Finger Print History, Registration, Enhancement, and Minutias Detection I

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29.10, 2013, Prague

Acknowledgments: Xavier Palathingal, Andrzej Drygajlo, Handbook of Fingerprint Recognition

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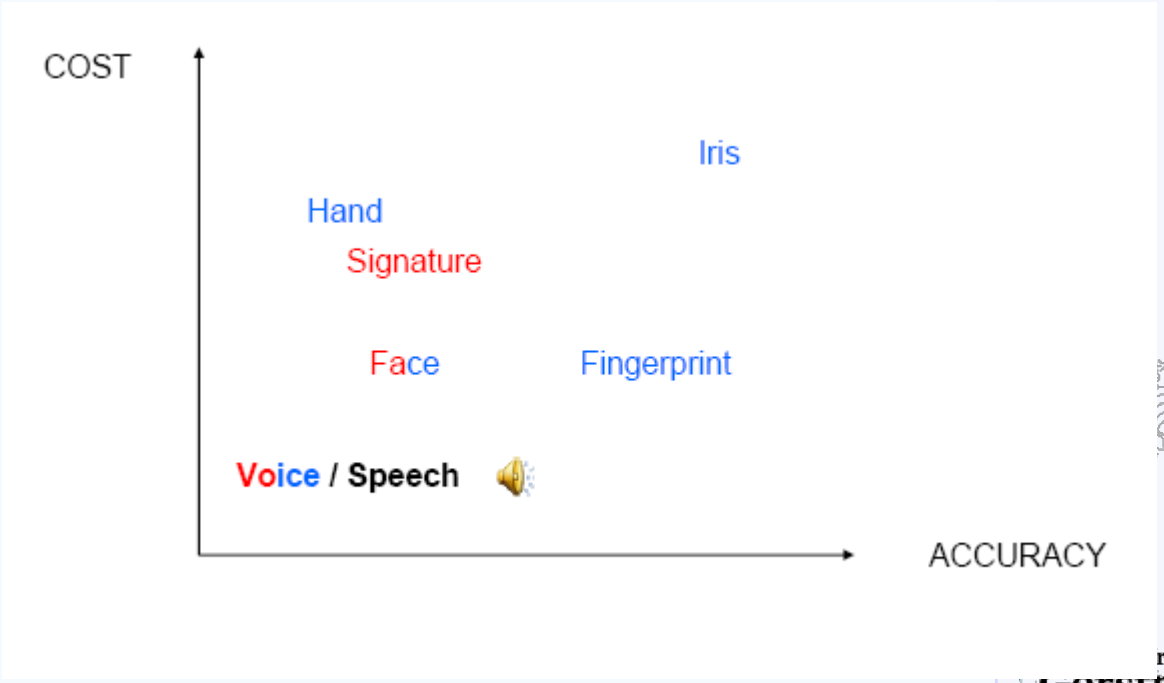
Outline

- Introduction to Fingerprint
- History
- Registration
- Enhancement
- Minutiaes detection

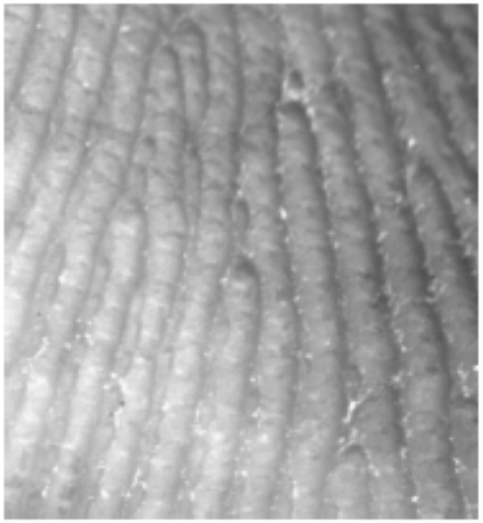


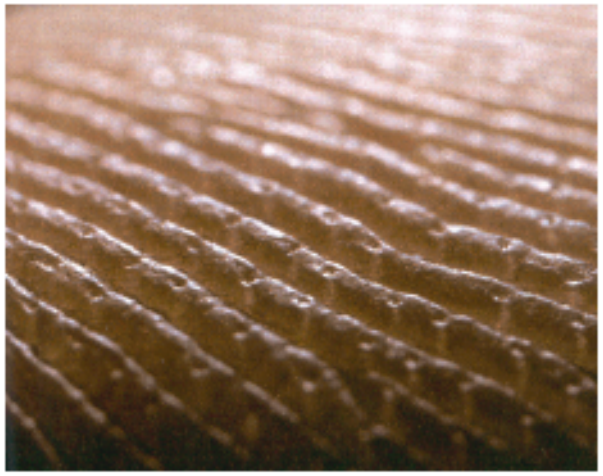
Fingerprint

- Fingerprints are "permanent" in that they are formed in the fetal stage, prior to birth, and remain the same throughout lifetime
- The changes can be made by: flexibility from the skin, growing, a dirty finger, scarring, a wound, or a disease of the skin
- They are only weakly determined by genetics, e.g. identical (monozygotic, one egg) twins (the same DNA) have fingerprints that are quite different
- Fingerprints of an individual are “unique”; they indeed are distinctive to a person
- The right definition of a fingerprint is strictly speaking the print (stamp) that a finger left on an object

Fingerprint

- The inside surfaces of hands and feet of humans (and, in fact, all primates) contain minute ridges of skin with furrows between each ridge
- The purpose of this skin structure is to:
  - Facilitate exudation of perspiration
  - Enhance sense of touch
  - Providing a gripping surface



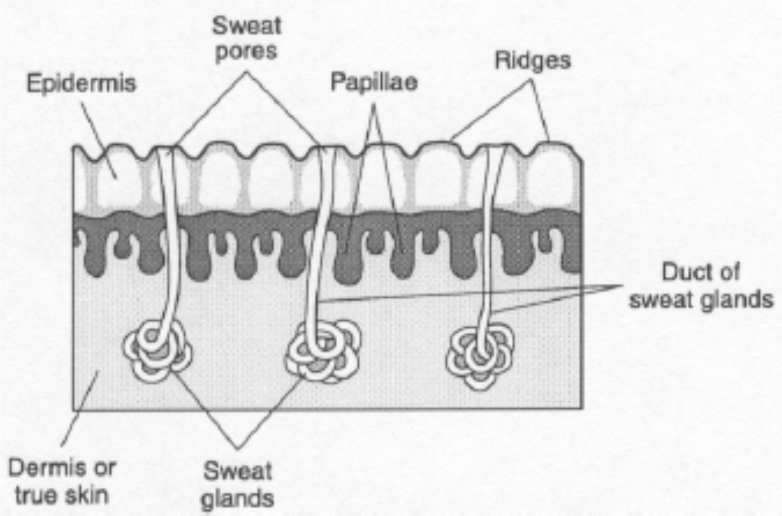


No fingerprint?

- In very rare cases there are people that do not have prints. Not on their fingers, their palms or their feet. They where born with it or the friction ridges have degenerated during their live
- Approximately 4% of fingerprint images have been observed to have poor ridge details

Friction Skin

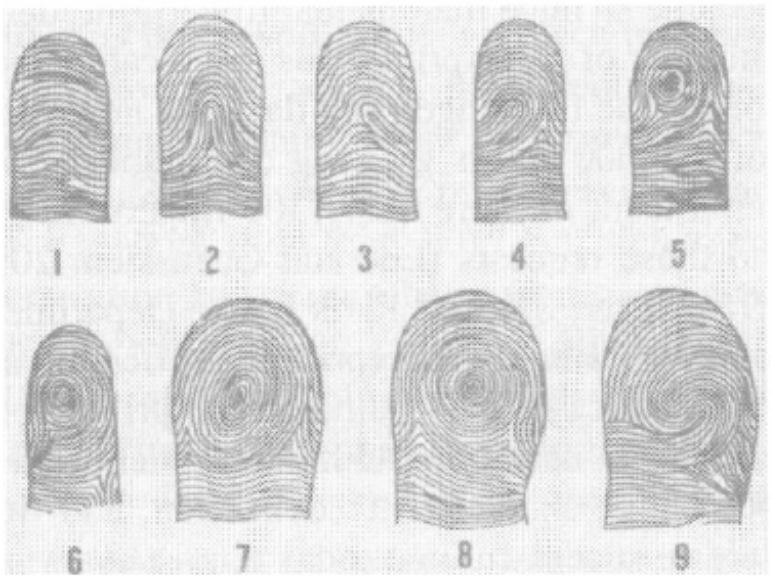
- **Friction skin** differs significantly in structure and function from the skin covering the rest of the body:
  - It is hairless
  - It contains no sebaceous (oil) glands
  - It has a much higher concentration of nerve endings
  - It has a much higher concentration of sweat glands
  - There is a lack of pigmentation

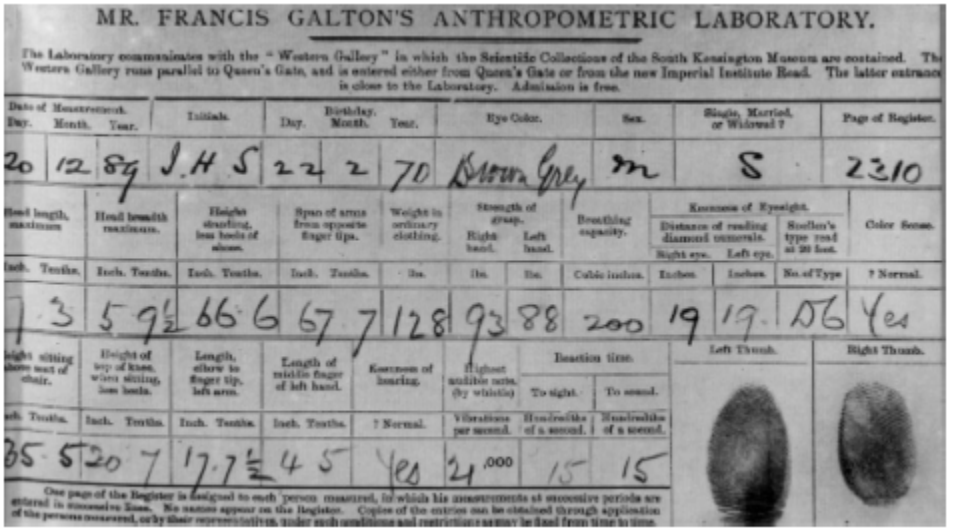


History of fingerprints

- Human fingerprints have been discovered on a large number of archaeological artifacts and historical items
- In 1684, the English plant morphologist, Nehemiah Grew, published the first scientific paper reporting his systematic study on the ridge, furrow, and pore structure
- In 1788, a detailed description of the anatomical formations of fingerprints was made by Mayer.
- In 1823, Purkinji proposed the first fingerprint classification, which classified into nine categories
- Sir Francis Galton introduced the minutae features for fingerprint matching in late 19th century
- 1924, an act of U.S. Congress established the Identification Division of the FBI (Federal Bureau of Investigation) with a database of 810 000 fingerprint cards. **TODAY: 200 mil !!!**

Purkynje classification & Galton individuality & FBI





MR. FRANCIS GALTON'S ANTHROPOMETRIC LABORATORY.

