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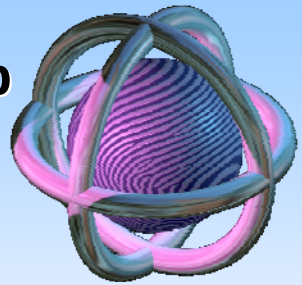

On the Operational Quality of Fingerprint Scanners

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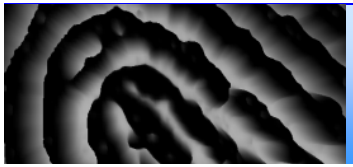
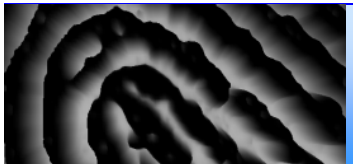
Outline

- The current state-of-the-art
  - IAFIS certification
  - PIV certification
- Objectives and motivations of this research
  - What is the right scanner for a given application?
  - Which are the most important quality criteria?
- Evaluating the effects of the various quality parameters on automated fingerprint recognition
  - Testing approach
  - Experimental results



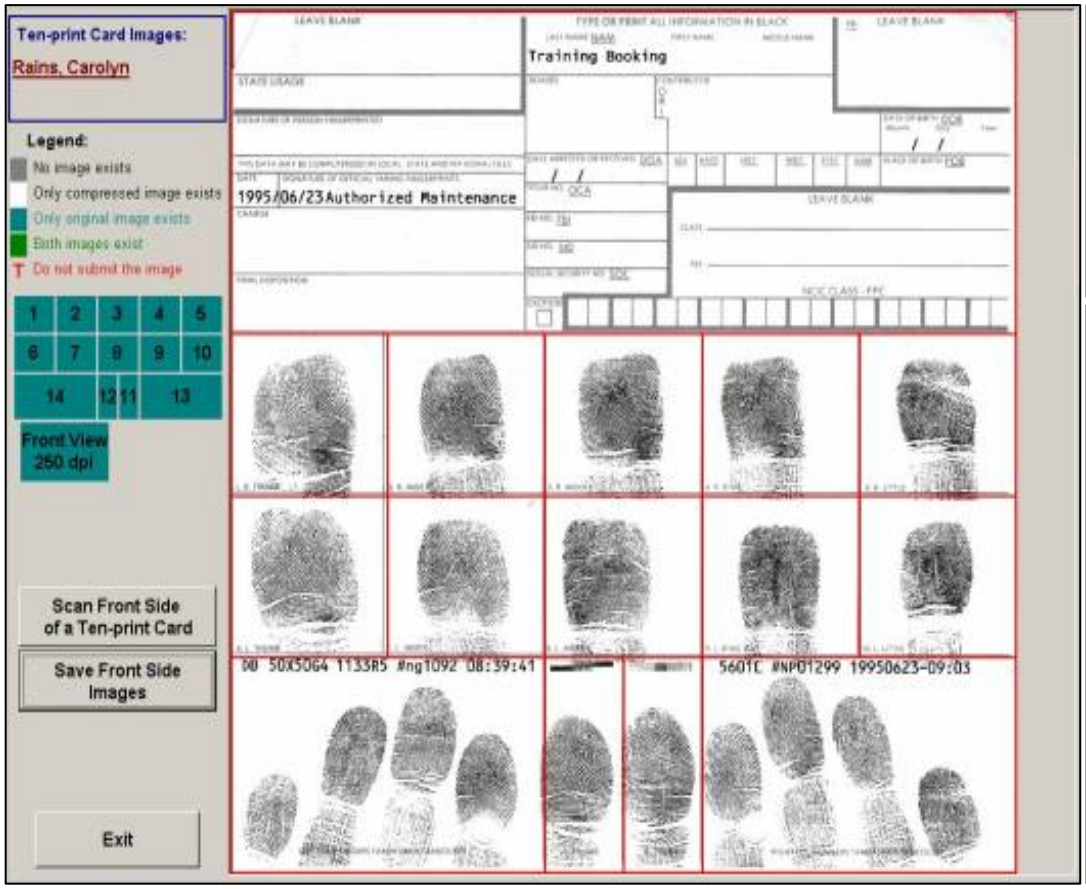
The right scanner for a given application

	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

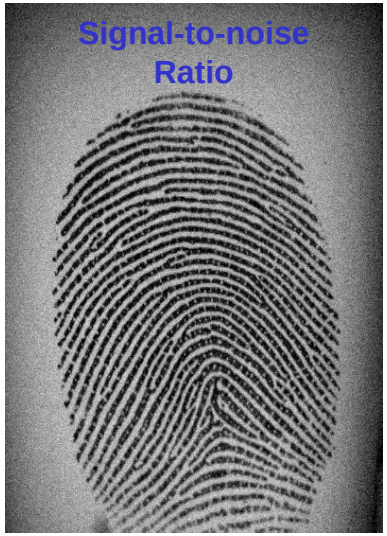
The FBI established an Image Quality Standard (IQS) in order to define the quantitative image quality requirements for IAFIS fingerprint scanners defined in Appendix F of the “Electronic Fingerprint Transmission Specification” (EFTS).

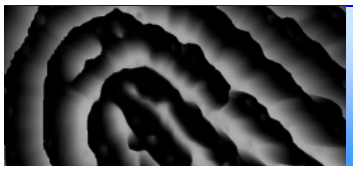


PIV certification

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.

