

Summer School for Advanced Studies on

BIOMETRICS:

AUTHENTICATION and RECOGNITION

Alghero, Italy – June, 2 – 6 2003



Fingerprint Recognition

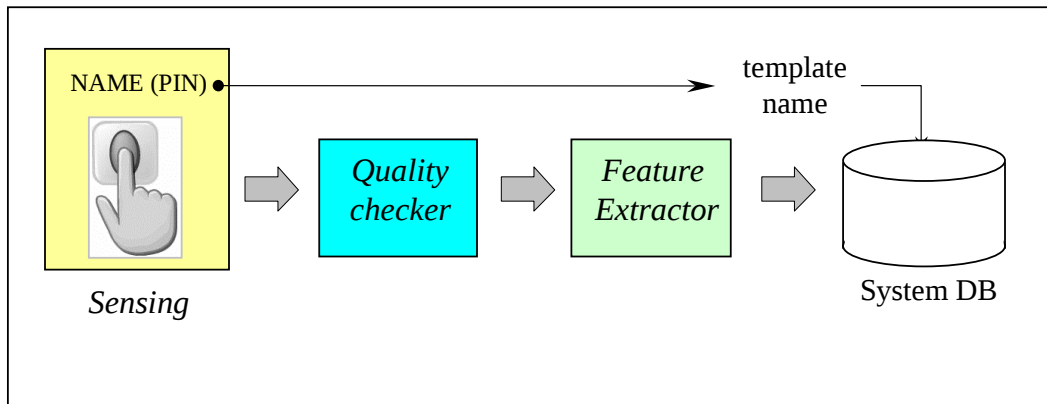
Sensing, feature extraction and matching

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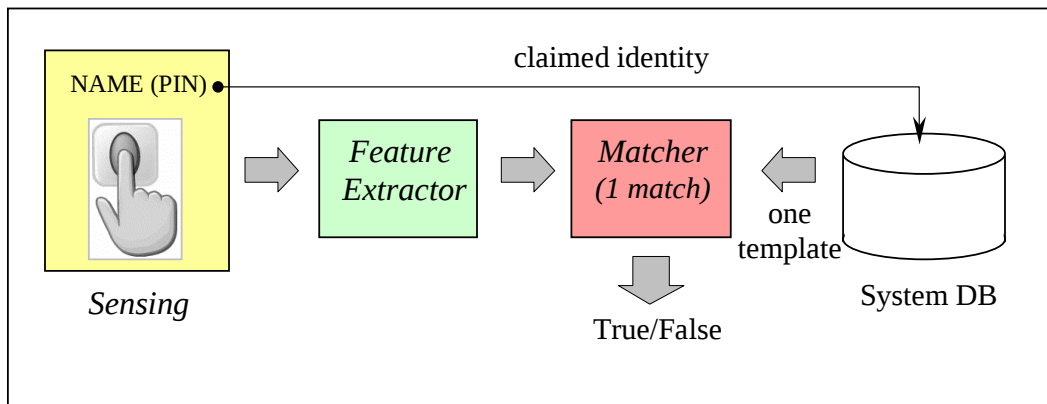
DEIS - University of Bologna - ITALY

Enrollment, Verification and Identification

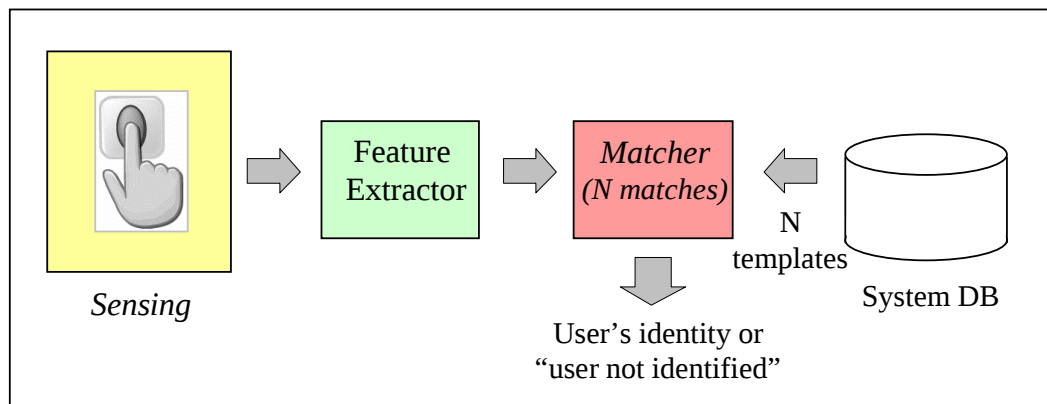
Enrollment



Verification



Identification



Sensing, Feature extraction and matching

Sensing



- Fingerprint images
- Off-line acquisition
- On-line acquisition
- Sweep sensors
- Fingerprint scanners
- Sensing area and accuracy