The Laboratory communicates with the "Western Gallery" in which the Scientific Collections of the South Kensington Museum are contained. The Western Gallery runs parallel to Queen's Gate, and is entered either from Queen's Gate or from the new Imperial Institute Road. The latter entrance is close to the Laboratory. Admission is free.

Date of Measurement. Day.	Month.	Year.	Initials.	Birthday. Day.	Month.	Year.	Eye Color.	Sex.	Single, Married, or Widowed?	Page of Register.
20	12	89	J.H.S	22	2	70	Brown Grey	m	S	2310

Head length, maximum.	Head breadth maximum.	Height standing, less heels of shoes.	Span of arms from opposite finger tips.	Weight in ordinary clothing.	Strength of grasp. Right hand.	Left hand.	Breathing capacity.	Keenness of Eyesight. Distance of reading diamond numerals. Right eye.	Left eye.	Snellen's type read at 20 feet.	Color Sense.
Inch. Tenths.	Inch. Tenths.	Inch. Tenths.	Inch. Tenths.	lbs.	lbs.	lbs.	Cubic inches.	Inches.	Inches.	No. of Type	? Normal.
7 3	5 9½	66 6	67 7	128	93	88	200	19	19	06	Yes

Height sitting above seat of chair.	Height of top of knee, when sitting, less heels.	Length, elbow to finger tip, left arm.	Length of middle finger of left hand.	Keenness of hearing.	Highest audible note. (by whistle)	Reaction time. To sight.	To sound.
Inch. Tenths.	Inch. Tenths.	Inch. Tenths.	Inch. Tenths.	? Normal.	Vibrations per second.	Hundredths of a second.	Hundredths of a second.
35 5	20 7	17 7½	4 5	Yes	24,000	15	15

Left Thumb.

Right Thumb.

One page of the Register is assigned to each person measured, in which his measurements at successive periods are entered in successive lines. No names appear on the Register. Copies of the entries can be obtained through application of the persons measured, or by their representatives, under such conditions and restrictions as may be fixed from time to time.

Fingerprints as evidence

- 1892–Juan Vucetich(Argentina) made the first criminal fingerprint identification
- 1914 –Edmond Locard wrote that if 12 points(Galton's details) were the same between two fingerprints, it would suffice as a positive identification.

ARCHIVES

D'ANTHROPOLOGIE CRIMINELLE

DE MÉDECINE LÉGALE

ET DE PSYCHOLOGIE NORMALE ET PATHOLOGIQUE

MÉMOIRES ORIGINAUX

LA PREUVE JUDICIAIRE PAR LES EMPREINTES DIGITALES

Données physiologiques. — Pratique policière (empreintes fragmentaires; la question des gants; les fausses empreintes). — Nature et valeur de la preuve dactyloscopique. Calcul des chances d'erreur. — Jurisprudence comparée (France, Allemagne, Argentine, Belgique, Etats-Unis, Grande-Bretagne, Italie, Norvège, Portugal, Suisse).

Par Edmond LOCARD

Docteur en médecine, licencié en droit,
Directeur du Laboratoire de Police de Lyon.

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History of fingerprints

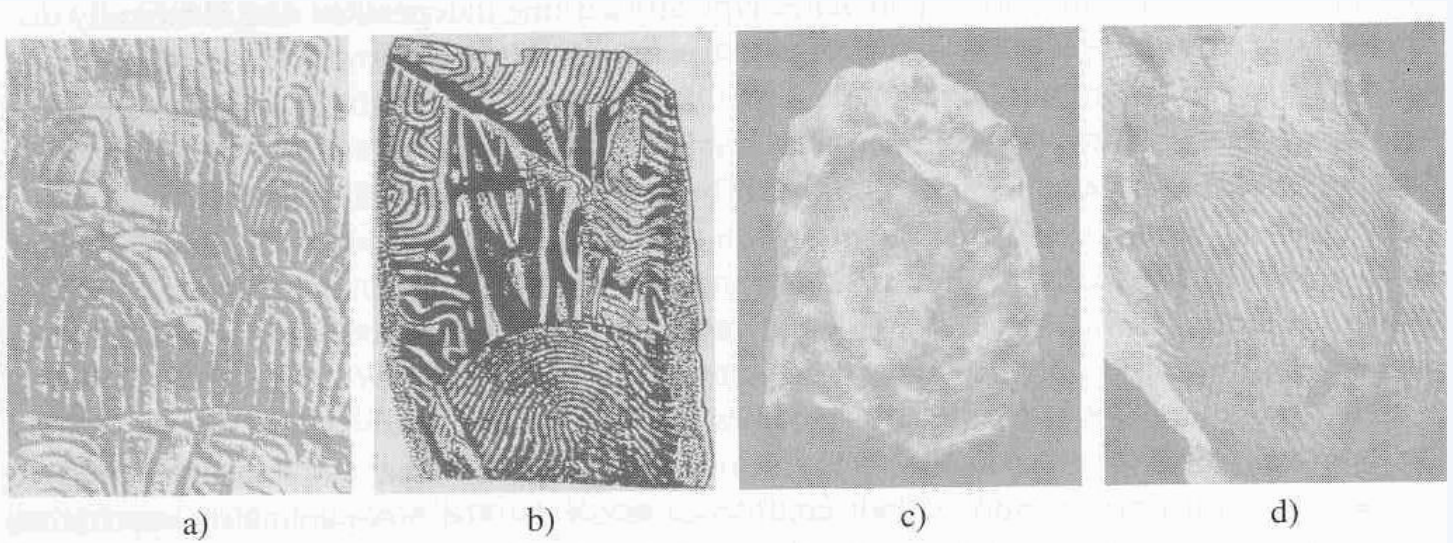

Figure 1.8. Examples of archaeological fingerprint carvings and historic fingerprint impressions a) Neolithic carvings (Gavrinis Island) (Moenssens, 1971); b) standing stone (Goat Island, 200 B.C.) (Lee and Gaensslen, 2001); c) a Chinese clay seal (300 B.C.) (Lee and Gaensslen 2001); d) an impression on a Palestinian lamp (400 A.D.) (Moenssens, 1971). Although impressions on the Neolithic carvings and the Goat Island standing stones might not be used to indicate identity, there is sufficient evidence to suggest that the Chinese clay seal and impressions on the Palestinian lamp were used to indicate the identity of the providers. Figures courtesy o A. Moenssens, R. Gaensslen, and J. Berry.

Formation of fingerprints

- Fingerprints are fully formed at about **seven months** of fetus development
- General characteristics of the fingerprint emerge as the skin on the fingertip begins to differentiate.
- flow of amniotic fluids around the fetus and its position in the uterus change during the differentiation process
- Thus the cells on the fingertip grow in a microenvironment that is slightly different from hand to hand and finger to finger

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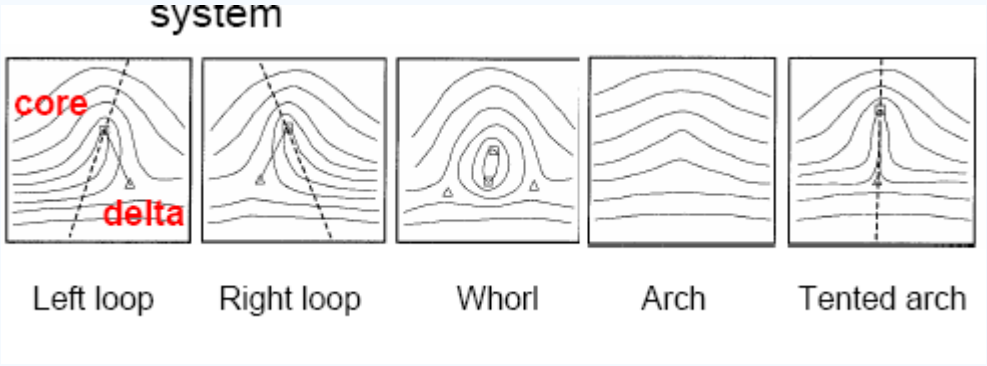
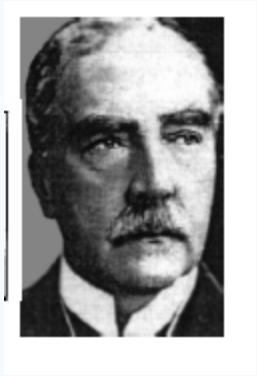
Fingerprint feature extraction

- Fingerprint pattern, when analyzed at different scales, exhibits different types of features
  - global level - delineates a ridge line flow pattern
    - » Sir Edward Henry 1897
  - local level – minute details can be identified
  - Very fine level – intra-ridge details can be detected





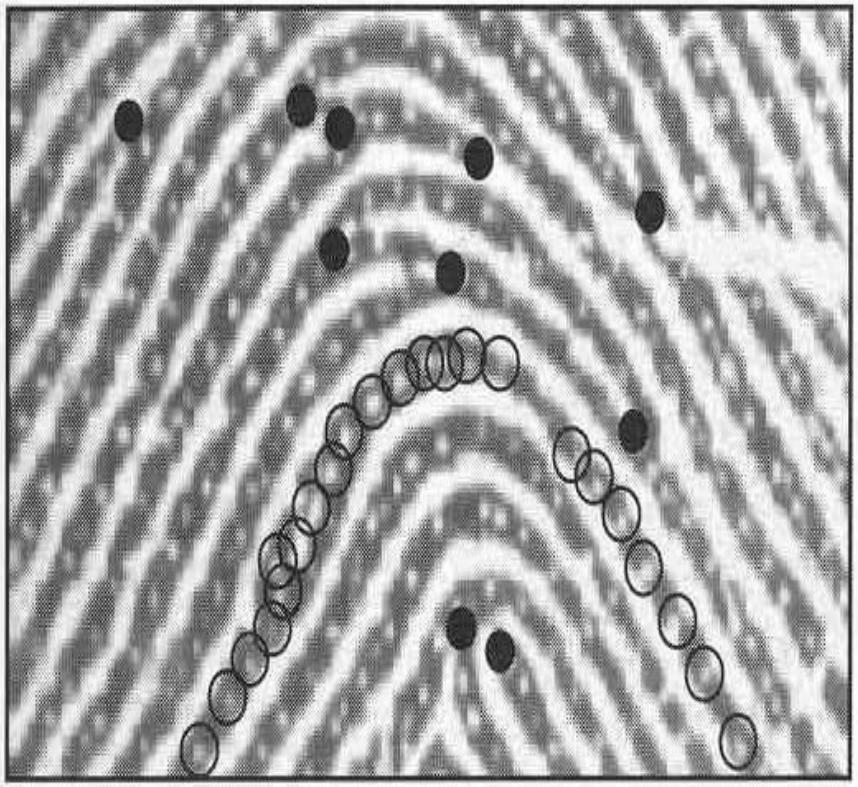


Figure 1.13. Minutiae (black-filled circles) in a portion of fingerprint image; sweat pores (empty circles) on a single ridge line.

