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Definition of Fingerprint Scanner Image Quality Specifications by Operational Quality

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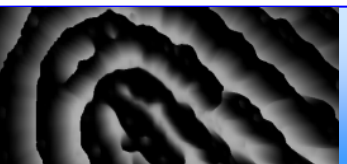
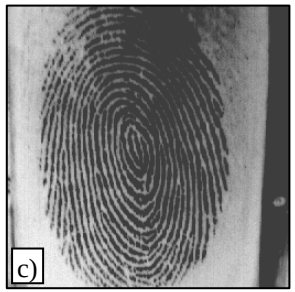
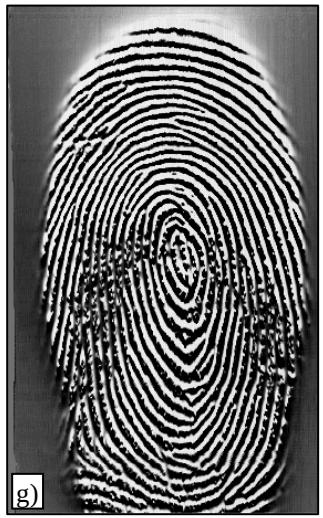
Outline

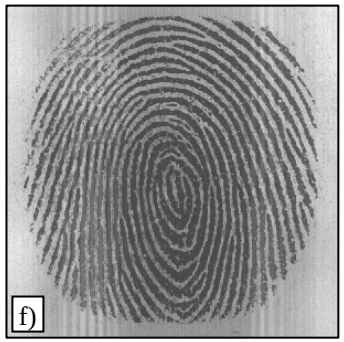
- The current state-of-the-art
  - IAFIS certification
  - PIV certification
  - PassDEÜV certification
- Objectives and motivations of this research
  - What is the right scanner for a given application?
  - Which are the most important quality criteria?
  - How to define quality specifications with an optimal accuracy/cost trade-off?
- Evaluating the effects of the various image quality specifications (IQS) on automated fingerprint recognition
  - Testing approach
  - Experimental results



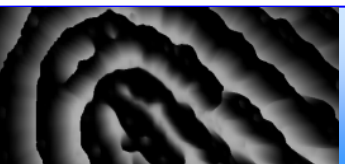
The right scanner for a given application







	Sensor	Technology	DPI	Area
a)	Biometrika FX2000	Optical	569	0.98"×0.52"
b)	Digital Persona UareU2000	Optical	440	0.67"×0.47"
c)	Identix DFR 200	Optical	380	0.67"×0.67"
d)	Ethentica TactilSense	Electro-optical	403	0.76"×0.56"
e)	ST-Microelectronics TouchChip	Capacitive	508	0.71"×0.50"
f)	Veridicom FPS110	Capacitive	500	0.60"×0.60"
g)	Atmel FingerChip	Thermal (sweep)	500	0.02"×0.55"
h)	Authentec AES4000	Electric field	250	0.38"×0.38"



IAFIS certification

The FBI established an Image Quality Standard (IQS) in order to define the quantitative image quality requirements for IAFIS fingerprint scanners defined in Appendix F of the “Electronic Fingerprint Transmission Specification” (EFTS).

PIV certification

Recently, to support Personal Identity Verification (PIV) program FBI established an IQS for single-fingerprint capture devices to improve the identification and authentication for access to U.S. Federal facilities and information systems.

PassDEÜV certification

The German Federal Office for Information Security (BSI) established an IQS for the capture and quality assurance of fingerprints by the passport authorities and the transmission of passport application data.

