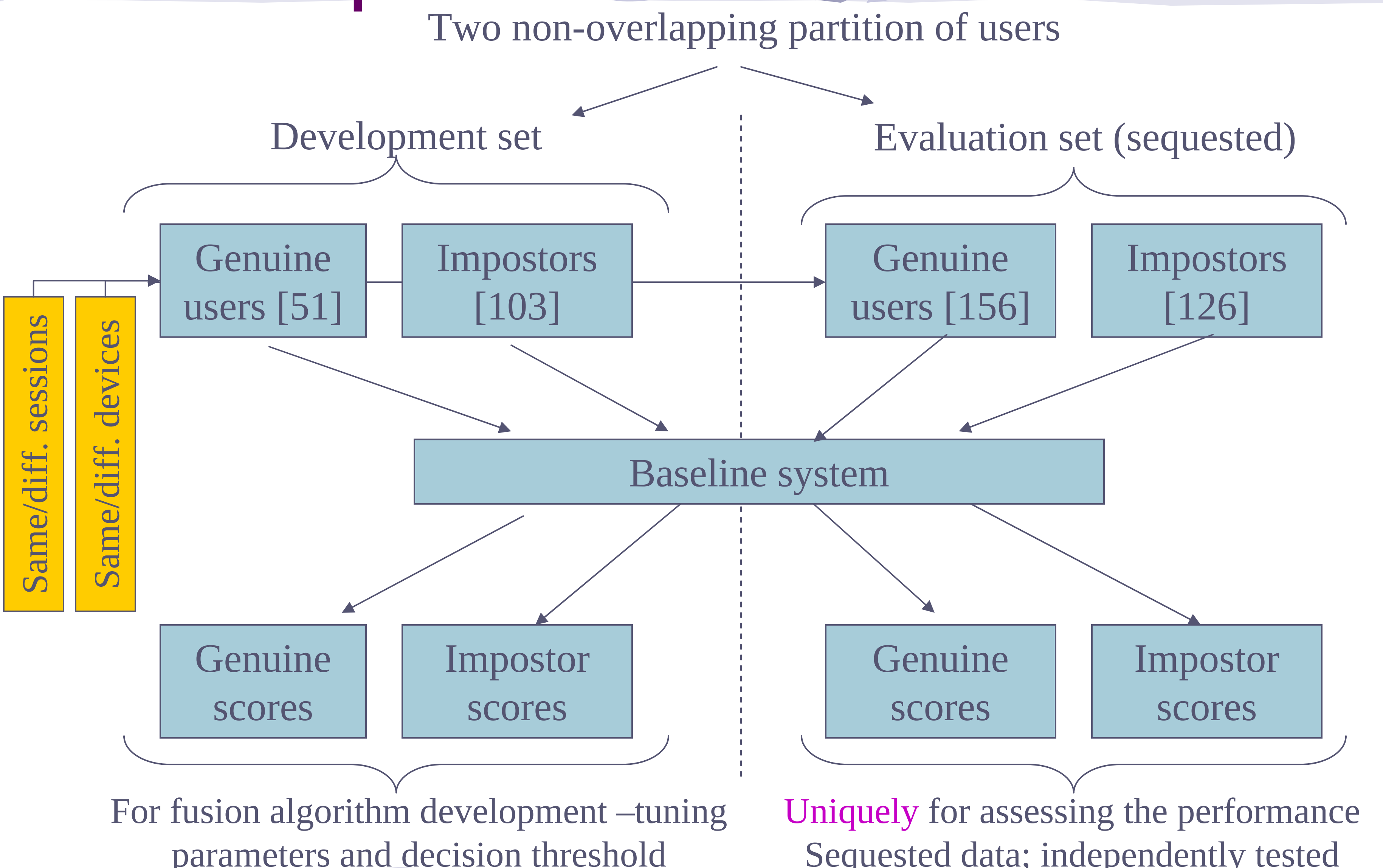
Cross-site diversity

Examples of Segmented Face Images

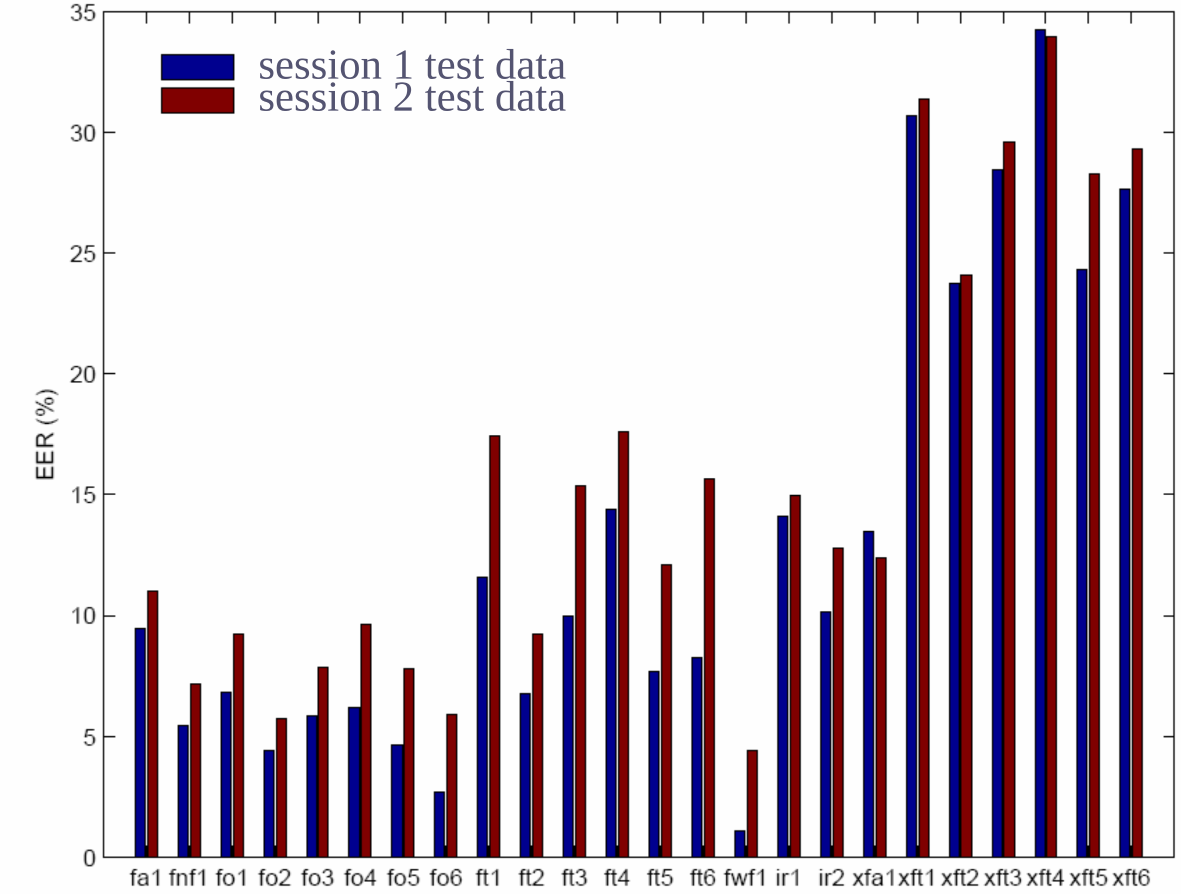
Face detection may fail, but the matching will proceed anyway!

Examples of bad iris segmentation

Experimental Protocol



Preliminary Performance Analysis



Same device
(17 channels of data)

Device mismatch
(7 channels of data)

Fa: face (webcam)
Fnf: face (digital; no flash)
Fwf: face (digital; with falsh)
Fo: fingerprint (optical)
Ft: fingerprint (thermal)
xFa: mismatch (query is Fa; template is Fnf)
xFt: mismatch (query is Ft; template is Fo)

- Intra session performance is consistantly optimisitically biased compared to the inter-session one
- Device mismatch can degrade the performance