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Difficulty in fingerprint matching

- Fingerprint matching is a difficult problem due to large variability in different impressions of the same finger
- Main factors responsible for intra-class variations are: displacement, rotation, partial overlap, non-linear distortion, variable pressure, skin condition, noise and feature extraction errors

Two impressions from the same finger

Two impressions from different fingers

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Fingerprint classification and Indexing

- To reduce the search time and computational complexity
- technique used to assign a fingerprint to one of the several pre-specified types
- Only a limited number of categories have been identified, and there are many ambiguous fingerprints

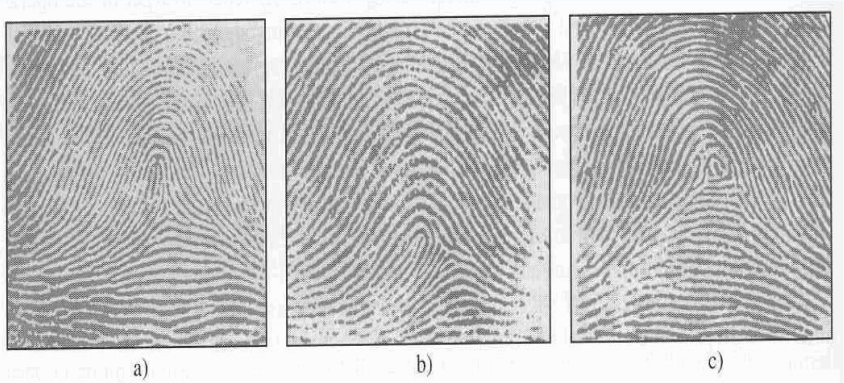

Figure 1.15. Examples of fingerprints that are difficult to classify; a) tented arch; b) a loop; c) a whorl; it seems that all the fingerprints shown here should be in the loop category.

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Synthetic fingerprints

- Performance evaluation of fingerprint recognition systems is very data dependent

- To obtain tight confidence intervals at very low error rates, **large databases** of images are required and its expensive

- To solve this problem synthetic fingerprint images are introduced, **cost reduction**

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The main parameters characterizing a fingerprint image are

Resolution ,Area,Number of pixels, Dynamic Range, Geometric Accuracy, Image Quality

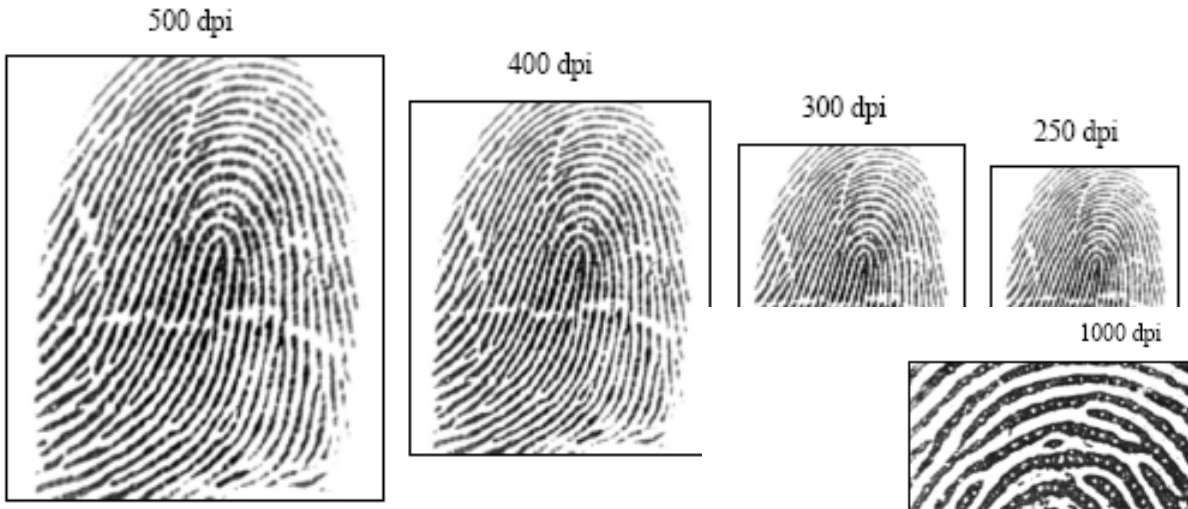


Figure 2.15. The fingerprint on the left, acquired at 50
lower resolutions: 400, 300, and 250 dpi, respectively.

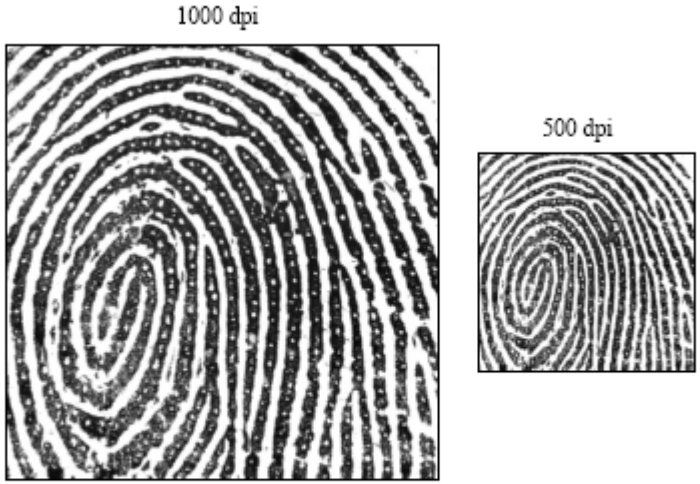


Figure 2.16. The fingerprint portion on the left is acquired at 1000 dpi; sweat pores and other fine details are clearly visible; on the right, the fingerprint portion is sub-sampled at 500 dpi while the fine details are not as clear.

Fingerprint images

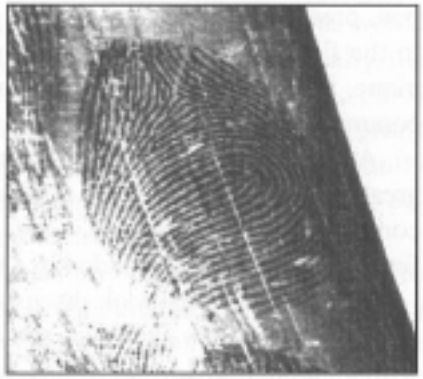
Optical scanner

Capacitive scanner

Piezoelectric scanner

Thermal scanner

Inked impression



Latent fingerprint

Off-line & On-line fingerprint Acquisition

- Although the first fingerprint scanners were introduced more than 30 years ago, still ink-technique is used in some applications

Why & What are the advantages?

Because it has the possibility of producing

Rolled impressions

http://crime.about.com/od/police/ss/fingerprints.htm

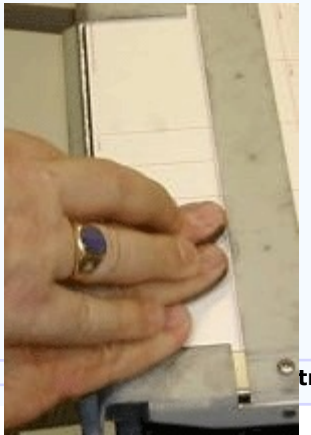
Latent impressions

- The most important part of a fingerprint scanner is the sensor.
- All the existing scanners belong to one of the 3 families

Optical sensors

Solid state sensors

Ultrasound sensors



Rolled & Plain FP

Figure 2.3. The same finger acquired as a plain impression (on the left) and as a rolled impression (on the right): the portion of the rolled fingerprint corresponding to the plain fingerprint is highlighted.

Daktylospopie

– Daktyloskopie (Antropometrie)

-na světě neexistují dva jedinci, kteří mají absolutně shodné obrazce papilárních linií,

-obrazce papilárních linií jsou po celý život relativně neměnné,

-obrazce papilárních linií jsou trvale neodstranitelné, pokud není odstraněna zárodečná vrstva pokožky.

–0.8% zamen, v USA az 2000 pripadu

–Simon A. Cole, "More Than Zero: Accounting for Error in Latent Fingerprint Identification," *Journal of Criminal Law & Criminology*, Volume 95, Number 3 (Spring 2005), pp. 985-1078.

1.Shoda otisků musí být potvrzena dalším hodnotitelem.

2.Hodnotitel musí být spolehlivý a prověřený expert.

3.Pro určení shody je potřeba velký počet identifikačních rysů.

4.Obhájce obžalovaného si může vyžádat dodatečné posouzení shody otisků nezávislým expertem.

–*http://socialecology.uci.edu/faculty/scole*

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Rolled fingerprint Impressions

Figure 2.4. Rolled fingerprint images acquired off-line with the ink technique.