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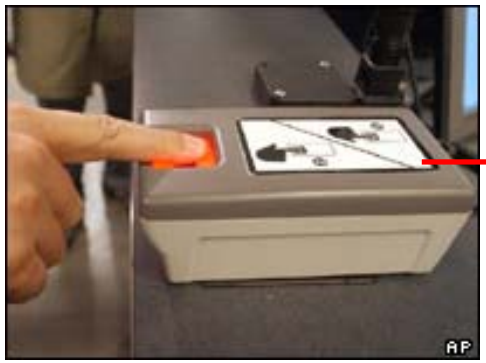
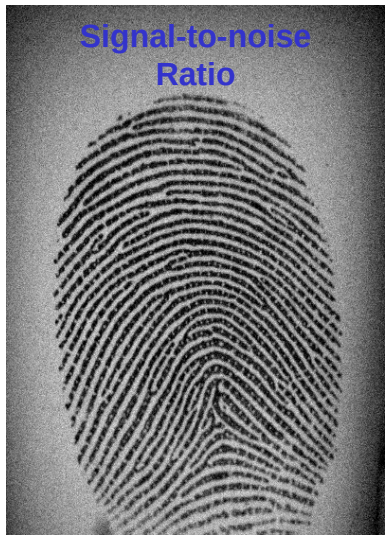
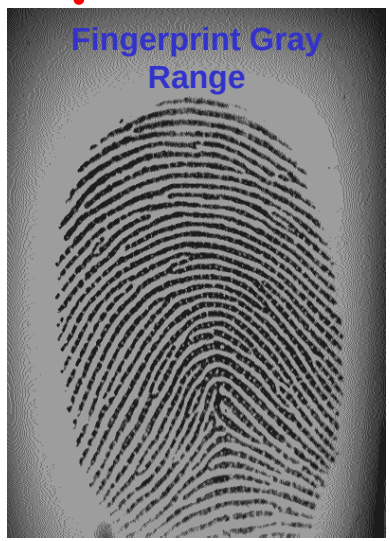
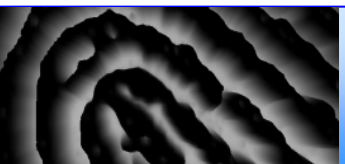


Main quality parameters



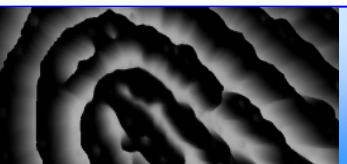




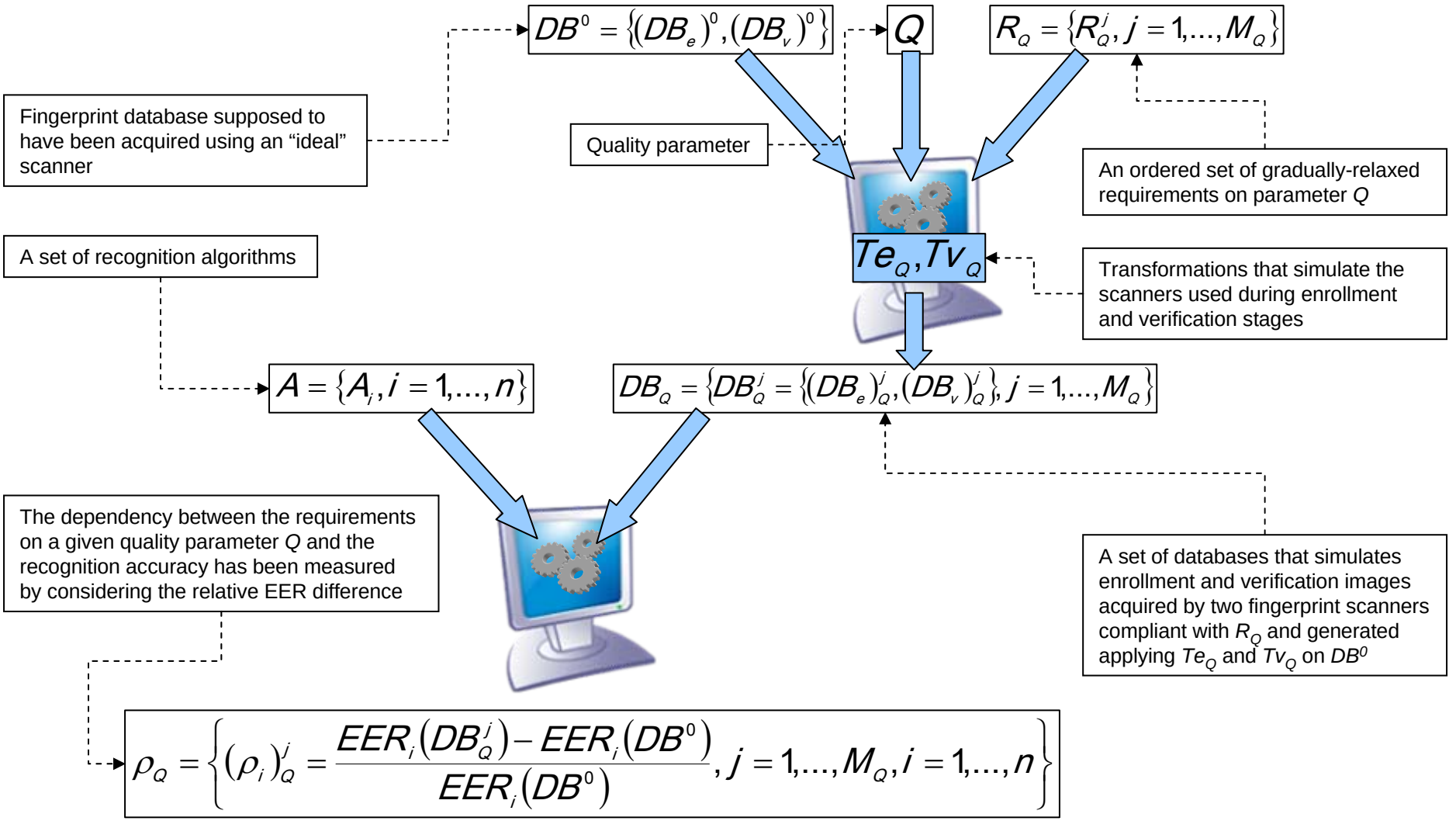
Quality parameters and recognition accuracy