Feature Extraction

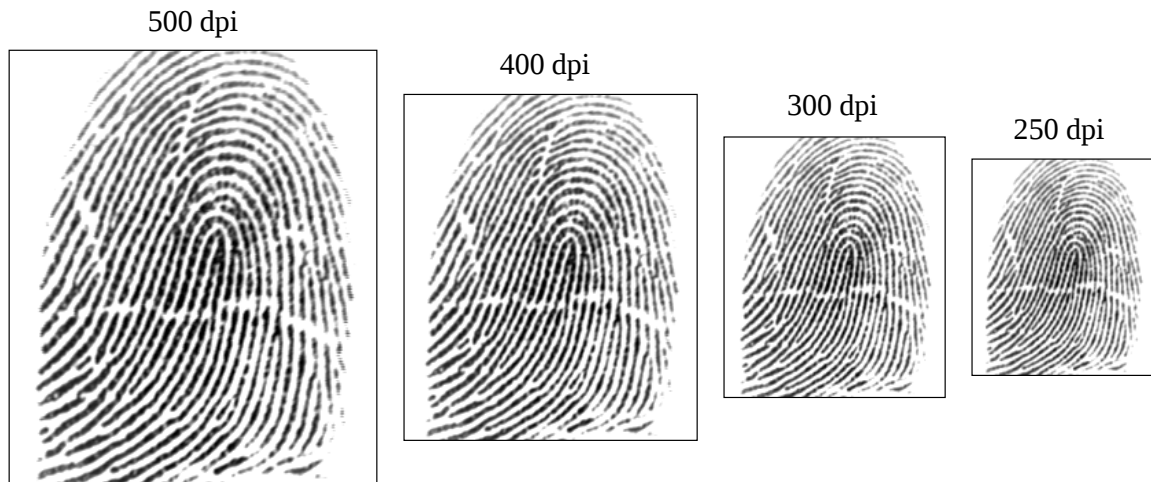
- Anatomy of fingerprints
- Local orientation and local frequency
- Singularity detection
- Segmentation
- Enhancement
- Minutiae extraction

Matching

- Problems in fingerprint matching
- Correlation-based matching
- Minutiae-based (global) approach
- Minutiae-based (local) approach
- Texture-based approach
- Dealing with distortion

Fingerprint images

- **Resolution:** number of Dots or pixels Per Inch (dpi). 500 dpi is the minimum resolution for FBI-compliant scanners; 250 to 300 dpi is probably the minimum resolution that allows the extraction algorithms to locate the minutiae in fingerprint patterns.



- **Area:** rectangular area sensed by a fingerprint scanner. The larger the area, the more ridges and valleys are captured. An area greater than or equal to 1×1 square inches (FBI specifications) permits a full plain fingerprint impression to be acquired. Most of the recent fingerprint scanners sacrifice area to reduce cost and to have a smaller device size.
- **Number of pixels:** can be simply derived by the resolution and the fingerprint area: the image produced by a scanner working at r dpi over an area of $height(h) \times width(w)$ inch² has $rh \times rw$ pixels.
- **Dynamic range (or depth):** denotes the number of bits (usually 8) used to encode the intensity value of each pixel. Color information is not considered useful for fingerprint recognition.
- **Geometric accuracy:** specified as the maximum geometric distortion introduced by the acquisition device, and expressed as a percentage with respect to x and y directions.

Fingerprint images (2)

- **Image quality**: not easy to precisely define the quality of a fingerprint image, and it is even more difficult to decouple the fingerprint image quality from the intrinsic finger quality or status.

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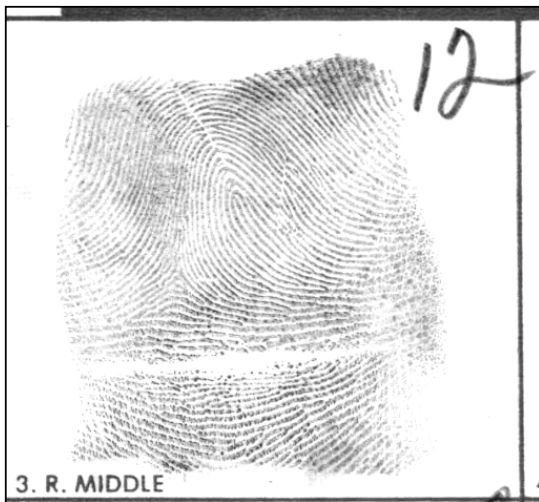


The FBI specifications cover only some numerical aspects such as **MTF** (Modulation Transfer Function) and **SNR** (Signal-to-Noise Ratio) concerning the fidelity of reproduction with respect to the original pattern.