Latent fingerprint images

10 % visible

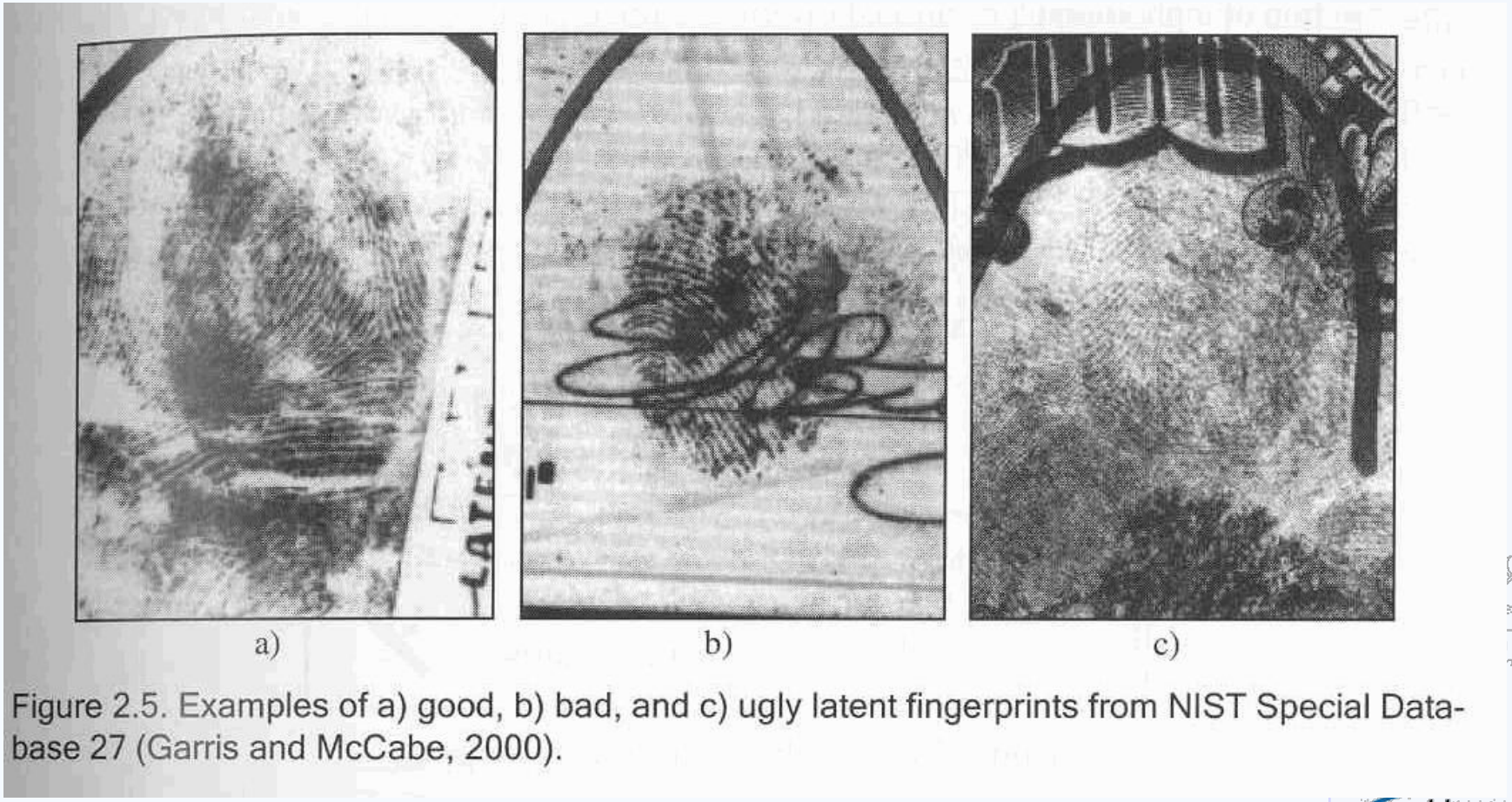
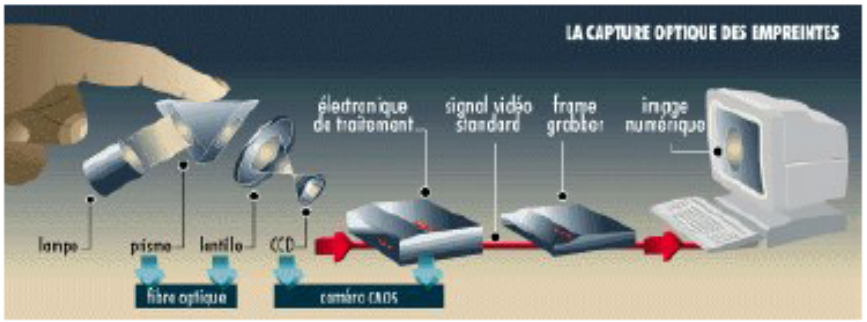


Figure 2.5. Examples of a) good, b) bad, and c) ugly latent fingerprints from NIST Special Database 27 (Garris and McCabe, 2000).

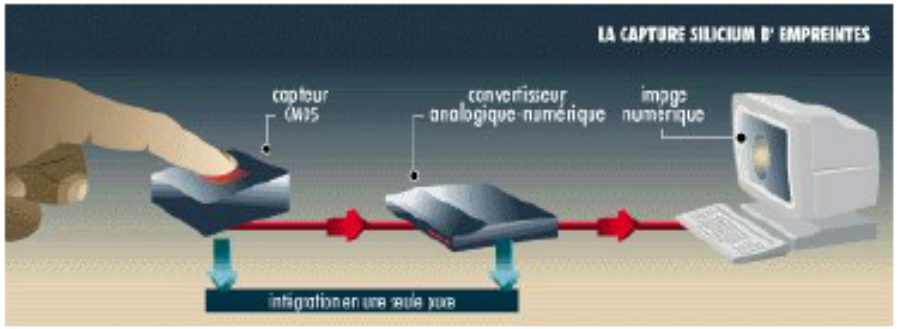
Live scan fingerprint sensing

- The most important part of a fingerprint scanner is the sensor.
- All the existing scanners belong to one of the 3 families
  - Optical sensors
  - Solid state sensors
  - Ultrasound sensors

Optical scanner



CMOS scanner



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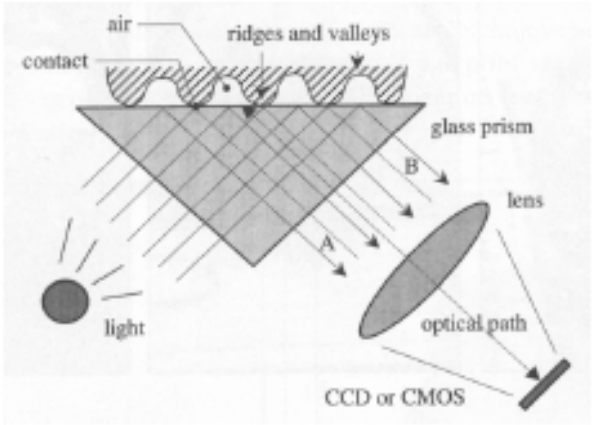
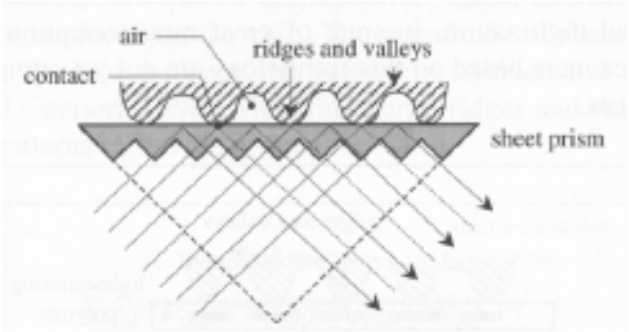
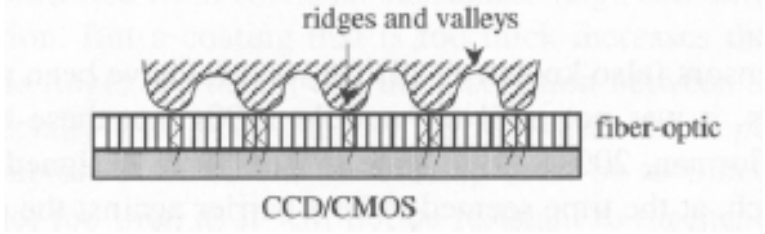
Optical sensors



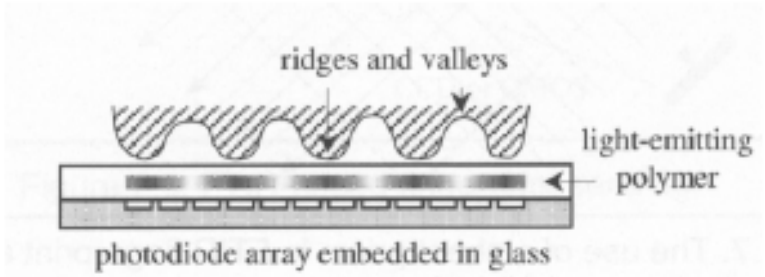
Internal reflection optical sensor



Sheet prism optical sensor



Sensor based on optical fibers



Electro-optical fingerprint sensor

Optical scanner

Good quality fingerprint

Dry finger

Wet finger

Intrinsically bad fingerprint

Solid state sensors

- These are designed to overcome the size and cost problems
- Silicon based sensors are used in this
- Neither optical components nor external CCD/CMOS image sensors are needed
- Four main effects have been produced to convert the physical information into electrical signals
    - Capacitive
    - Thermal
    - Electric field
    - Piezo Electric

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Capacitive & Piezo- Electric

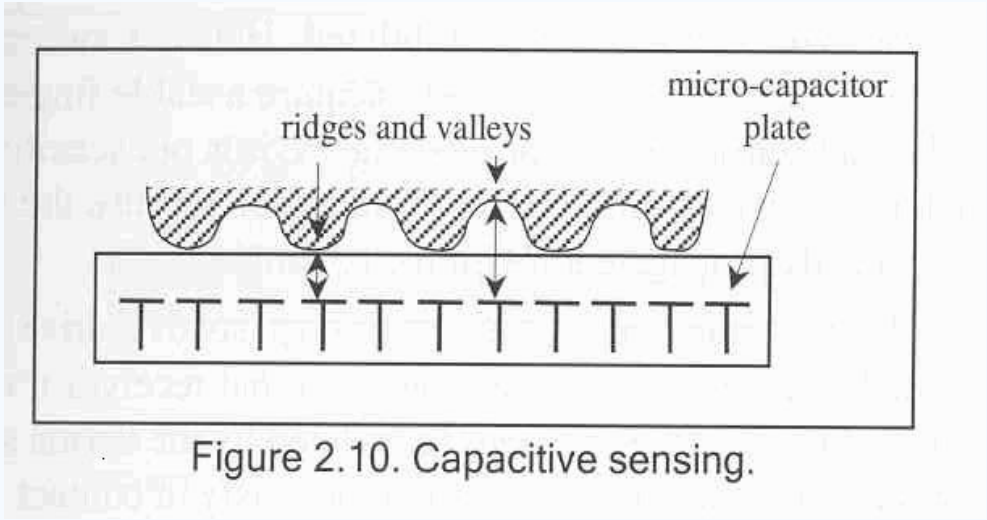

Figure 2.10. Capacitive sensing.