Evaluation Results

7 teams, 22 fusion algorithms, 2 evaluation protocols, 6 months

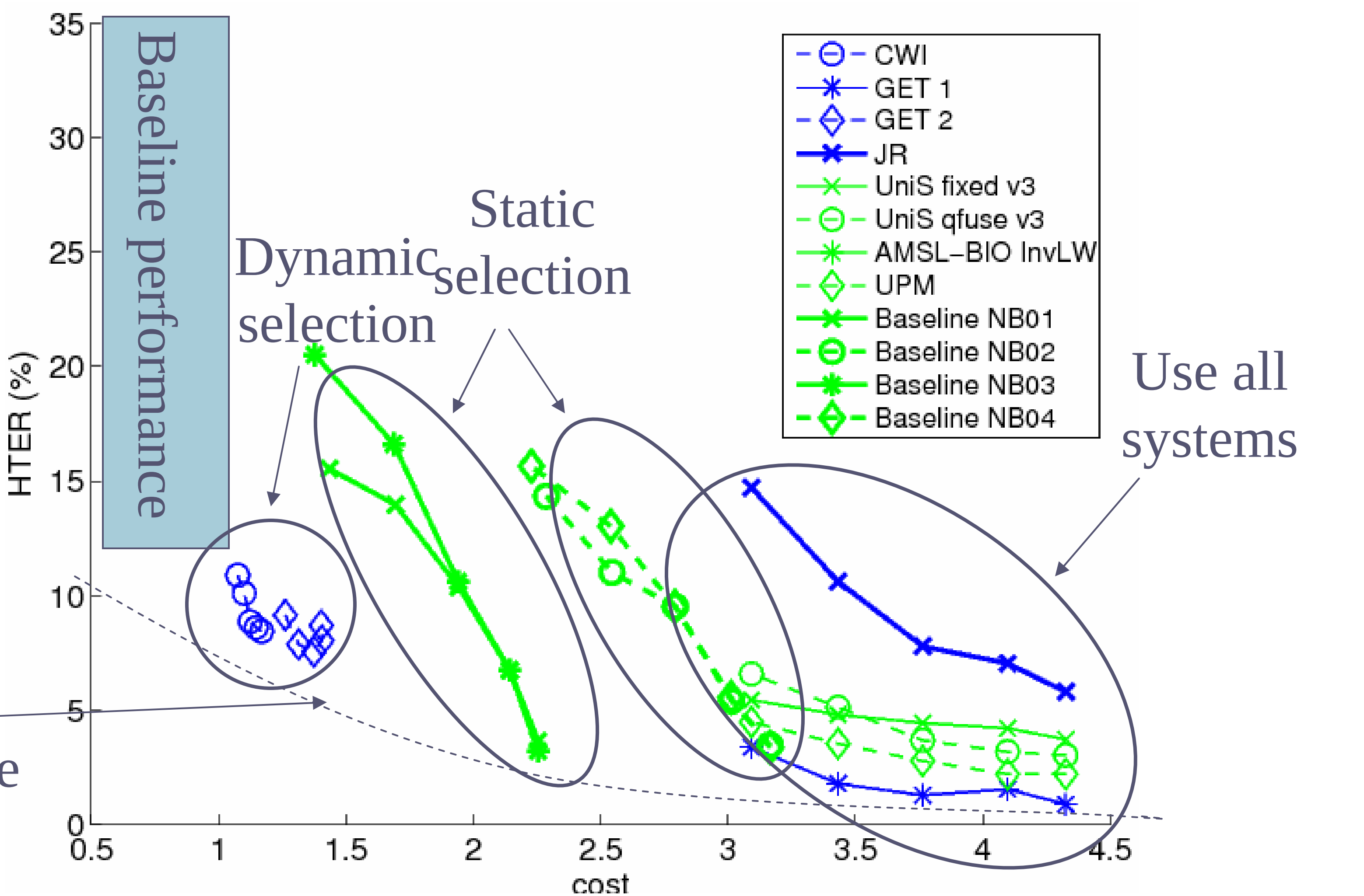
Examples of algorithms submitted:
Naive bayes, Bayes classifier with GMM density estimator and mixture of factor alayzers, logsitic regression, fixed rule, device-specific fusion, linear classifier (with error-dependen weights), SVM, bayesian network, Dempster fusion rule