Other scanner characteristics, such as the ability of dealing with dry and wet fingers should also be taken into account.

Off-line acquisition

In the **ink-technique** the finger skin is first **spread with black ink** and then **pressed** against a **paper card**; the card is then converted into digital form by means of a **paper-scanner** or by using a high-quality CCD camera. The **default** resolution is **500 dpi**. An advantage of this technique is the possibility of simply producing **rolled** impressions (by rolling “nail-to-nail” a finger against the card).



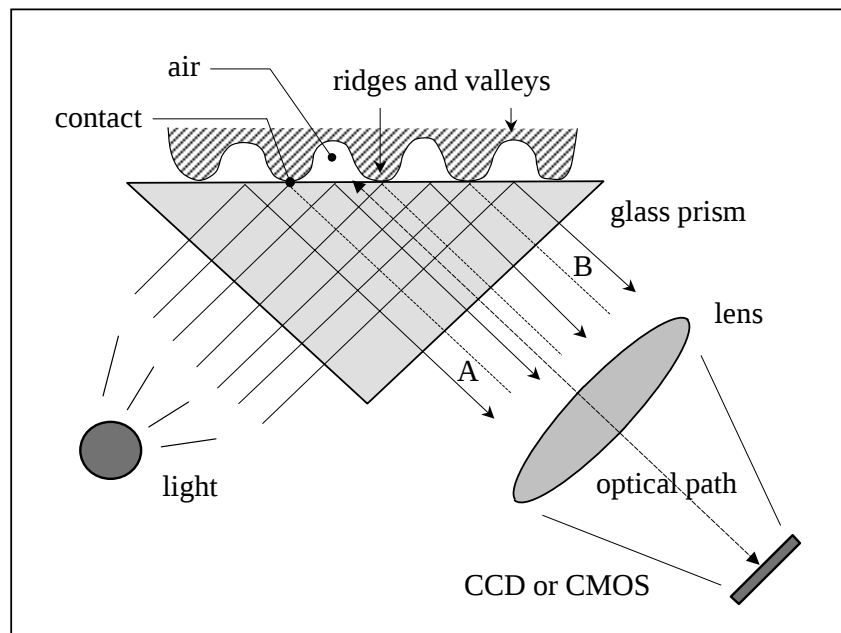
In **forensics**, a special kind of fingerprints, called **latent fingerprints**, is of great interest. Usually they are **very low quality**!



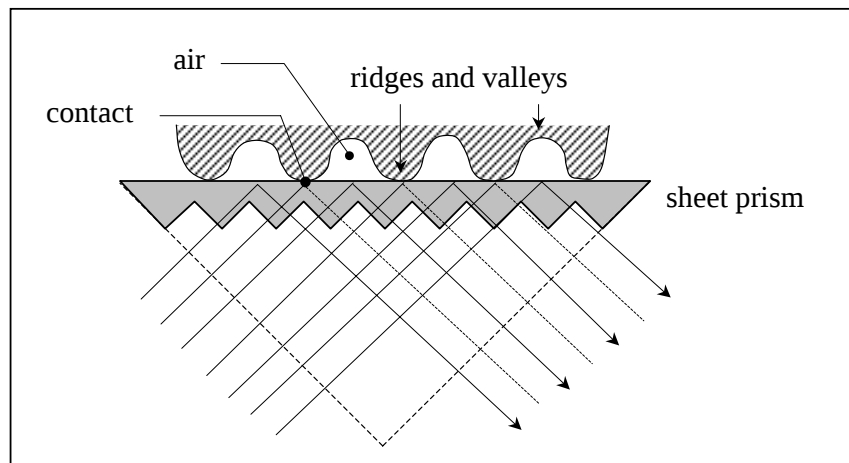
On-line acquisition

Optical sensors

- **Frustrated Total Internal Reflection (FTIR):** the light entering the prism is **reflected** at the **valleys**, and randomly **scattered** (absorbed) at the **ridges**. The lack of reflection allows the ridges (which appear dark in the image) to be discriminated from the valleys (appearing bright).