- Pressure sensitive sensors
- Produce an electrical signal when mechanical stress is applied to them
- Sensor surface is made up of a non-conducting dielectric material
- Ridges and valleys are present at different distances from the surface , they result in different amounts of current

Thermal sensors & Electric field

- Works based on temperature differentials
- Sensors are made of pyro electric material
- Temperature differential produces an image, but this image soon disappears
  - because the thermal equilibrium is quickly reached and pixel temperature is stabilized
- Solution is sweeping method
- Advantages
  - Not sensitive to ESD
  - Can accept thick protective coating
- **Electric field**
- Sensor consists of drive ring
- This generates a sinusoidal signal and a matrix of active antennas
- To image a fingerprint, the analogue response of each element in the sensor matrix is amplified, integrated and digitized

Ultrasound sensors

- Principle is Echography

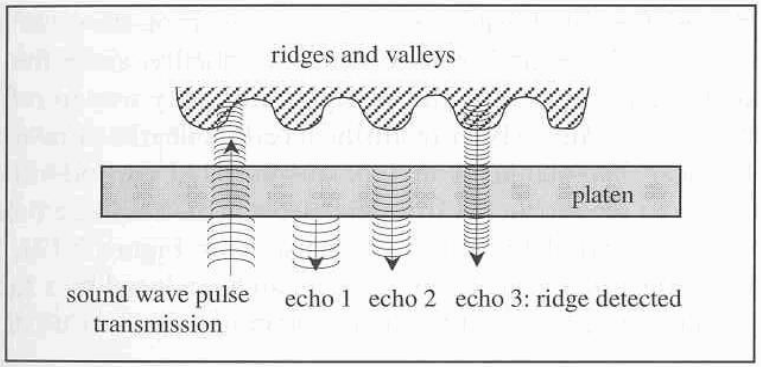

Figure 2.11. The basic principle of the ultrasound technique. Characteristic of sound waves is the ability to penetrate materials, giving a partial echo at each impedance change.

- Advantages of Ultrasound sensors
  - Good Quality images
- Disadvantages
  - Scanner is large
  - Mechanical parts are quite expensive

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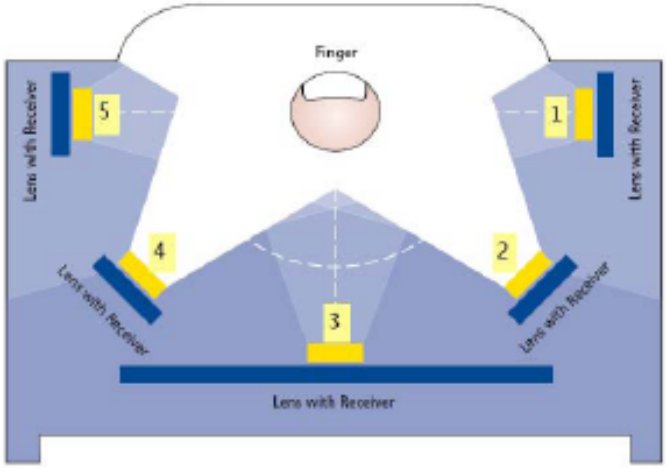
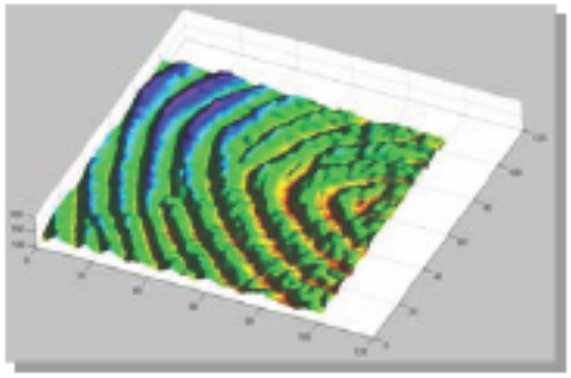
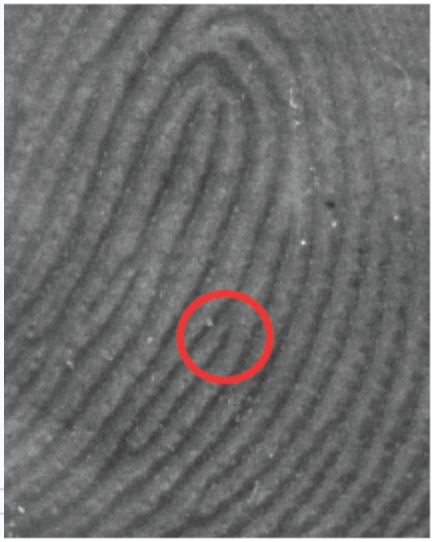
Touchless sensor: TBS – Surround Imager





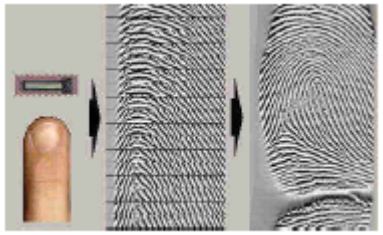
3D Imaging (correct)



2D imaging (wrong)

Touch Vs Sweep

- Drawbacks of Touch method
  - Sensor can become dirty
  - Visible latent fingerprints remains on the sensor
  - Rotation of the fingerprint may be a problem
  - Strict trade-off between the cost and the size of the sensing area



Advantages and drawbacks of Sweeping Method

- Equilibrium is continuously broken when sweeping, as ridges and valleys touch the pixels alternately, introducing a continuous temperature change
- Sensors always look clean
- No latent fingerprints remain
- No rotation

- Novice user may encounter difficulties
- Interface must be able to capture a sufficient number of fingerprint slices
- Reconstruction of the image from the slices is time consuming

Sweeping Method

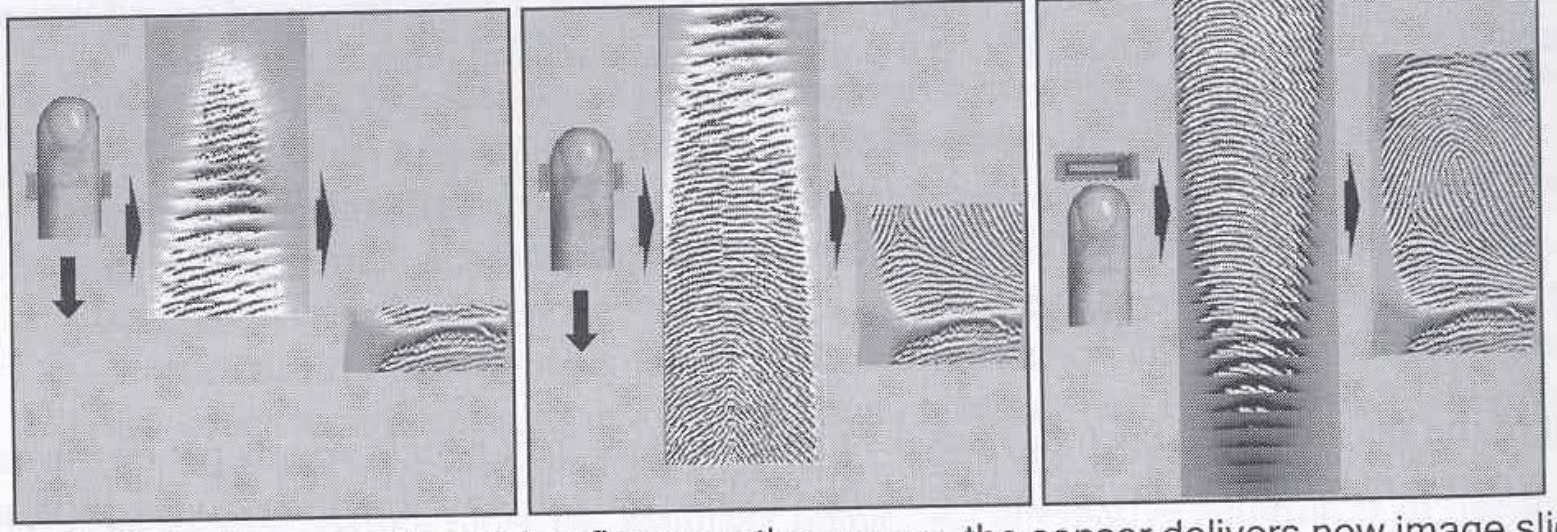


Figure 2.12. As the user sweeps her finger on the sensor, the sensor delivers new image slices, which are combined into a two-dimensional image.

Algorithm for fingerprint recognition from the slices

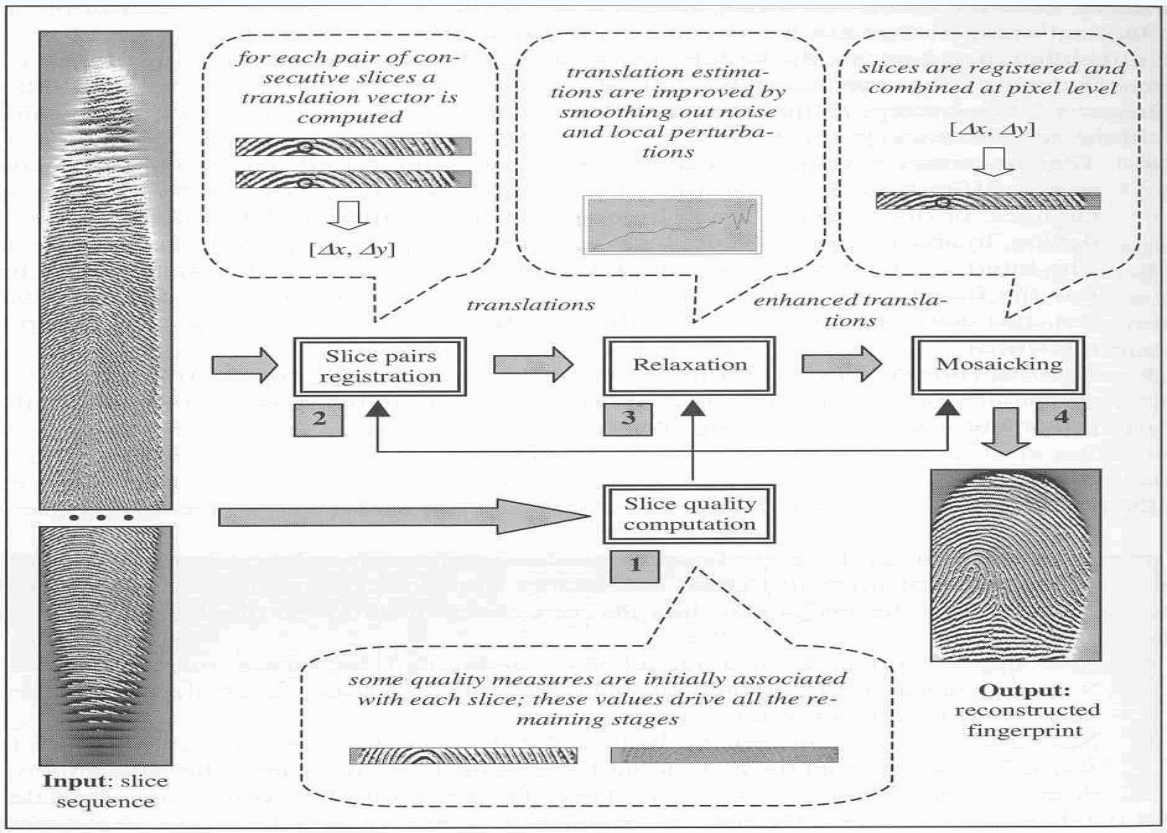


Figure 2.13. An algorithm for fingerprint reconstruction from slices. All the steps are performed sequentially on the whole set of slices. The output of the slice pair registration is a set of translation estimates that are globally enhanced by the relaxation step. These improved estimates drive the mosaicking phase in order to reconstruct the whole fingerprint image.