Short name

- Tobias Scheidat (AMSL-BIO, U. of Magdeburg)
- Lorene Allano, Institut National des Télécommunications (GET-INT), France.
- Fernando Alonso, Universidad Autonoma de Madrid, (UPM), Spain
- O Fatukasi and N. Poh, U. of Surrey (UniS), UK.
- Harald Ganster, Joanneum Research (JR), Austria
- Albert Salah and Onkar Ambekar, Centrum voor Wiskunde en Informatica (CWI), the Netherlands
- John Baker, Johns Hopkins University Applied Physics Laboratory (JHUAPL), USA

Cost-sensitive evaluation

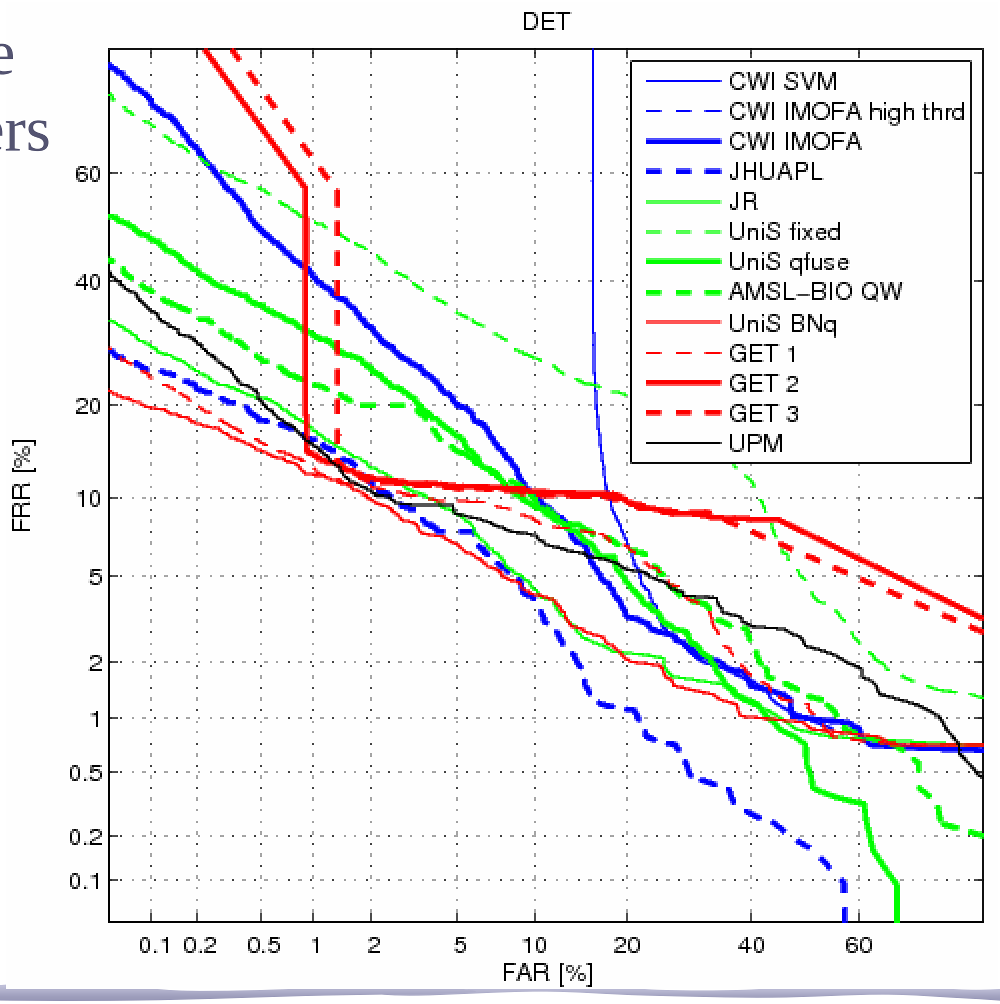
1 face
6 fingers
1 iris



More systems→more costly but also higher robustness to hardware/software failure

Quality-based Evaluation

1 face
3 fingers



Template: good quality
Query data: same or different device

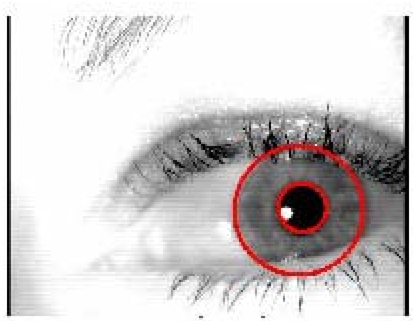
All systems degrade with missing data (not shown here)