- In these specifications, the quality is:
  - defined as “fidelity” of the scanner in reproducing the original fingerprint pattern
  - quantified by measures traditionally used for vision, acquisition and printing systems
  - useful if the application requires human examination. Human experts’ fingerprint comparison heavily relies on very fine details such as pores, incipient ridges, etc.

- **“*Operational quality*”:**
  - *defined as “The ability of a fingerprint scanner to acquire images that maximize the accuracy of automated recognition algorithms”*
  - useful if the application is totally automated, because the choice of a particular scanner should be driven by the desired performance

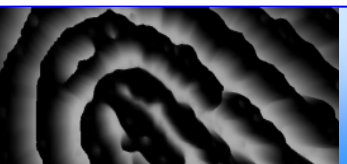


Test approach



Experiments

- The FVC2006 DB2 has been used
  - 1680 images: 140 fingers of 50 subjects, 12 impressions per fingers
  - Acquisition area: *w*=17.8mm, *h*=25.0mm
- Quality parameters considered:
  - Acquisition area
  - Output resolution
  - Geometric accuracy
  - Spatial frequency response
  - Signal-to-noise ratio
  - Fingerprint gray range
- From FVC2006 ten of the best performing algorithms on DB2 have been selected (not only minutiae-based)
- Experiment size
  - 176,400 image transformations
  - 16,314,200 fingerprint pairs compared



Test approach: Acquisition area

$DB^0 =$  …

Acquisition area

R_{Area}={352, 332, 291, 271, 251, 231, 211, 191, 171, 151}

Each requirement is given as a minimum acquisition area (in mm²)