- Main stages are
- Slice quality computation
- Slice pair registration
- Relaxation
- Mosaicking

Figure 2.14. Fingerprint images of the same finger with ideal skin condition as acquired by different commercial scanners. Images are reported with right proportions: 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.

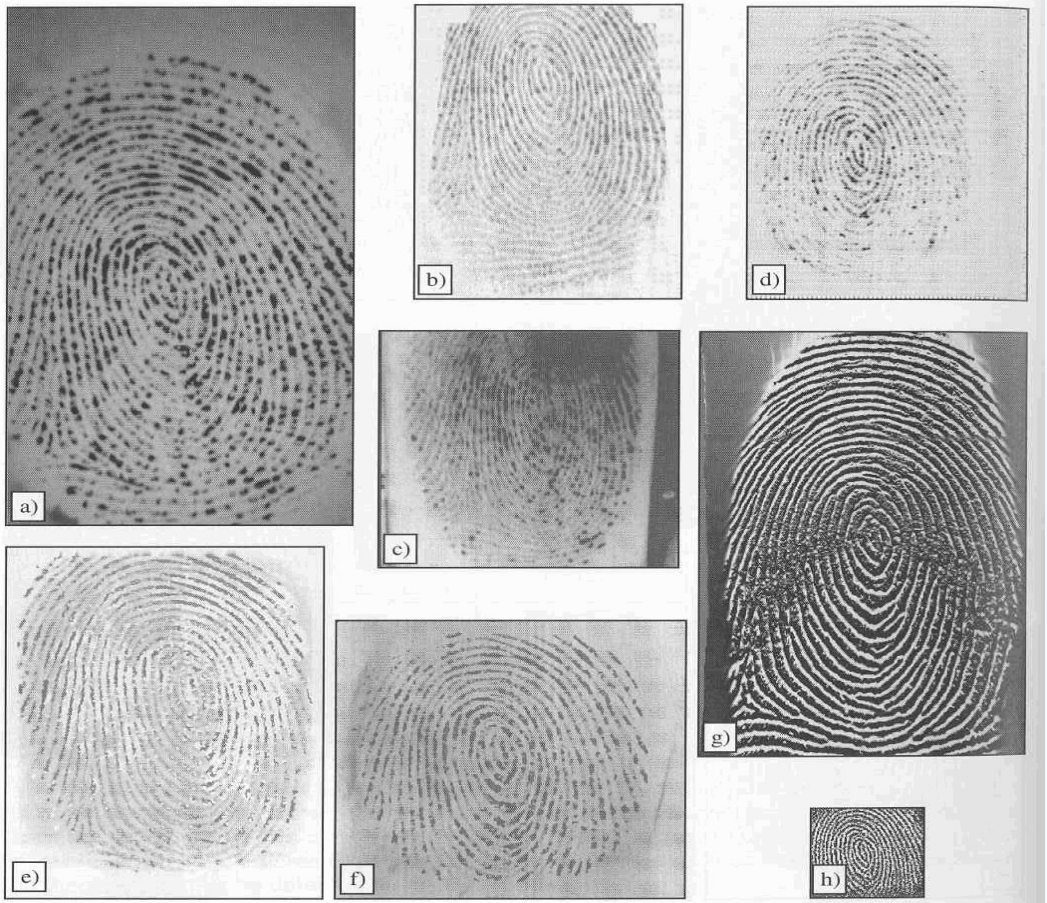


Figure 2.15. Fingerprint images of the same dry finger as acquired by different commercial scanners. Images are reported with right proportions: a) Biometrika FX2000, b) Digital Persona UareU2000, c) Identix DFR200, d) Ethentica TactilSense T-FPM, e) ST-Microelectronics TouchChip TCS1AD, f) Veridicom FPS110, g) Atmel FingerChip AT77C101B, h) Authentec AES4000.

Figure 2.16. Fingerprint images of the same wet finger as acquired by different commercial scanners. Images are reported with right proportions: 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.

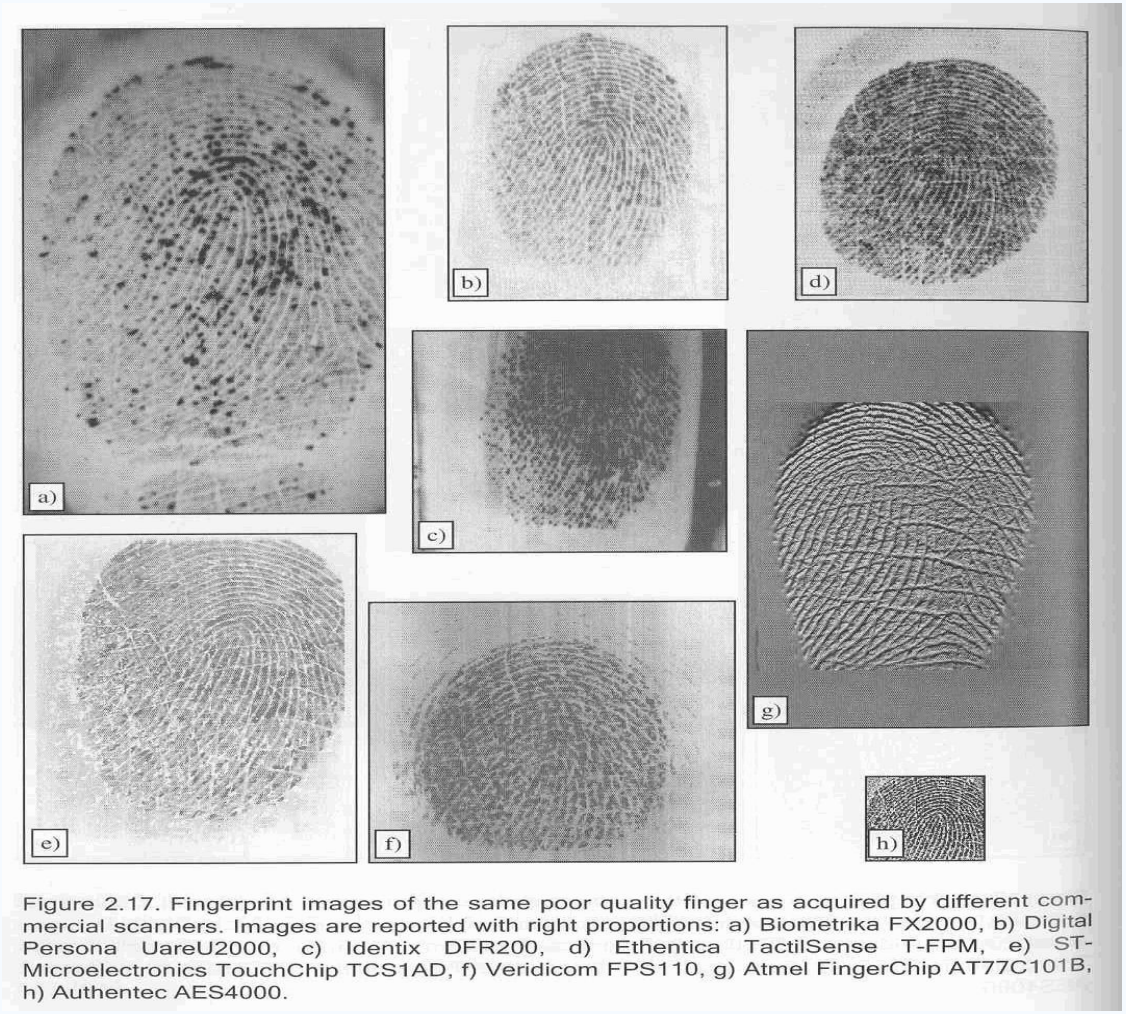


Figure 2.17. Fingerprint images of the same poor quality finger as acquired by different commercial scanners. Images are reported with right proportions: a) Biometrika FX2000, b) Digital Persona UareU2000, c) Identix DFR200, d) Ethentica TactilSense T-FPM, e) ST-Microelectronics TouchChip TCS1AD, f) Veridicom FPS110, g) Atmel FingerChip AT77C101B, h) Authentec AES4000.

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Comparison

- FTIR: frustrated total fingerprint sensing
- FBI: IAFIS Image Quality Specification (IQS)
- PIV: Personal Identity Verification, improve the identification and authentication for access to U.S. Federal facilities and information systems

	Technology	Company	Model	Dpi	Area (h×w)	IAFIS IQS compliant
Optical	FTIR	Crossmatch www.crossmatch.net	L SCAN 1000	1000	3.0"×3.2"	√
	FTIR	L-1 Identity www.l1id.com	TouchPrint 4100	500	3.0"×3.2"	√
	FTIR	Papillon www.papillon.ru	DS-30	500	3.07"×3.38"	√

Table 2.3. Some examples of multi-finger commercial scanners based on optical FTIR tec ogy. Companies are listed in alphabetical order.

	Technology	Company	Model	Dpi	Area (h×w)	PIV IQS compliant
Optical	FTIR	Biometrika www.biometrika.it	HiScan	500	1"×1"	√
	FTIR	Crossmatch www.crossmatch.net	Verifier 300 LC 2.0	500	1.2"×1.2"	
	FTIR	Digital Persona www.digitalpersona.com	UareU4000	512	0.71"×0.57"	
	FTIR	L-1 Identity www.identix.com	DFR 2100	500	1.05"×1.05"	√
	FTIR	Sagem www.morpho.com	MSO350	500	0.86"×0.86"	√
	FTIR	Secugen www.secugen.com	Hamster IV	500	0.66"×0.51"	√
Solid-state	Capacitive	Upek www.upek.com	TouchChip TCS1	508	0.71"×0.50"	√
	Thermal (sweep)	Atmel www.atmel.com	FingerChip AT77C101B	500	0.02"×0.55"	
	Electric field	Authentec www.authentec.com	AES4000	250	0.38"×0.38"	
	Piezoelectric	BMF www.bm-f.com	BLP-100	406	0.92"×0.63"	

Table 2.4. Commercial scanners grouped by technology. Technologies are presented in the order listed in Section 2.3, and within each technology, companies are listed in alphabetical order. For sweep sensors, the vertical number of pixels varies depending on the length of the sweep, and therefore, cannot be determined a priori.