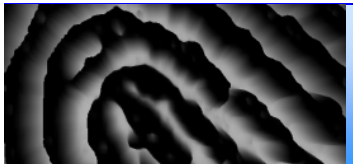
IAFIS and PIV main quality parameters





IAFIS and PIV requirements

Parameter	Requirement	
	IAFIS IQS	*PIV IQS*
Acquisition area	Depending on the scanner type; for a plain 4-fingers scanner: $w \geq$ 73.2mm (2.88") and $h \geq$ 45.7mm (1.8")	$w \geq$ **12.8mm (0.504")** and $h \geq$ **16.5mm (0.650")**
Native resolution	$R_N \geq$ 500ppi *(500ppi scanners)* $R_N \geq$ 1000ppi *(1000ppi scanners)*	$R_N \geq$ 500ppi
Output resolution	$R_O =$ 500ppi ± 1% *(500ppi scanners)* $R_O =$ 1000ppi ± 1% *(1000ppi scanners)*	$R_O =$ 500ppi ± 2%
Gray-level quantization	256 gray-levels (8 bpp)	256 gray-levels (8 bpp)
Geometric accuracy	At least in 99% of the test measurements: $D_{AC} \leq$ max{0.0007", 0.01·X}, X≤1.50" *(500ppi)* $D_{AC} \leq$ max{0.0005", 0.0071·X}, X≤1.50" *(1000ppi)* $D_{AL} \leq$ 0.016"	At least in 99% of the test measurements: $D_{AC} \leq$ max{**0.0013"**, **0.018**·X}, X≤1.50" $D_{AL} \leq$ **0.027"**
Input/output linearity	$D_{Lin} \leq$ 7.65	No requirements
Spatial frequency response	For each spatial frequency f considered: $MTF_{min}(f) \leq MTF(f) \leq$ 1.05	For each spatial frequency f considered: $\mathbf{MTF_{min}(f)} \leq MTF(f) \leq$ **1.12**
Gray level uniformity	At least in 99% of the cases: $D_{RC}^{dark} \leq 1$; $D_{RC}^{light} \leq 2$ At least for 99.9% of the pixels: $D_{PP}^{dark} \leq 8$; $D_{PP}^{light} \leq 22$ For every two small areas: $D_{SA}^{dark} \leq 3$; $D_{SA}^{light} \leq 12$	At least in 99% of the cases: $D_{RC}^{dark} \leq$ **1.5** ; $D_{RC}^{light} \leq$ **3** At least for **99%** of the pixels: $D_{PP}^{dark} \leq 8$; $D_{PP}^{light} \leq 22$ For every two small areas: $D_{SA}^{dark} \leq 3$; $D_{SA}^{light} \leq 12$
Signal-to-noise ratio	$SNR_{dark} \geq 125$; $SNR_{light} \geq 125$	$SNR_{dark} \geq$ **70.6** ; $SNR_{light} \geq$ **70.6**
Fingerprint gray range	At least for 80% of the fingerprint images: $DR \geq 200$ At least for 99% of the fingerprint images: $DR \geq 128$	At least for 80% of the fingerprint images: $DR \geq$ **150**
Fingerprint artifacts and anomalies	Artifacts or anomalies […] shall not be significant enough to adversely impact support to […] Automated Fingerprint Identification System (AFIS) search reliability.	Artifacts, anomalies, […] shall not significantly adversely impact supporting the intended applications.
Fingerprint sharpness and detail rendition	The sharpness and detail rendition […] shall be high enough to support the […] Automated Fingerprint Identification System (AFIS) search reliability.	The sharpness and detail rendition […] shall be high enough to support the intended applications.