Te_Q, Tv_Q

$$Te_{Area} = Tv_{Area} = Crop\left(F, w\sqrt{\frac{R^j_{Area}}{w \cdot h}}, h\sqrt{\frac{R^j_{Area}}{w \cdot h}}\right)$$

where $Crop(F, w', h')$ returns the $w' \times h'$ image centered in F

A set of recognition algorithms

$A = \{A_i, i = 1, \ldots, n\}$

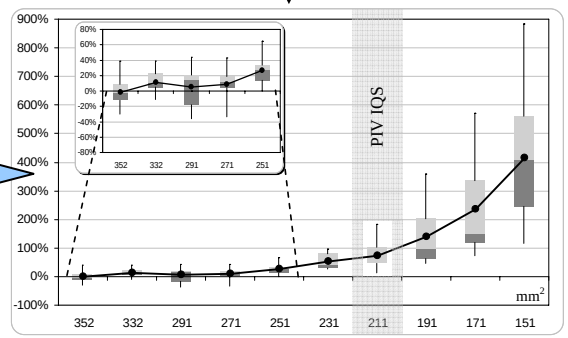
$DB^1_{Area} =$ …

$DB^2_{Area} =$ …

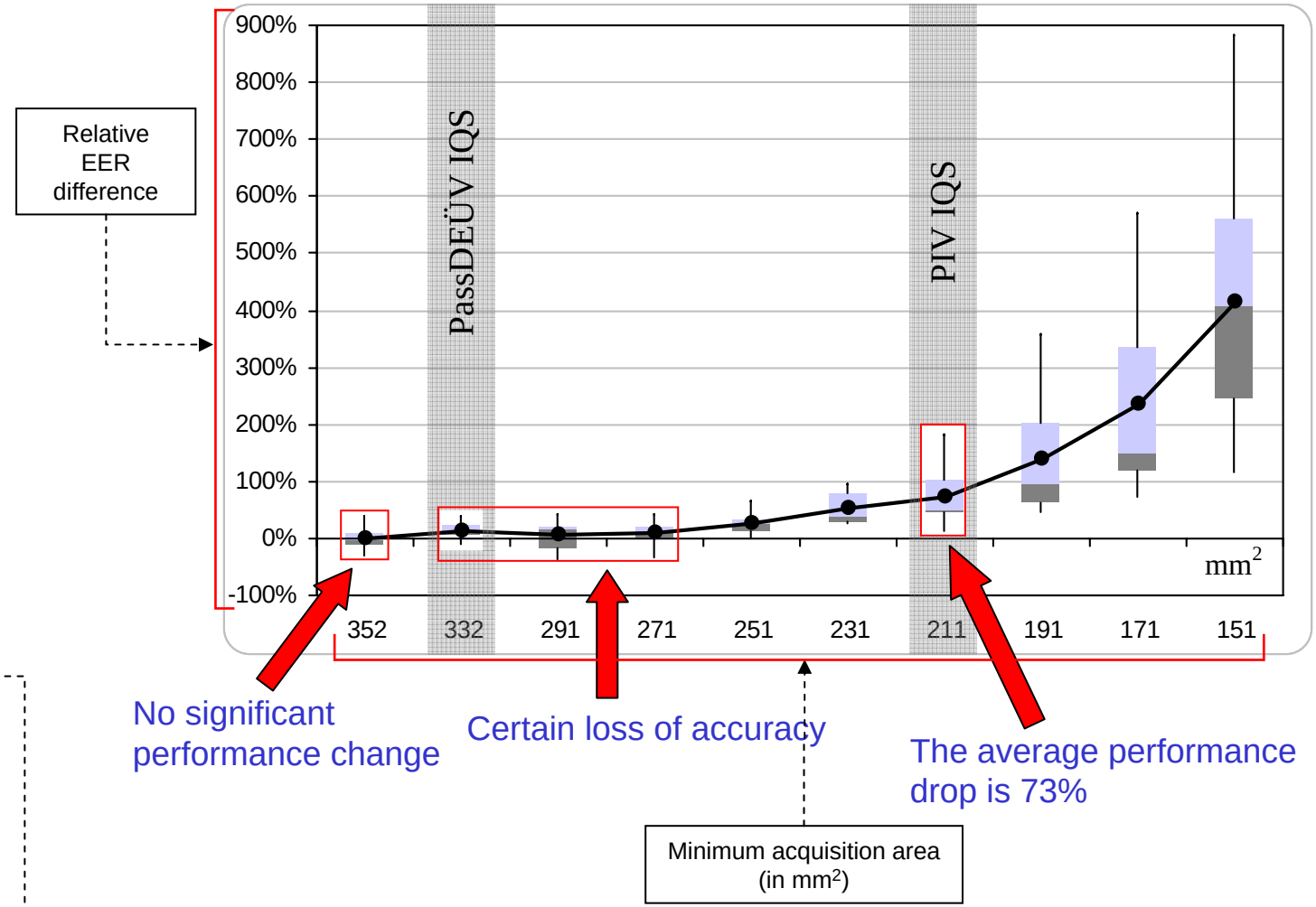
…

$DB^{10}_{Area} =$ …

Experimental results are reported as box plots

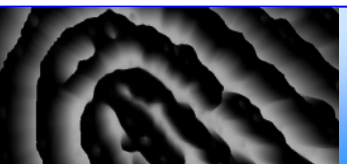


Results: Acquisition area



Observations on the individual quality parameters

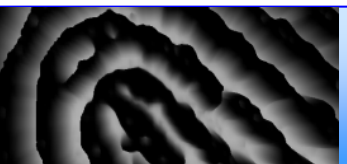
- Acquisition area
  - PIV/PassDEÜV IQS: simulating scanners with the minimum allowed acquisition area caused a performance drop (**73%** and **12%** on the average respectively)
- Output resolution
  - IAFIS/PassDEÜV IQS: simulating scanners with the minimum/maximum allowed resolution (500ppi±1%) did not cause significant performance drops
  - PIV IQS: simulating scanners with the minimum/maximum allowed resolution (500ppi±2%) caused a noticeable performance drop (**20%** on the average)
- Geometric accuracy and Spatial Frequency Response
  - No significant performance drops for IAFIS, PassDEÜV and PIV IQS
  - Performance drops for quality levels lower than the PIV IQS
- Signal-to-noise ratio and Fingerprint dynamic range:
  - No noticeable effects on the matching accuracy even for quality levels much lower than the PIV IQS requirements (e.g. $SNR<25$, $DR<32$)



New specifications

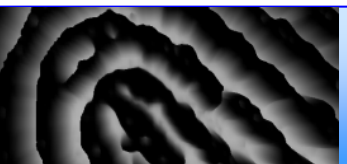
Starting from the results obtained by the previous experiments on ***operational quality***, three new sets of IQS are proposed:

- CNIPA-A:
  - enrolment in large-scale applications where device interoperability is crucial (e.g. passports, identity card);
  - identity verification in large-scale applications where the enrolment has been performed with IAFIS or CNIPA-A IQS complaint scanners (e.g. passport or visa verification).
- CNIPA-B:
  - enrolment and verification in medium-scale project;
  - identity verification in large-scale applications where the enrolment has been performed with CNIPA-A IQS complaint scanners (e.g. identity card verification).
- CNIPA-C:
  - enrolment and verification in small-scale applications, where typically the user are authenticated on the same device (e.g. logical and physical security in small organizations).