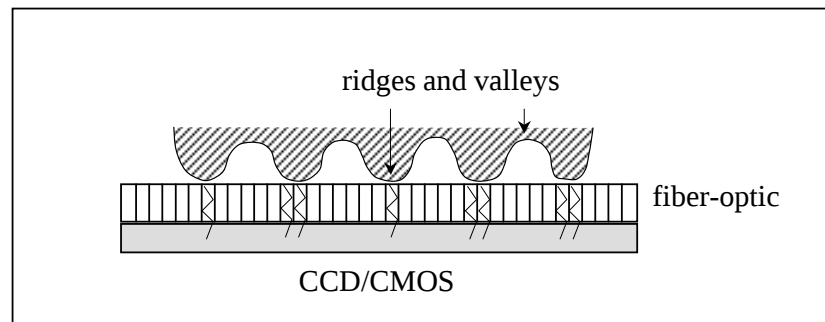


- **FTIR with a sheet prism:** to reduce the size/cost, uses a sheet prism made of a number of “**prismlets**” adjacent to each other.

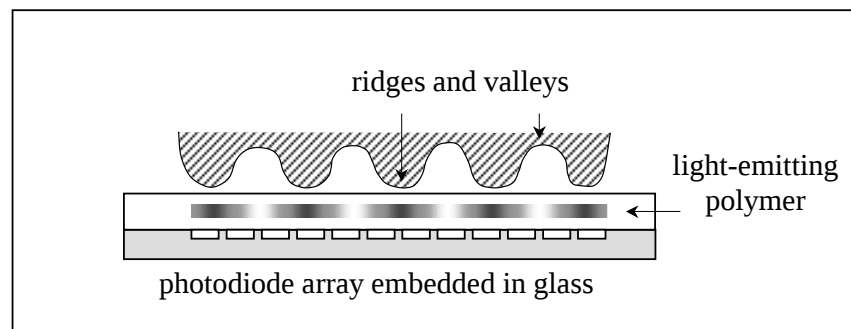


On-line acquisition (2)

- **Optical fibers:** the finger is in direct contact with the upper side of the platen; on the opposite side, a CCD or CMOS, tightly coupled with the platen, receives the finger residual light conveyed through the glass fibers.



- **Electro-optical:** constituted of two main layers: **light emitting polymer** and **photodiode array**. As ridges touch the polymer and the valleys do not, the potential is not the same across the surface when a finger is placed on it and the amount of light emitted varies, thus allowing a luminous representation of the fingerprint pattern to be generated and acquired by the photodiode array.

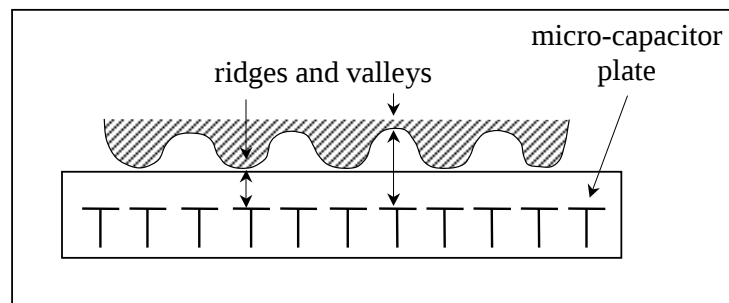


- **Direct reading:** uses a high-quality camera to directly focus the fingertip. The finger is not in contact with any surface, but the scanner is equipped with a mechanical support that facilitates the user in presenting the finger at a uniform distance.

On-line acquisition (3)

Solid-state sensors

- **Capacitive:** is a two-dimensional array of **micro-capacitor plates** embedded in a chip. The other plate of each micro-capacitor is the finger skin itself. Small electrical charges are created between the surface of the finger and each of the silicon plates when a finger is placed on the chip. The magnitude of these electrical charges **depends on the distance** between the fingerprint surface and the capacitance plates.