Top 3 systems make use of quality information – first identify device, then pick the right fusion

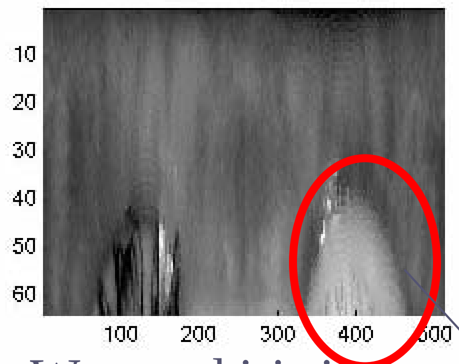
Q&A

Thank you!

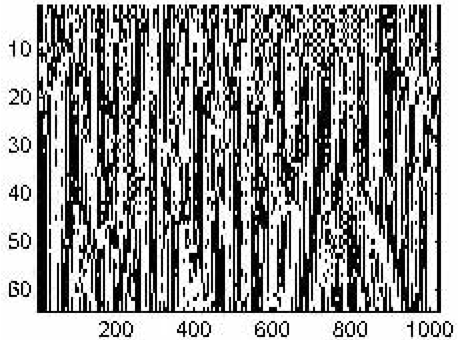
Minimally Optimized Eye-lid and Eyelashes Segmentation



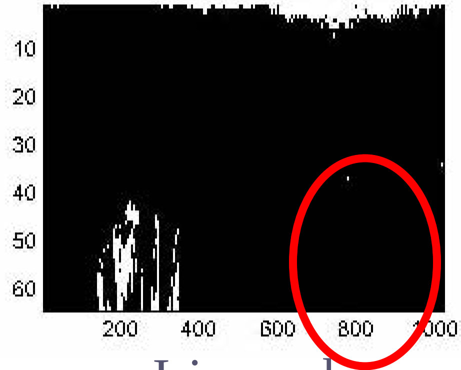
Segmented iris



Wrapped iris image



Iris code



Iris mask

Eye-lid included in matching

Ideally, two thresholds are needed for the mask:
to remove eye-lids and eyelashes

The threshold for eyelashes are not optimal too (not shown here)