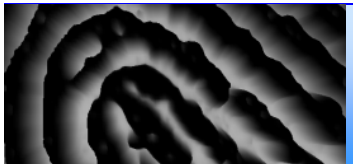


Quality parameters and recognition accuracy

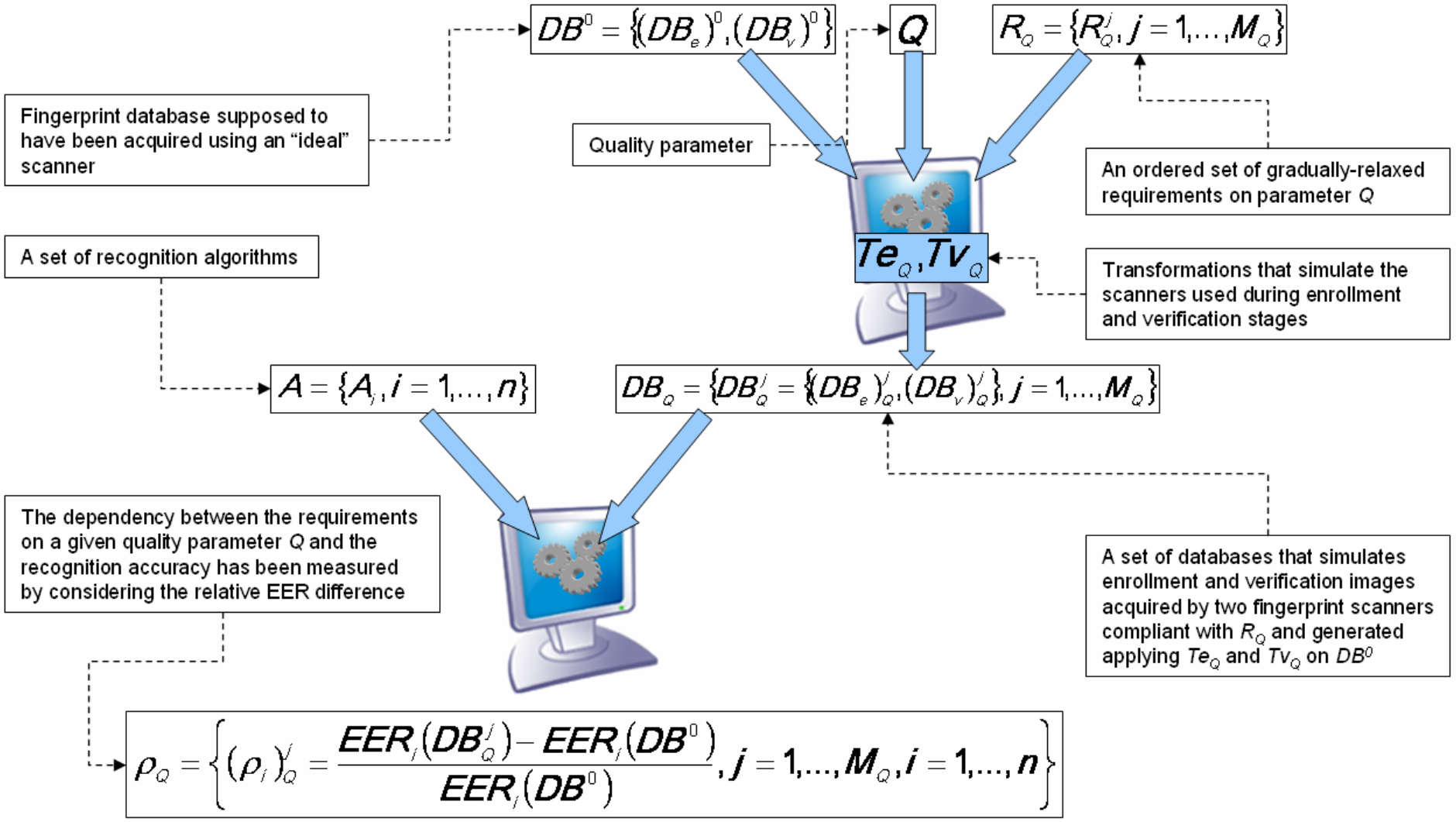
- In the FBI specifications, the quality is:
  - defined as “fidelity” of the scanner in reproducing the original fingerprint pattern
  - quantified by measures traditionally used for vision, acquisition and printing systems

- To date no scientific work systematically analyzed the effects of the various scanner quality parameters on *automated fingerprint recognition accuracy*

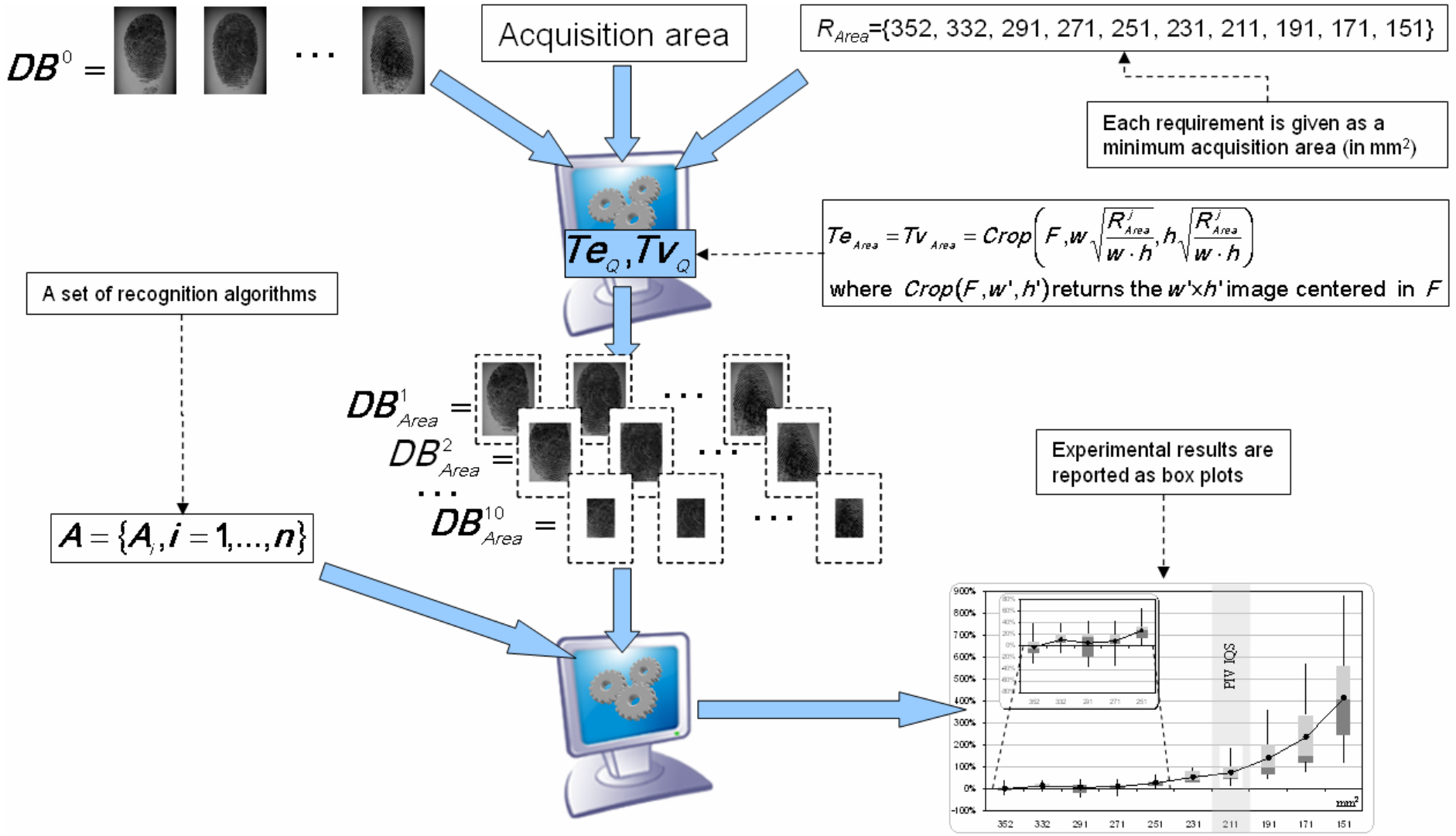
- **“Operational quality”**
  - The ability of a fingerprint scanner to acquire images that maximize the accuracy of automated recognition algorithms