- An interesting alternative to deal with small sensing areas is fingerprint Mosaicking

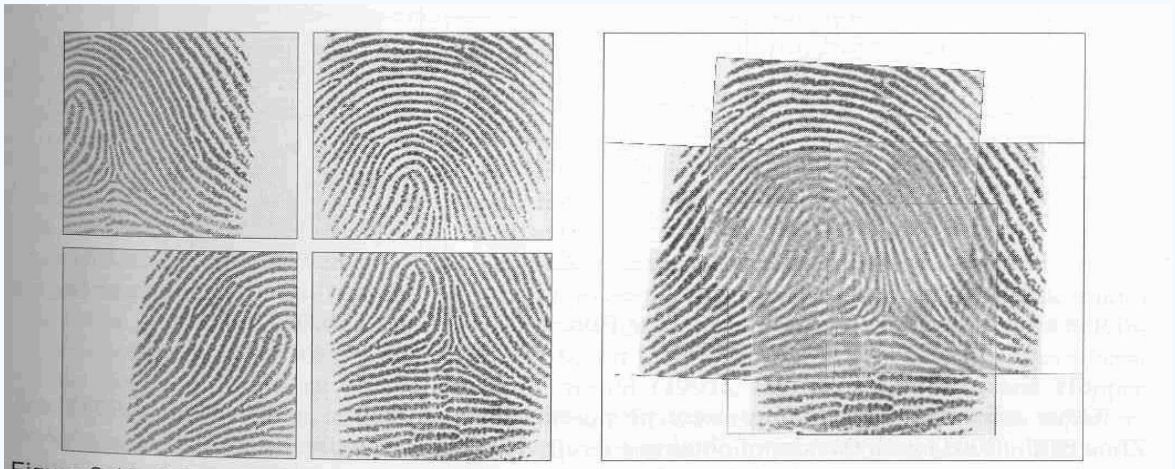

Figure 2.19. A fingerprint mosaic image obtained by combining four fingerprint images acquired with a 0.51×0.51 square inch optical sensor working at 500 dpi.

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Storing and Compressing fingerprint images

- Each fingerprint impression produces an image of 768 x 768 (when digitized at 500 dpi)
- In AFIS applications, this needs more amount of memory space to store these images
- Neither lossless methods or JPEG compression techniques are satisfactory
- A new compression technique called Wavelet Scalar Quantization (WSQ) is introduced to compress the images

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WSQ

- Based on Adaptive scalar quantization

- Performs following steps
  - Fingerprint image is decomposed into a number of spatial frequency sub-bands using a Discrete wavelet transform
  - the resulting DWT coefficients are quantized into discrete values
  - the quantized sub-bands are concatenated into several blocks and compressed using an adaptive Huffman-run length encoding

  A compressed image can be decoded into the original image by applying steps in reverse order

  WSQ compress a fingerprint image by a factor of 10 to 25

  –

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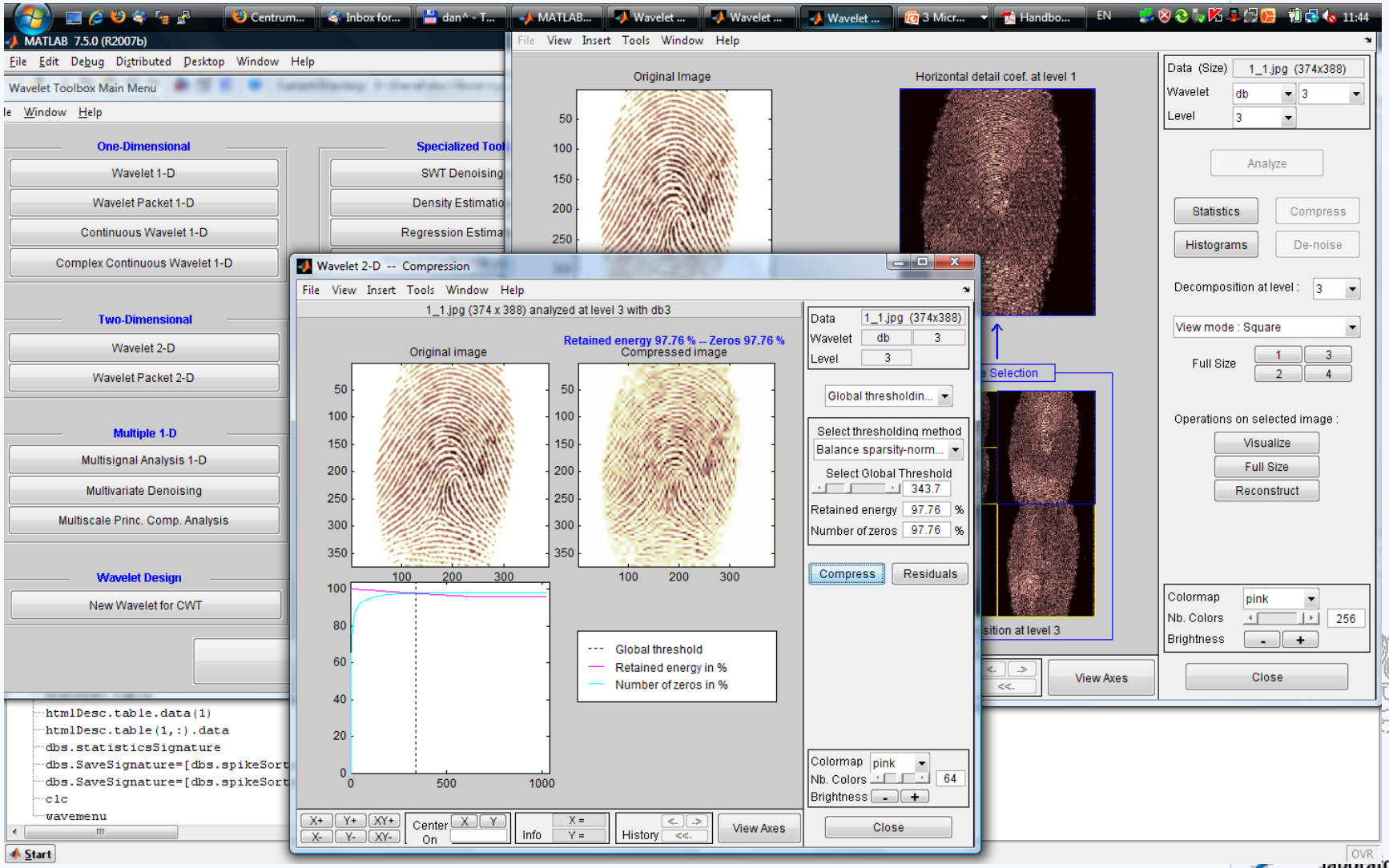
DEMO, wavemenu



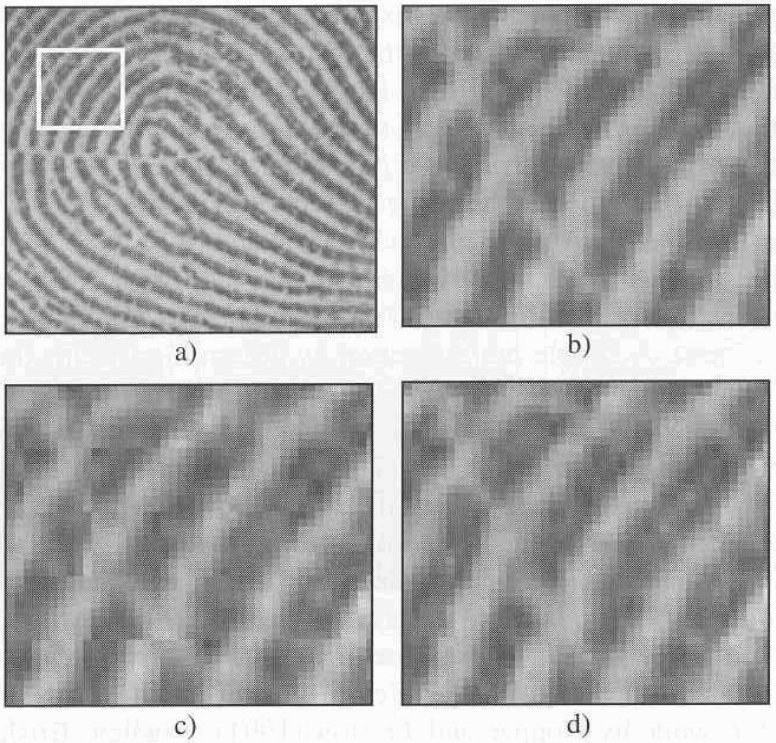


Figure 2.21. Fingerprint compression: a) the central section of a fingerprint image scanned at 500 dpi resolution; b) the marked portion of the image in a); c) the marked portion of the image in a) after the image was compressed using a generic JPEG (www.jpeg.org) image compression algorithm; and d) the marked portion of the image in a) is shown after the image was compressed using the WSQ compression algorithm. Both JPEG and WSQ examples used a compression ratio of 1:12.9; JPEG typically introduces blocky artifacts and obliterates detailed information. Images courtesy of Chris Brislawn, Los Alamos National Laboratory.