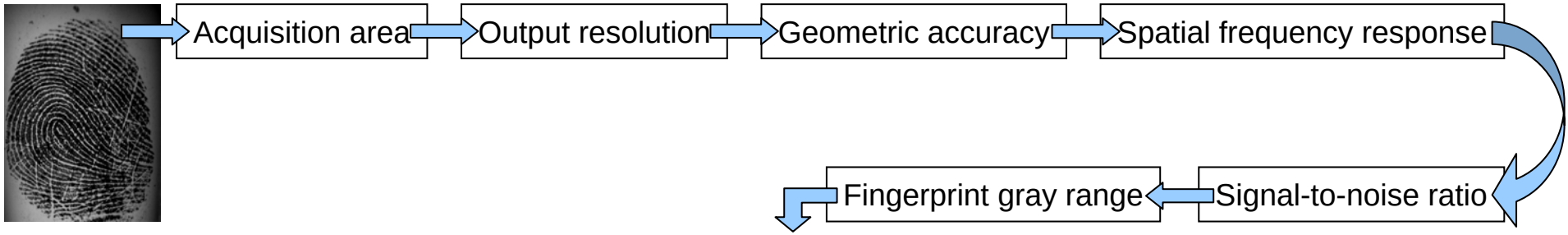
The requirements of the five IQS

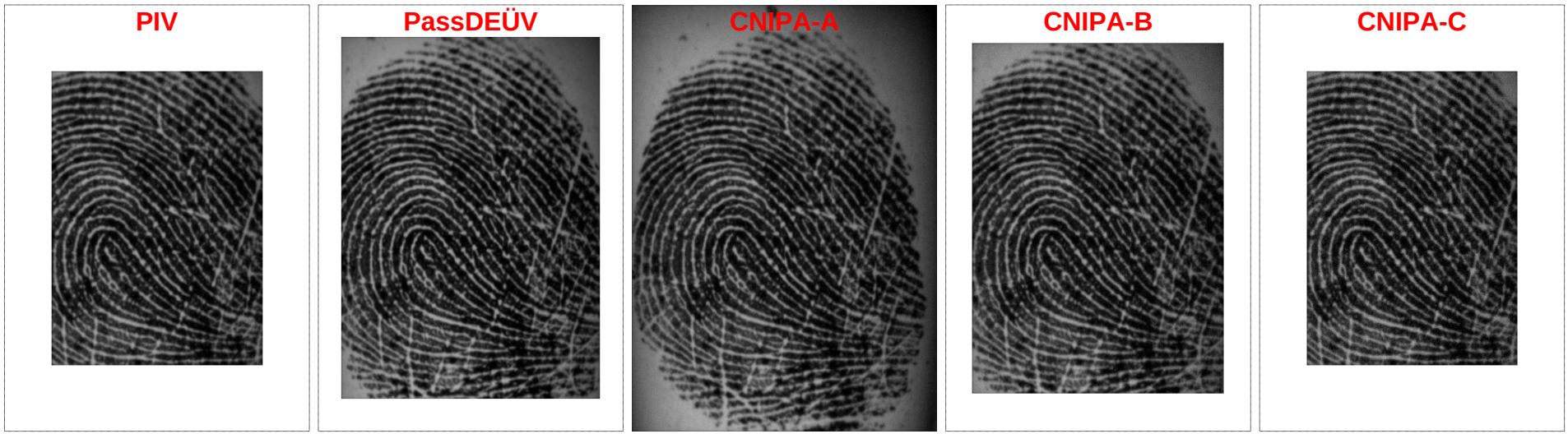
Parameter	Requirement				
	PIV IQS	PassDEÜV IQS	CNIPA		
			IQS A	IQS B	IQS C
Acquisition area	w ≥ 12.8mm h ≥ 16.5mm	w ≥ 16.0mm h ≥ 20.0mm	w ≥ 25.4mm h ≥ 25.4mm	w ≥ 15.0mm h ≥ 20.0mm	w ≥ 12.8mm h ≥ 16.5mm
Native resolution	$R_N \geq 500$ppi				
Output resolution	$R_N \pm 2\%$	$R_N \pm 1\%$	$R_N \pm 1\%$	$R_N \pm 1.5\%$	$R_N \pm 2\%$
Gray-level quantization	256 gray-levels (8 bpp)				
Geometric accuracy	In 99% of the tests: $D_{AC} \leq \max\{0.0013", 0.018 \cdot X\}$ $D_{AL} \leq 0.027"$	In 99% of the tests: $D_{AC} \leq \max\{0.0007", 0.01 \cdot X\}$ $D_{AL} \leq 0.016"$	In all the tests: $D_{Rel} \leq 1.5\%$	In all the tests: $D_{Rel} \leq 2.0\%$	In all the tests: $D_{Rel} \leq 2.5\%$
Input/output linearity	No requirements	$D_{Lin} \leq 7.65$	No requirements		
Spatial frequency response	$MTF_{min}(f) \leq MTF(f) \leq 1.12$	$MTF_{min}(f) \leq MTF(f) \leq 1.05$	For each region: $TSI \geq 0.20$	For each region: $TSI \geq 0.15$	For each region: $TSI \geq 0.12$
Gray level uniformity	In 99% of the cases: $D_{RC}^{dark} \leq 1.5$; $D_{RC}^{light} \leq 3$ For 99% of the pixels: $D_{PP}^{dark} \leq 8$; $D_{PP}^{light} \leq 22$ For every two small areas: $D_{SA}^{dark} \leq 3$; $D_{SA}^{light} \leq 12$	In 99% of the cases: $D_{RC}^{dark} \leq 1$; $D_{RC}^{light} \leq 2$ For 99.9% of the pixels: $D_{PP}^{dark} \leq 8$; $D_{PP}^{light} \leq 22$ For every two small areas: $D_{SA}^{dark} \leq 3$; $D_{SA}^{light} \leq 12$	No requirements		
Signal-to-noise	SNR ≥ 70.6	SNR ≥ 125	SNR ≥ 70.6	SNR ≥ 49.4	SNR ≥ 30.9
Fingerprint gray range	For 80% of the images: DR ≥ 150	DR ≥ 200 for 80% images; DR ≥ 128 for 99% images	For 10% of the images: DR ≥ 150	For 10% of the images: DR ≥ 140	For 10% of the images: DR ≥ 130