Test approach

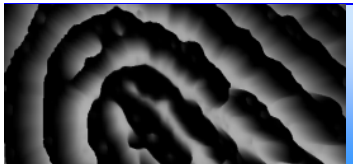


Test approach: example

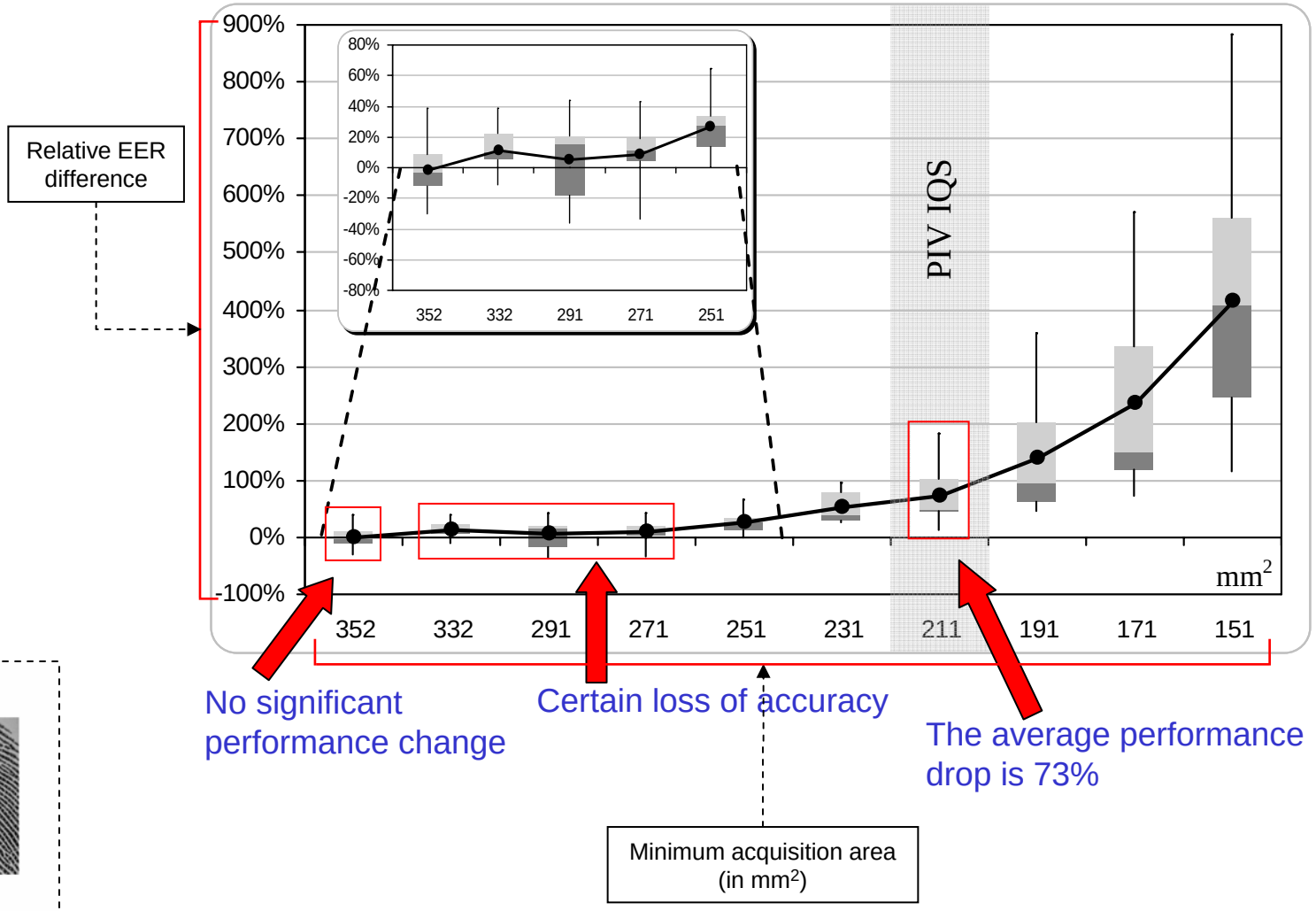


Experiments

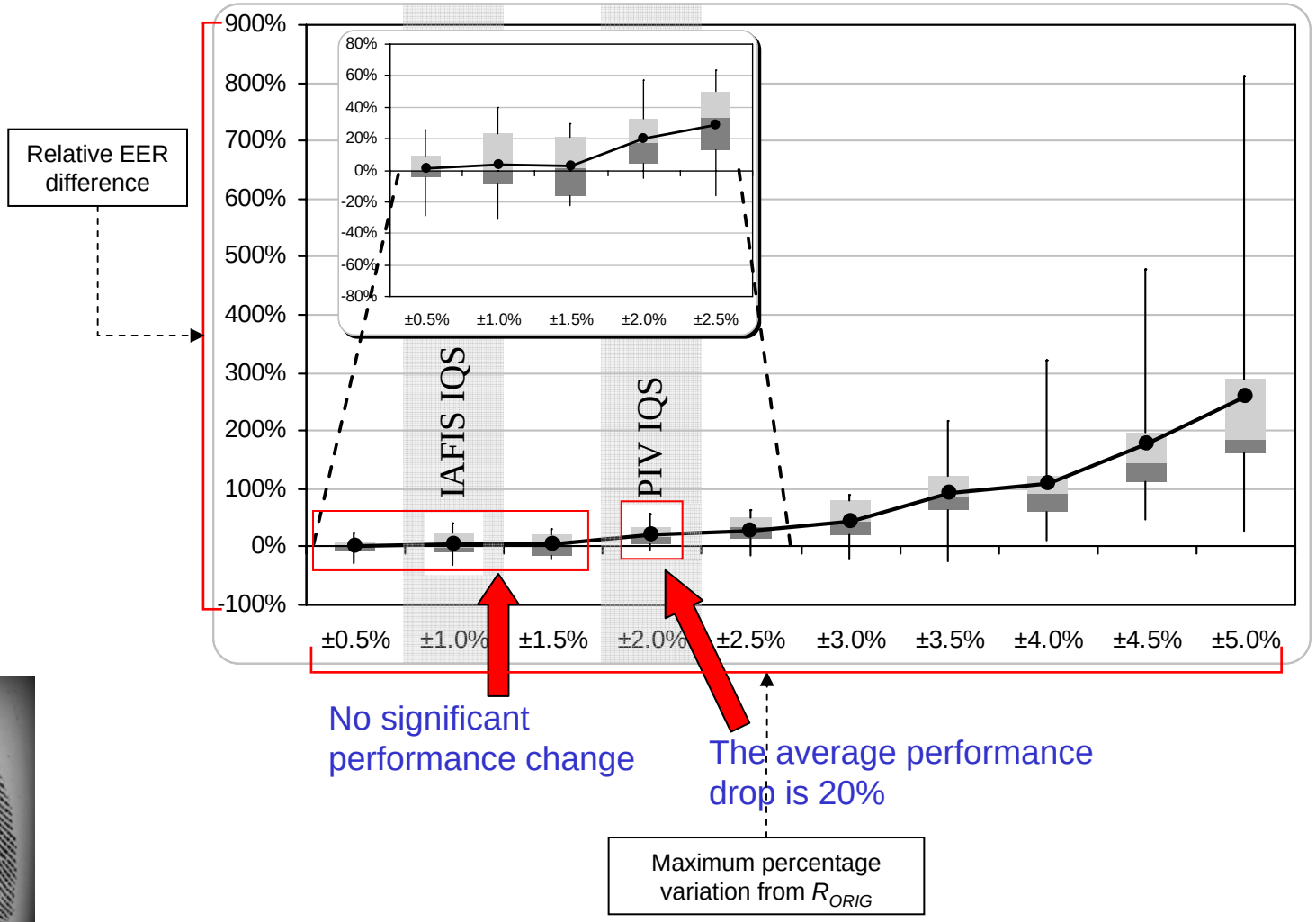
- The FVC2006 DB2 has been used
  - 1680 images: 140 fingers, 12 impressions per fingers
  - Acquisition area: *w*=17.8mm, *h*=25.0mm
- Quality parameters considered:
  - Acquisition area
  - Output resolution
  - Geometric accuracy
  - Spatial frequency response
  - Signal-to-noise ratio
  - Fingerprint gray range
- From FVC2006 ten of the best performing algorithms on DB2 have been selected (not only minutiae-based)
- Experiment size
  - 115,920 image transformations
  - 11,192,300 fingerprint pairs compared