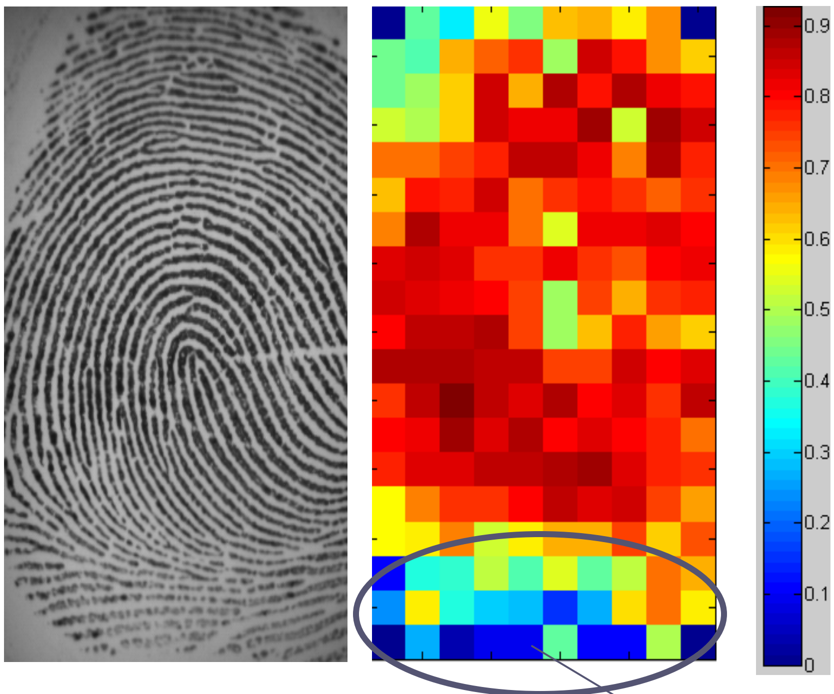
Intra-site Diversity

Each row represents data collected at a site

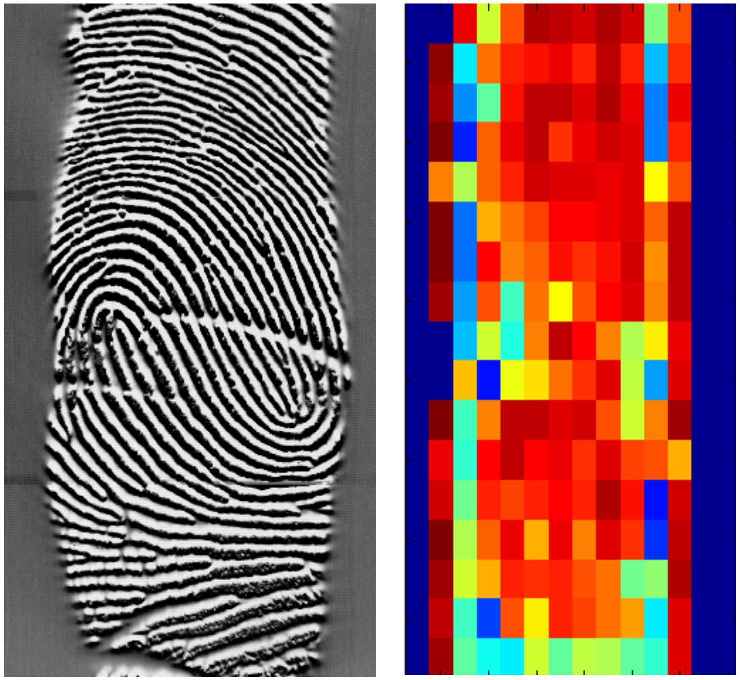
Cross -site Diversity

Fingerprint Quality Measure

Optical sensor (impression)



Thermal sensor (sliding)



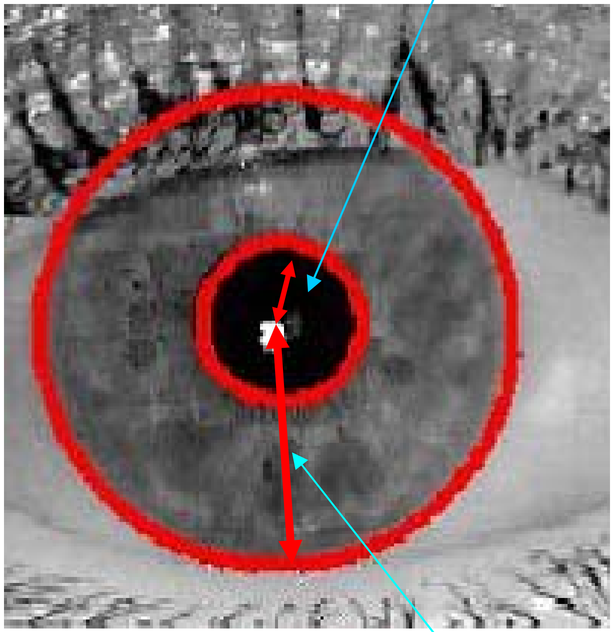
image

Quality map

Low quality region (low contrast)