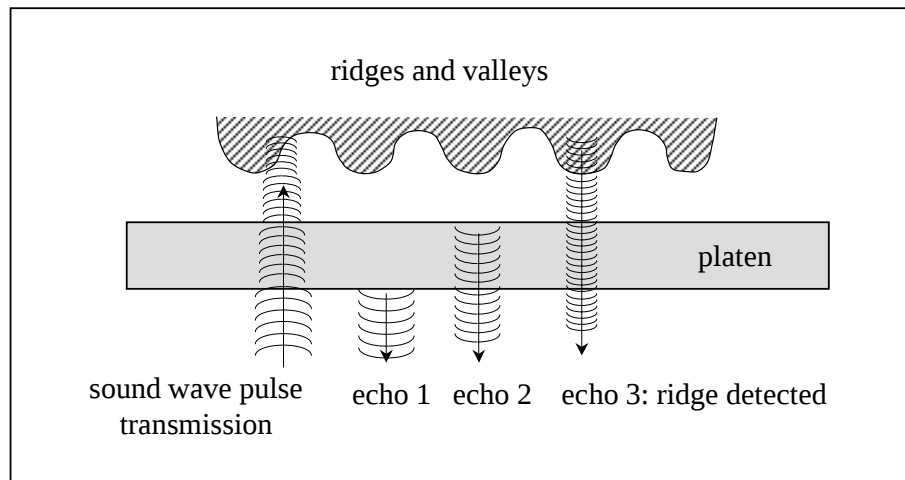
- **Thermal:** are made of **pyro-electric material** that generates current based on temperature differentials. The fingerprint ridges, being in contact with the sensor surface, **produce a different temperature differential than the valleys**, which are away from the sensor surface. The temperature differential produces an image when contact occurs, but this image soon disappears because the thermal equilibrium is quickly reached. Hence a **sweeping method** may be necessary to acquire a stable fingerprint image.
- **Electric field:** the sensor consists of a drive ring that generates a sinusoidal signal and a **matrix of active antennas** that receives a very small signal transmitted by the drive ring and **modulated by the derma structure** (subsurface of the finger skin).
- **Piezoelectric:** the sensor surface is made of a non-conducting dielectric material which, on encountering **pressure** from the finger, generates a small amount of current (**piezoelectric effect**). Since ridges and valleys are present at different distances from the sensor surface, they result in different amounts of pressure.



On-line acquisition (4)

Ultrasound sensors

Ultrasound sensing may be viewed as a kind of **echography**. It is based on sending acoustic signals toward the fingertip and capturing the echo signal. The echo signal is used to compute the range image of the fingerprint and, subsequently, the ridge structure itself.



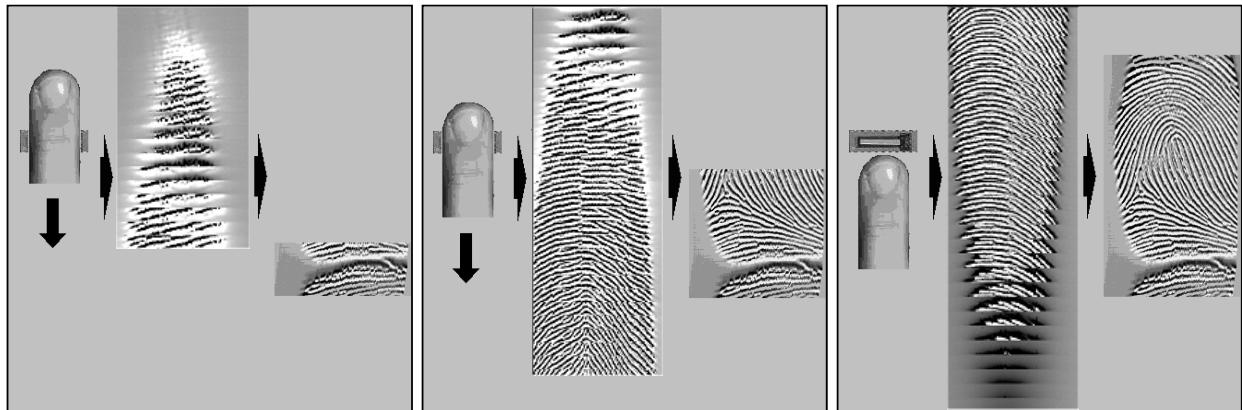
This method images the **subsurface of the finger skin** (even through thin gloves); therefore, it is **resilient to dirt and oil accumulations** that may visually mar the fingerprint.

Good quality images may be obtained by this technology. However, the scanner is large with mechanical parts and quite expensive. Moreover, it takes a few seconds to acquire an image.

On-line acquisition (5)

Sweeping sensors

The sensor surface is a **small rectangle** whose **width** is larger than the finger, but whose **height** is just few pixels (e.g. 8). As the user **sweeps** her finger on the sensor, the sensor delivers new image **slices**, which are combined into a two-dimensional image.



Pros:

- lower **cost** (proportional to the silicon area)
- the sweeping tend to **clean** the sensor
- **no latents** are left on the sensor surface

Cons:

- more **complicated user interaction**
- require **fast interface**
- **software reconstruction** can introduce errors and require extra computation.