IQS simulation

Fingerprint images acquired by hypothetical scanners compliant with each IQS have been simulated applying sequentially to the original images the following transformations:





“Strictness” of the five IQS considered

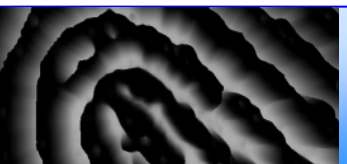
A comparison of the five IQS according to the “strictness” of the various quality parameters with respect to the FBI IAFIS IQS.

Parameter	Level of “strictness” of the requirements				
	PIV IQS	PassDEÜV	CNIPA-A	CNIPA-B	CNIPA-C
Acquisition area	LOW	MEDIUM	HIGH	MEDIUM	LOW
Output resolution accuracy	LOW	HIGH	HIGH	MEDIUM	LOW
Geometric accuracy	LOW	HIGH	HIGH	MEDIUM	LOW
Spatial frequency response	MEDIUM	HIGH	MEDIUM	LOW	LOW
Signal-to-noise ratio	MEDIUM	HIGH	MEDIUM	LOW	LOW
Fingerprint gray range	MEDIUM	HIGH	MEDIUM	LOW	LOW

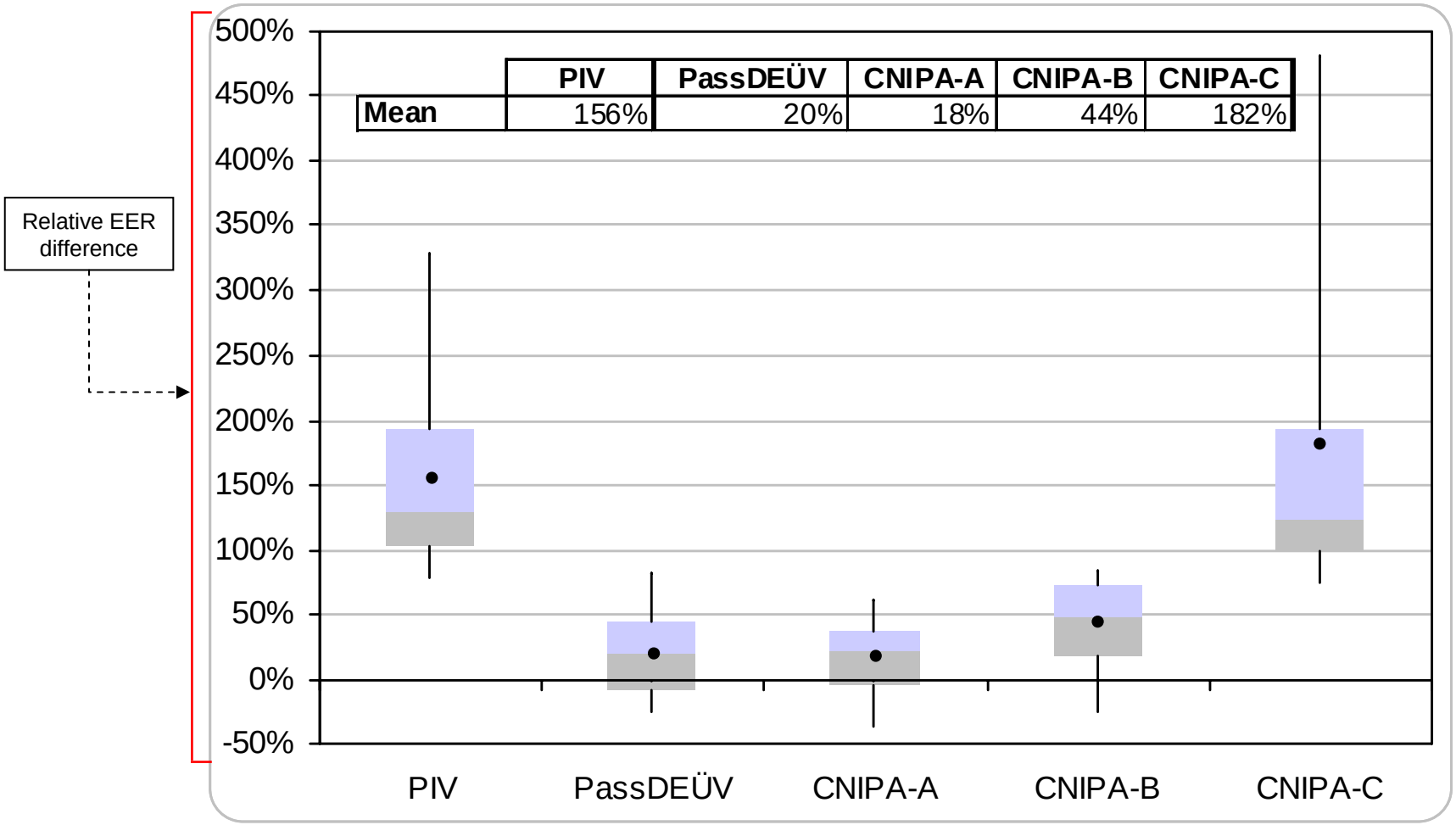
HIGH the constraint is as “strict” as in the FBI IAFIS-IQS

MEDIUM the constraint is moderately relaxed with respect to FBI IAFIS-IQS

LOW the constraint is significantly relaxed with respect to FBI IAFIS-IQS



Impact of the IQS on the recognition accuracy



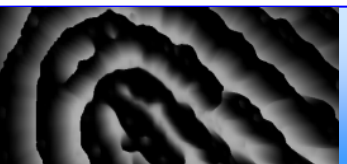
	PIV	PassDEÜV	CNIPA-A	CNIPA-B	CNIPA-C
Mean	156%	20%	18%	44%	182%

Conclusions

- **CNIPA-A:**
  - able to guarantee an accuracy analogous to PassDEÜV;
  - the cost of a device compliant to CNIPA-A would be definitely lower than the cost of PassDEÜV-compliant devices.

- **CNIPA-B:**
  - able to guarantee an accuracy better than PIV and not too far from PassDEÜV;
  - the cost of a device compliant to CNIPA-B would be similar to the cost of PIV-compliant devices and definitely lower than that of one compliant to PassDEÜV.

- **CNIPA-C:**
  - able to guarantee an accuracy similar to PIV;
  - the cost of a device compliant to CNIPA-C would be definitely lower than the cost of PIV-compliant devices.



References

- R. Cappelli, M. Ferrara and D. Maltoni, *"On the Operational Quality of Fingerprint Scanners"*, to appear on IEEE Transactions on Information Forensics and Security.

- In the BioLab website there is a new "*Scanner Quality*" section containing a brief summary of our work on this topic and the related publications.

Thank you for your attention

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