The global quality is the average of local quality measures

Iris Quality Measures



Q_1 = *Average texture gradient (similar to fingerprint quality map)*

$Q_2 = d_I - d_P$

Q_3 = *Proportion of masked use for matching*

Badly Segmented Iris Images

Good segmentation

Bad segmentation

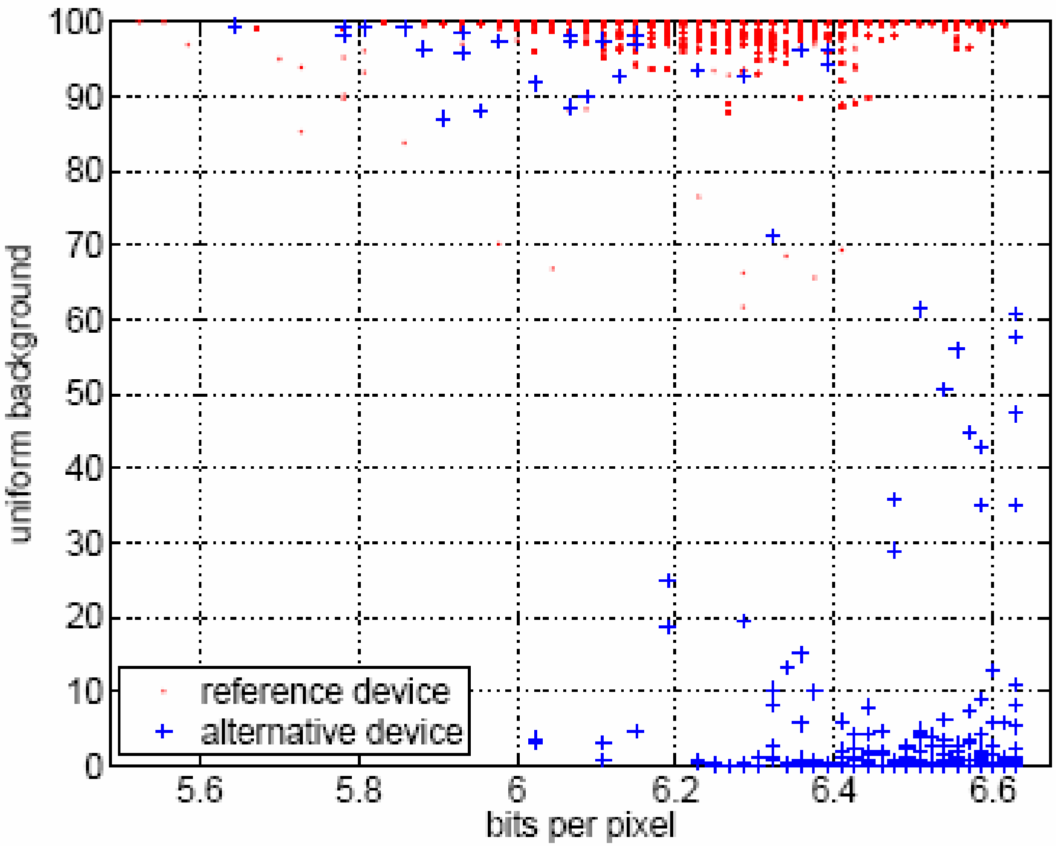
Devices and Modalities

Label	template ID {n}	Modality	Sensor	Remarks
fa	1	Still Face	web cam	Frontal face images (low resolution)
fnf	1	Still Face	CANON	Frontal face images without flash (high resolution)
fwf	1	Still Face	CANON	Frontal face images with flash (high resolution)
ir	1–2	Iris image	LG	1 is left eye; 2 is right eye
fo	1–6	Fingerprint	Optical	1/4 is right/left thumb; 2/5 is right/left index; 3/6 is right/left middle finger
ft	1–6	Fingerprint	Thermal	1/4 is right/left thumb; 2/5 is right/left index; 3/6 is right/left middle finger