Examples of Commercial Fingerprint Scanners

	Technology	Company	Model	Dpi	Area (h×w)	Pixels
Optical	FTIR	Biometrika www.biometrika.it/eng/	FX2000	569	0.98"×0.52"	560×296 (165,760)
	FTIR	Digital Persona www.digitalpersona.com	UareU2000	440	0.67"×0.47"	316×228 (72,048)
	FTIR (sweep)	Kinetic Sciences www.kinetic.bc.ca	K-1000	up to 1000	0.002"×0.6"	2×900 (H×900)
	FTIR	Secugen www.secugen.com	Hamster	500	0.64"×0.54"	320×268 (85,760)
	Sheet prism	Identix www.identix.com	DFR 200	380	0.67"×0.67"	256×256 (65,535)
	Fiber optic	Delsy www.delsy.com	CMOS module	508	0.71"×0.47"	360×240 (86,400)
	Electro-optical	Ethentica www.ethentica.com	TactilSense T-FPM	403	0.76"×0.56"	306×226 (69,156)
Solid-state	Capacitive (sweep)	Fujitsu www.fme.fujitsu.com	MBF300	500	0.06"×0.51"	32×256 (H×256)
	Capacitive	Infineon www.infineon.com	FingerTip	513	0.56"×0.44"	288×224 (64,512)
	Capacitive	ST-Microelectronics us.st.com	TouchChip TCS1AD	508	0.71"×0.50"	360×256 (92,160)
	Capacitive	Veridicom www.veridicom.com	FPS110	500	0.60"×0.60"	300×300 (90,000)
	Thermal (sweep)	Atmel www.atmel.com	FingerChip AT77C101B	500	0.02"×0.55"	8×280 (H×280)
	Electric field	Authentec www.authentec.com	AES4000	250	0.38"×0.38"	96×96 (9,216)
	Piezoelectric	BMF www.bm-f.com	BLP-100	406	0.92"×0.63"	384×256 (98,304)

Comparison of Fingerprint images (1)