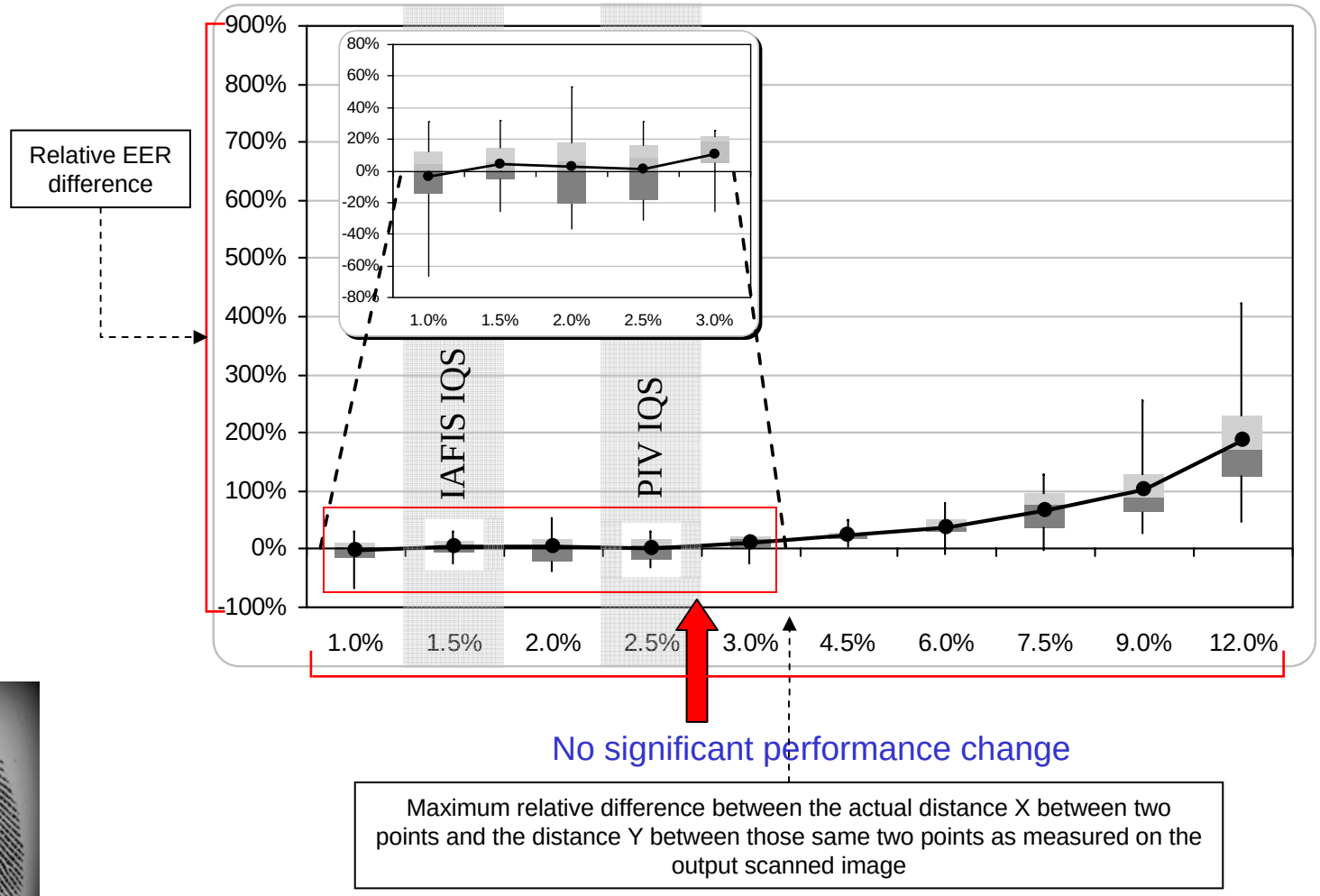
Results: Acquisition area



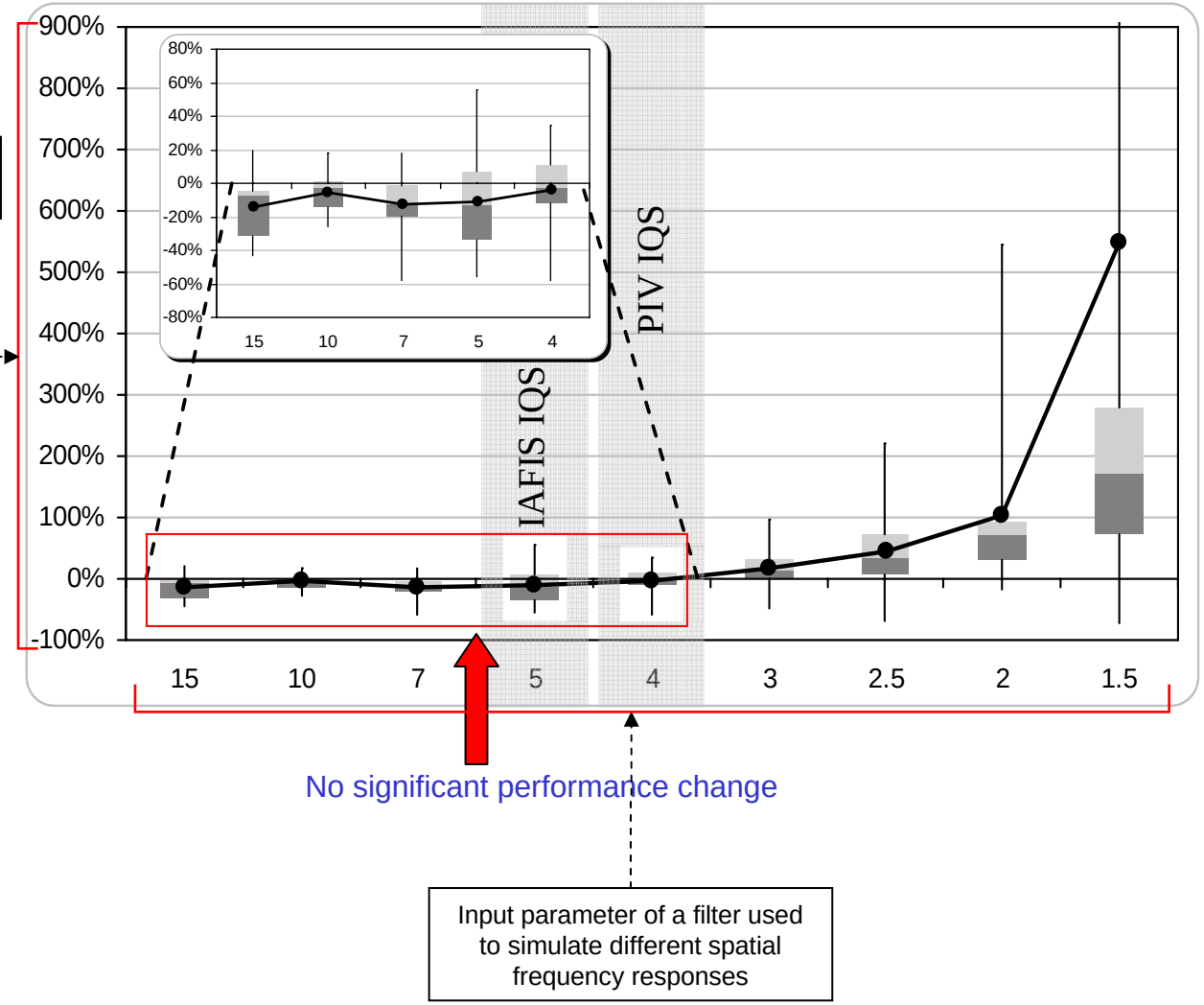
Results: Output resolution



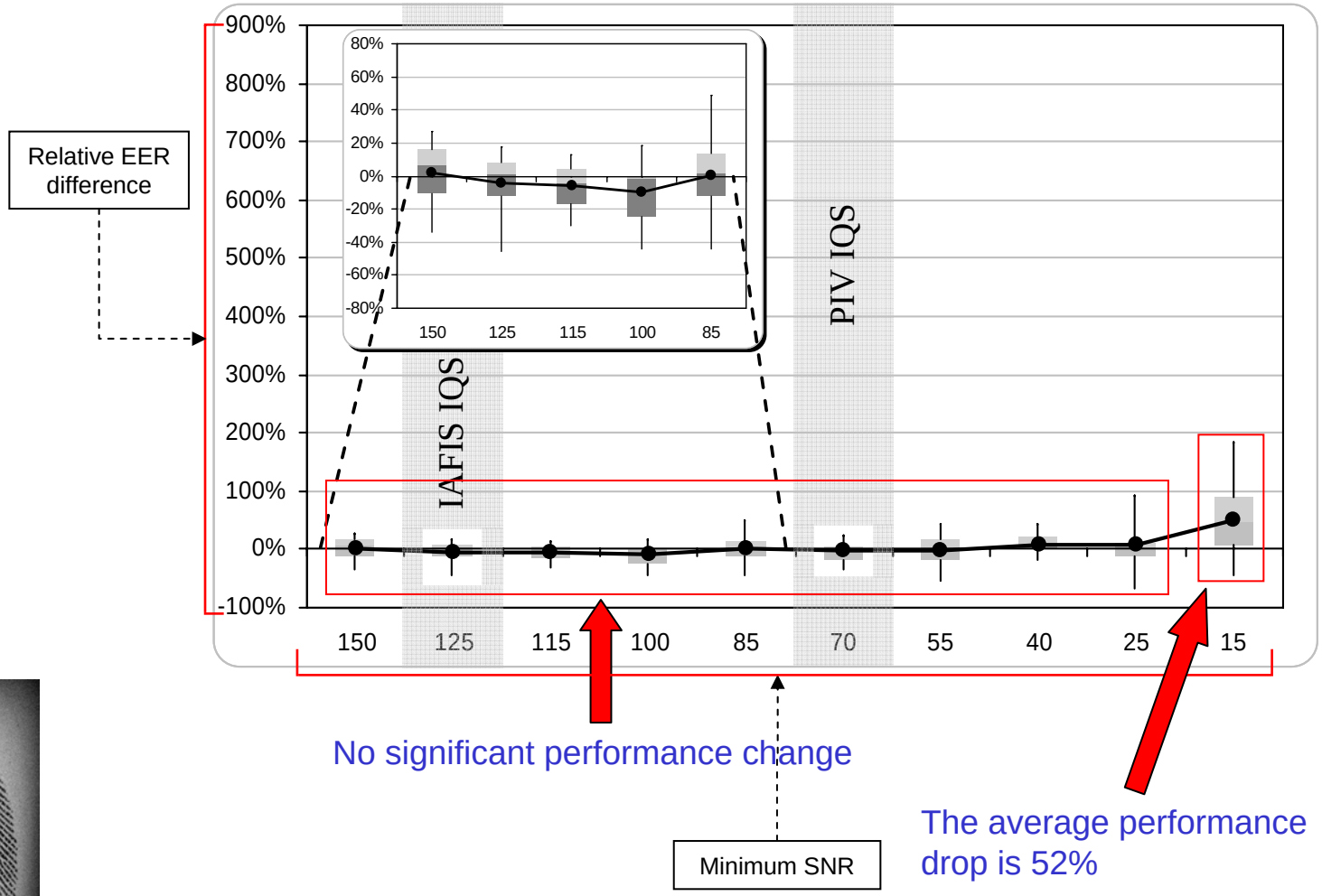
Results: Geometric accuracy



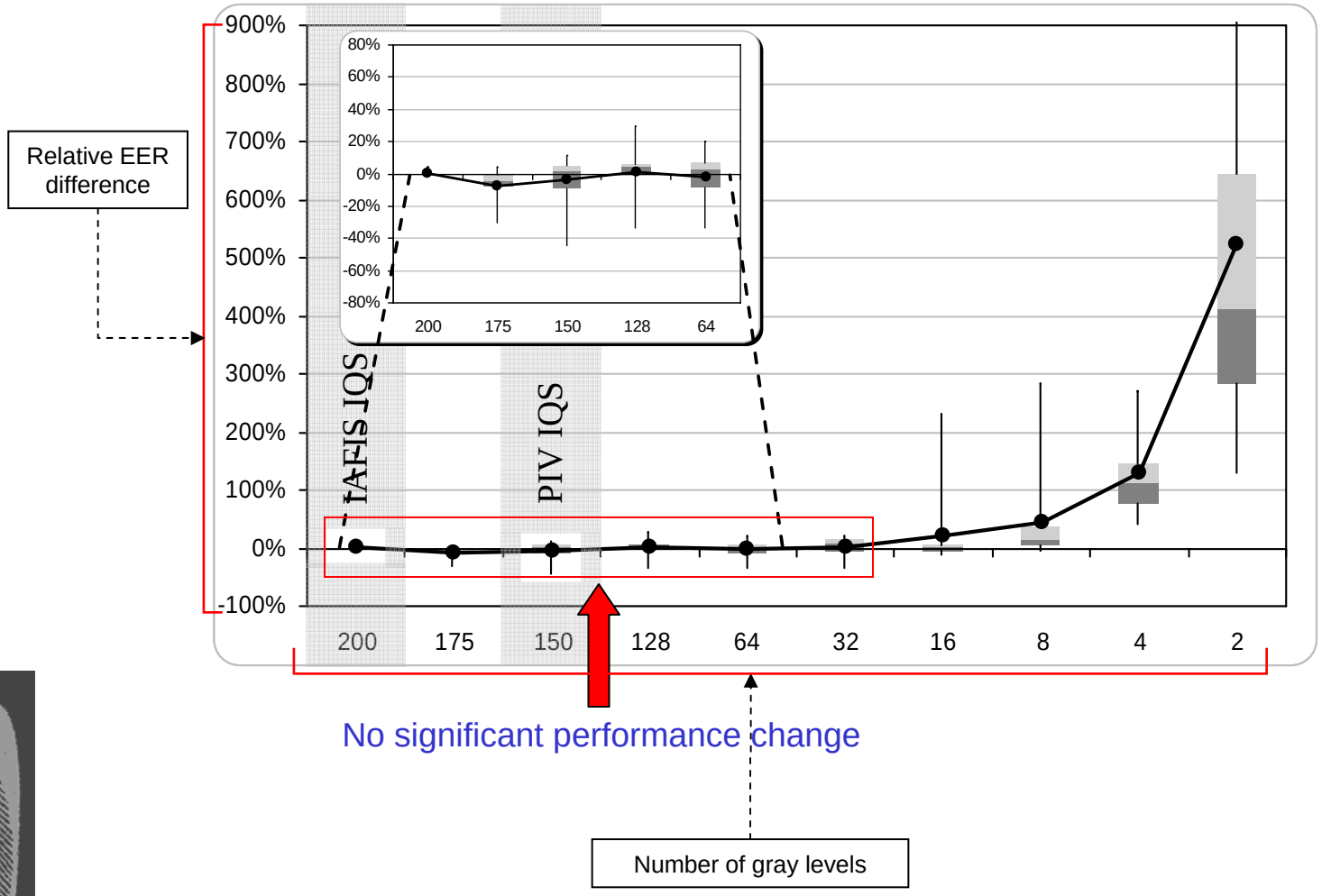
Results: Spatial frequency response



Results: Signal-to-noise ratio

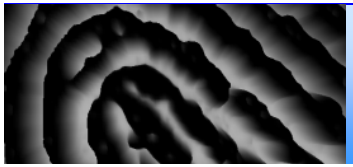


Results: Fingerprint gray range



Summary of the results

- Acquisition area
  - PIV IQS: simulating scanners with the minimum allowed acquisition area caused a sensible performance drop (73% on the average)
- Output resolution
  - IAFIS 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 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. $SNR<25$, $DR<32$)



Conclusions

- How may these results be exploited in practice to help choosing fingerprint scanners for a given application?
- The fundamental issue: does the application involve human examination of fingerprint images?

YES

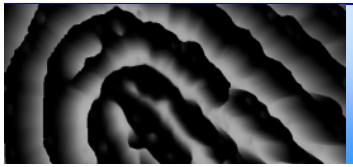
IAFIS and large scale systems where the images may be examined by forensic experts

It is clearly very important to define the scanner quality as fidelity to the original signal. In fact human experts' fingerprint comparison heavily relies on very fine details such as pores, incipient ridges, etc. for which the fidelity to the original signal is very important.

NO

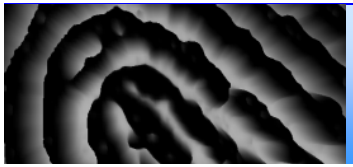
Totally-automated biometric systems

The definition of "operational quality" may be more important than the absolute fidelity to the original signal because the choice of a particular scanner should be driven by the desired performance.



Future works

- Define sets of quality requirements able to guarantee an optimal cost/performance tradeoff for totally-automated biometric applications.
- Understand and properly evaluate the *correlations* between the various quality parameters and the effect of degrading more parameters simultaneously.

Thank you for your attention

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