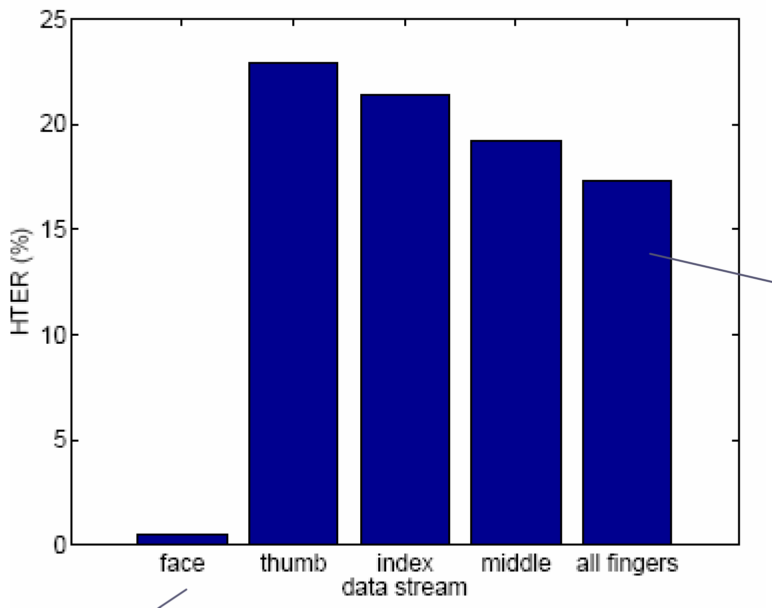
Reference Systems and Quality Measures

Modality	Reference systems	Quality measures
Still Face	Omniperception's Affinity SDK face detector; LDA-based face verifier	face detection reliability, brightness, contrast, focus, bits per pixel, spatial resolution (between eyes), illumination, degree of uniform background, background brightness, reflection, glasses, rotation in plane, rotation in depth and degree of frontal face (from Omniperception's Affinity SDK)
Fingerprint	NIST Fingerprint system	texture richness [5] (based on local gradient)
Iris	A variant of Libor Masek's iris system	texture richness [6], difference between iris and pupil diameters and proportion of iris used for matching

Example of Quality Measures to Distinguish Two Devices



Ability of Quality Measures to Distinguish Devices (fingerprint)



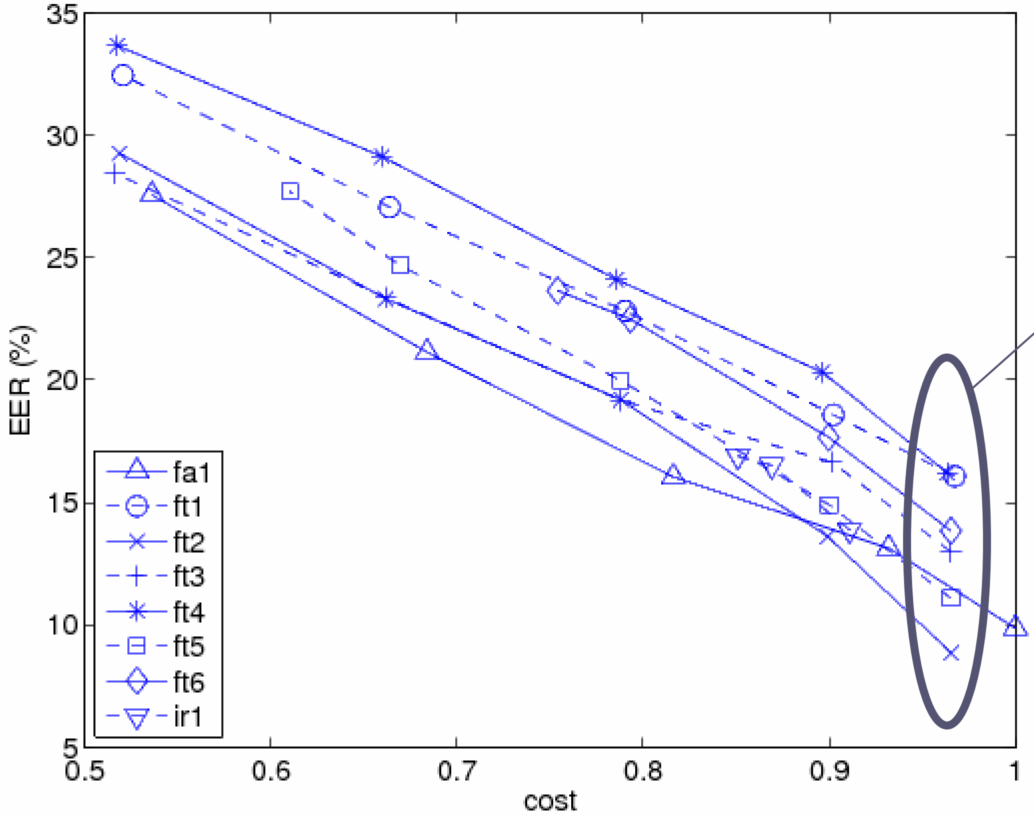
Decide the device after observing three fingerprints

Face quality measures used are 5,6,8

Some Observations

- Quality measures can be used to estimate the identity of the device
- Quality measures are device-dependent

Baseline Performance



The fingerprint data always contains missing data due to failure to process or to match queries

Note: If all the data in a channel is used, the average cost per access is simply 1.