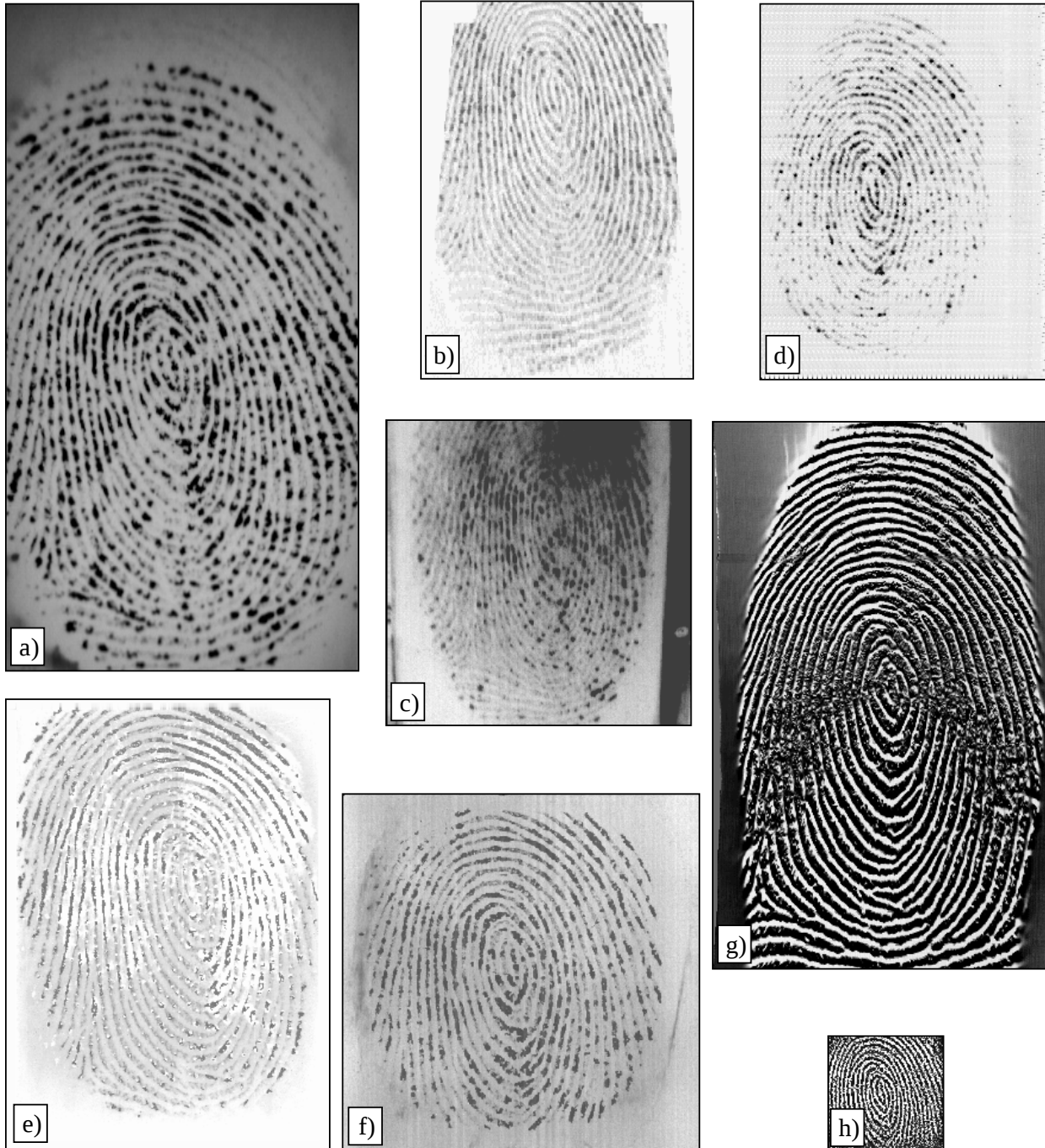
Ideal skin condition



a) Biometrika FX2000, b) Digital Persona UareU2000, c) Identix DFR200, d) Ethentica TactilSense T-FPM, e) ST-Microelectronics TouchChip TCS1AD, f) Veridicom FPS110, g) Atmel FingerChip AT77C101B, h) Authentec AES4000.

Comparison of Fingerprint images (2)

Dry finger



a) Biometrika FX2000, b) Digital Persona UareU2000, c) Identix DFR200, d) Ethentica TactilSense T-FPM, e) ST-Microelectronics TouchChip TCS1AD, f) Veridicom FPS110, g) Atmel FingerChip AT77C101B, h) Authentec AES4000.

Comparison of Fingerprint images (3)

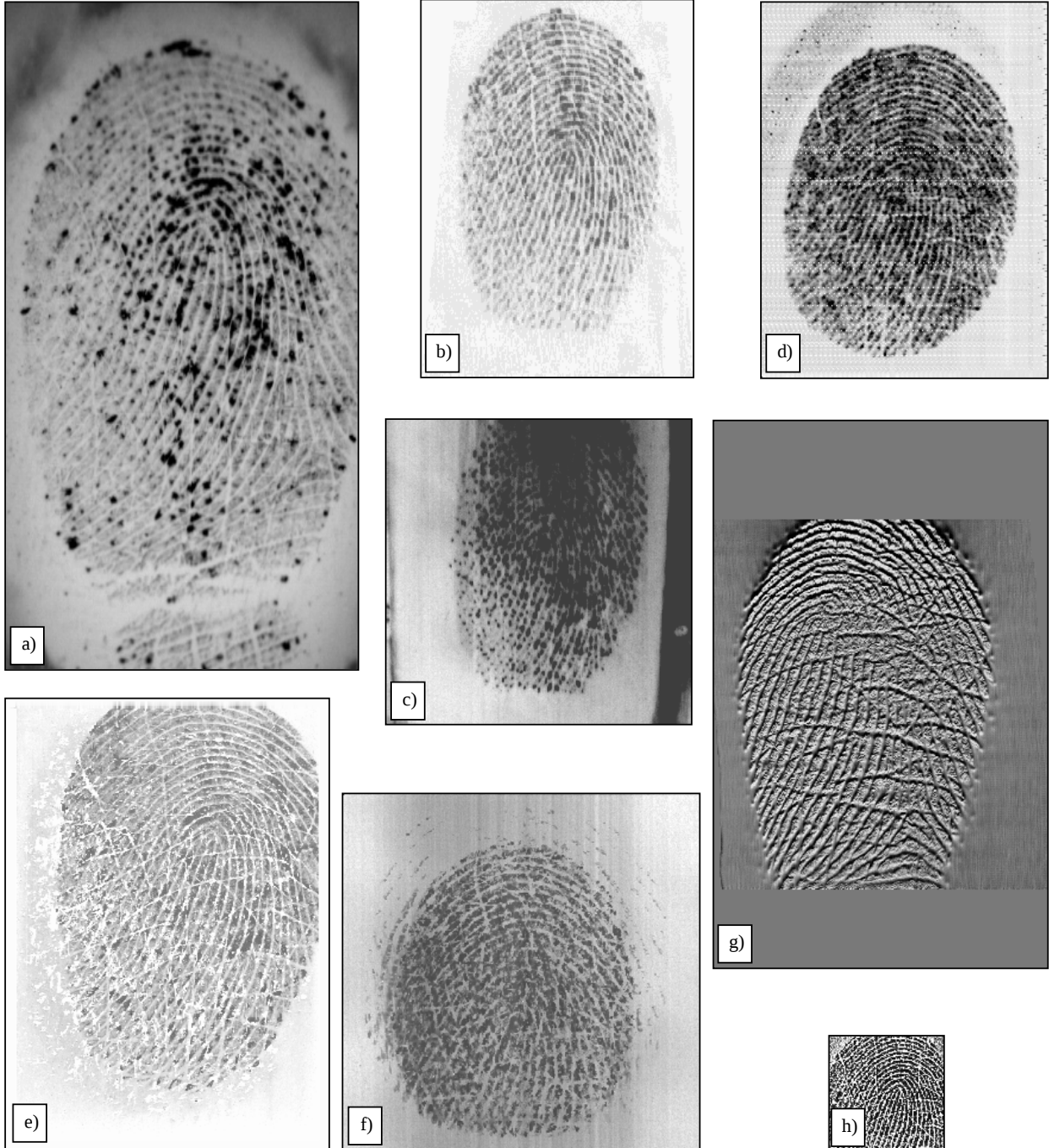
Wet finger



a) Biometrika FX2000, b) Digital Persona UareU2000, c) Identix DFR200, d) Ethentica TactilSense T-FPM, e) ST-Microelectronics TouchChip TCS1AD, f) Veridicom FPS110, g) Atmel FingerChip AT77C101B, h) Authentec AES4000.

Comparison of Fingerprint images (4)

Poor quality finger



a) Biometrika FX2000, b) Digital Persona UareU2000, c) Identix DFR200, d) Ethentica TactilSense T-FPM, e) ST-Microelectronics TouchChip TCS1AD, f) Veridicom FPS110, g) Atmel FingerChip AT77C101B, h) Authentec AES4000.

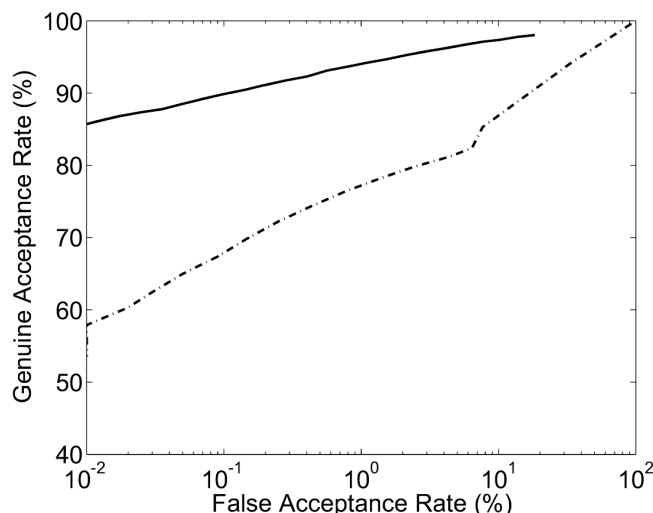


Sensing Area versus Accuracy

“Smaller is better” is certainly not a good slogan for fingerprint sensors!

Sensor manufacturers tend to **reduce the sensing area** in order to **lower the cost** of their devices, and to make it possible to **integrate** them in small devices.

Recognizing fingerprints acquired through small-area sensors is **difficult** due to the possibility of having **too little overlap** between different acquisitions of the same finger. This effect is even more marked on intrinsically poor quality fingers, where only a subset of the fingerprint features can be extracted and used with sufficient reliability.



Experiment performed by Jain, Prabhakar, and Ross (1999):

the solid line denotes the performance of a fingerprint verification algorithm over a database collected through a large-area FTIR optical scanner, whereas the dashed line denotes the performance of the same algorithm over a database acquired through a smaller area capacitive solid-state sensor.

In FVC2002 (Maio et al., 2002b): performance of algorithms on two databases acquired through two large area optical sensors was about 250% higher with respect to the performance on a database acquired with a smaller area capacitive sensor.

An interesting approach to deal with small sensor area is collecting **multiple images** of a finger during the user enrollment, and **fusing them** in a sort of a “**mosaic**” which is stored as a reference fingerprint. This technique is known as fingerprint **mosaicking**.