Enhancement, and Minutias Detection I

Daniel Novák

29.10, 2013, Prague

Acknowledgments: Xavier Palathingal, Andrzej Drygajlo, Handbook of Fingerprint Recognition

Department of Cybernetics, Czech Technical University

Fingerprint

- Interleaved ridges and valleys
- Ridge width: 100 μm-300 μm
- Ridge-valley cycle: 500 μm

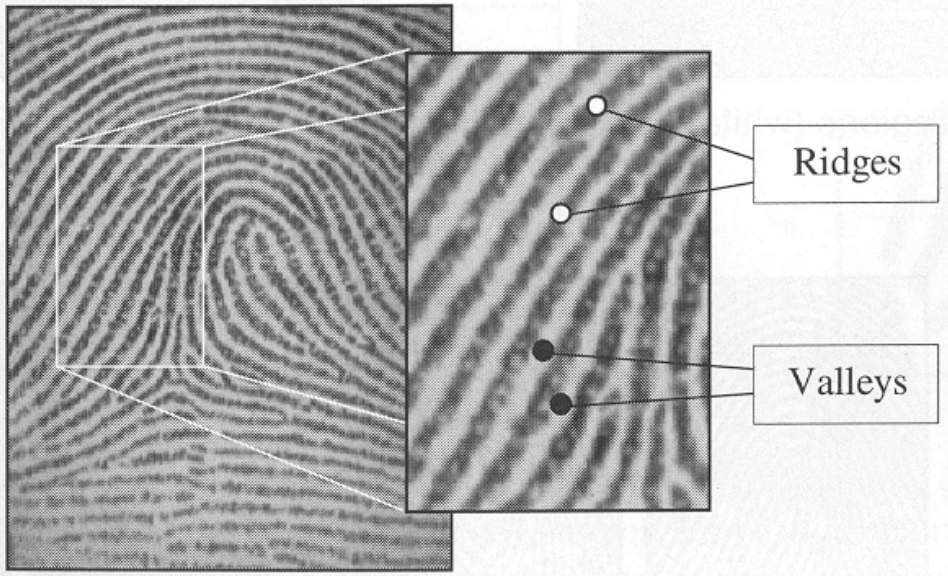
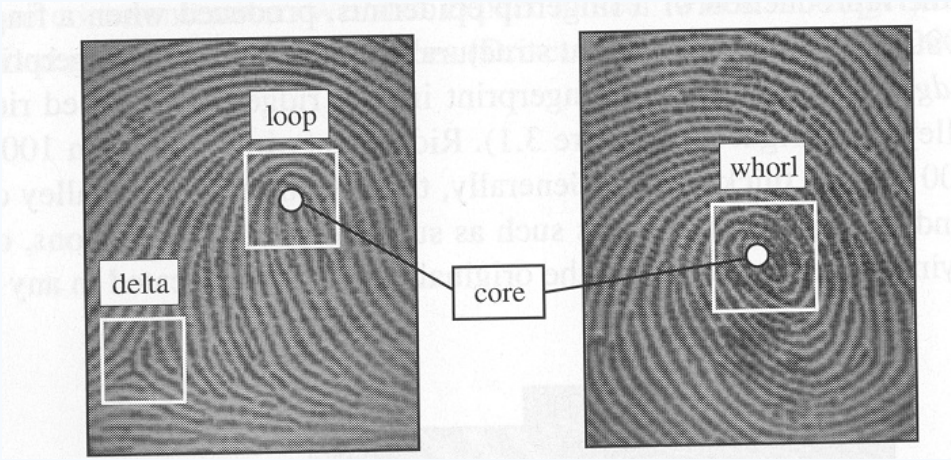


Figure 3.1. Ridges and valleys on a fingerprint image.

A Global Look

Singularities: In the global level the fingerprint pattern shows some distinct shapes

- Loop ( )
- Delta (Λ)
- Whorl (O)…Two facing loop



Core:

- A reference point for the alignment.
- The northmost loop type singularity.
- According to Henry(1900), it is the northmost point of the innermost ridgeline.
- Not all fingerprints have a core (Arch type fingerprints)

A Global Look

Singular regions are commonly used for fingerprint classification:

- Tzv Henryho systém, rozděluje otisky do pěti tříd
  - Závit (whorl)
  - Levá a pravá smyčka (loop)
  - Oblouk (arch)
  - Špičatý oblouk (tented arch)

Local Look

Minutia: Small details. Discontinuties in the ridges. (Sir Francis Galton)

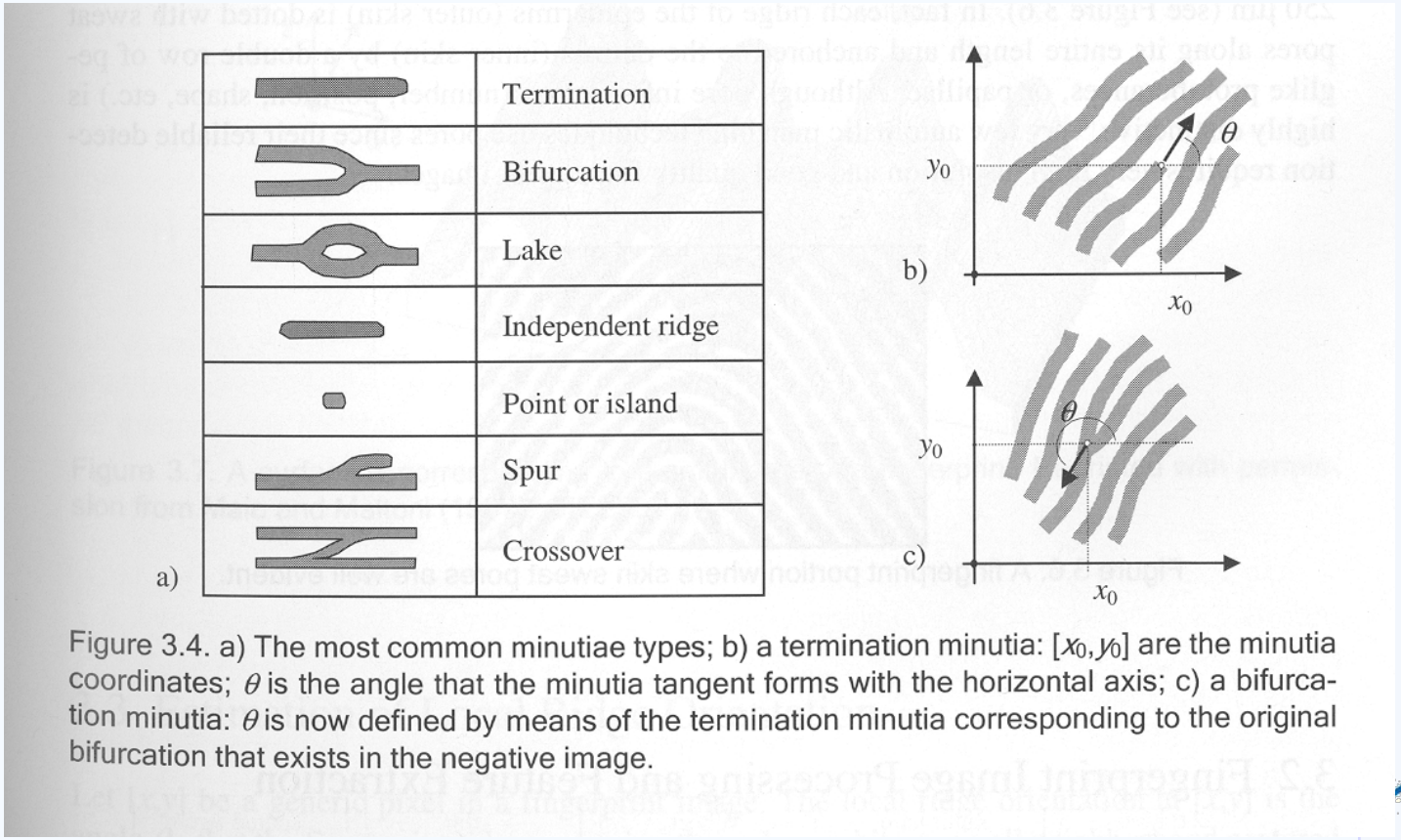


Figure 3.4. a) The most common minutiae types; b) a termination minutia: $[x_0, y_0]$ are the minutia coordinates; θ is the angle that the minutia tangent forms with the horizontal axis; c) a bifurcation minutia: θ is now defined by means of the termination minutia corresponding to the original bifurcation that exists in the negative image.

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Terminologie

- Papilarni linie
- Vyvýšeniny (ridge)+ prohlubeniny (furrow)

- Charakteristické body
  - Kritické (singulární) body – globálně význačné body
    - Jádro
    - Delty
  - Markanty (Minutiaes) – lokálně význačné body
    - Rozvětvení (bifurcation)
    - Zakončení (ridge ending)
    - Krátké hrany (short ridge)
    - Překřížení (crossover, bridge)
    - Krátké rozvětvení (spur)
    - Očka (ridge enclosures)

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Local Look

Ridge ending / ridge bifurcation **duality**

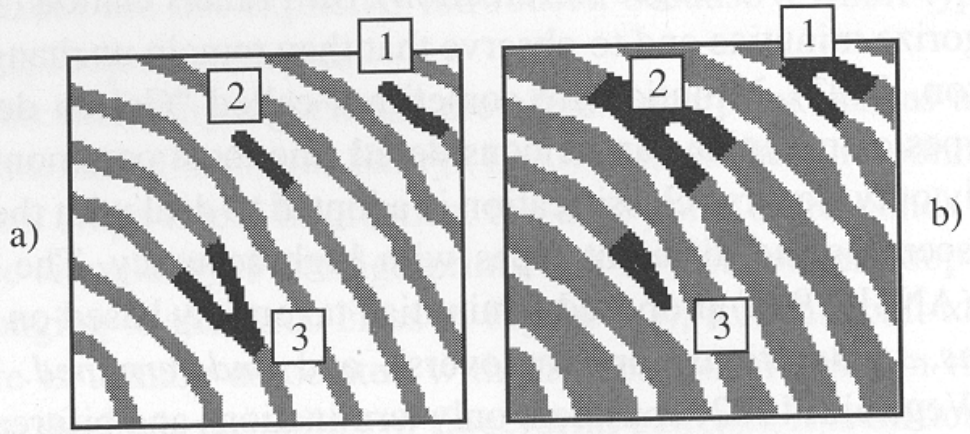

Figure 3.5. The termination/bifurcation duality on a) a binary image and b) its negative image.

Local Look

Sweat Pores

- High resolution images (1000 dpi)
- Size 60-250 μm
- Highly distinctive
- Not practical (High resolution, good quality images)

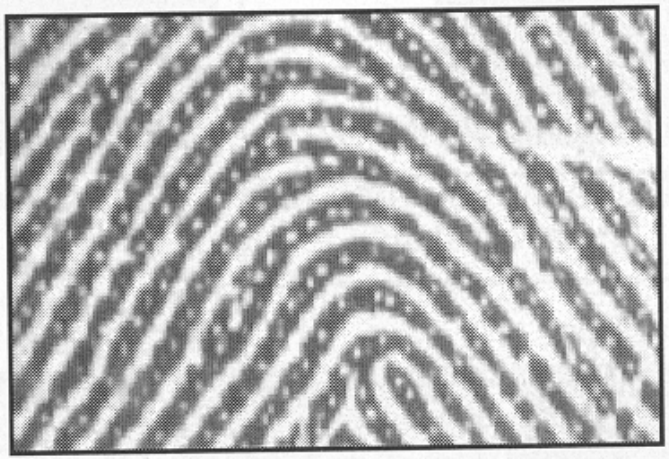

Figure 3.6. A fingerprint portion where skin sweat pores are well evident.

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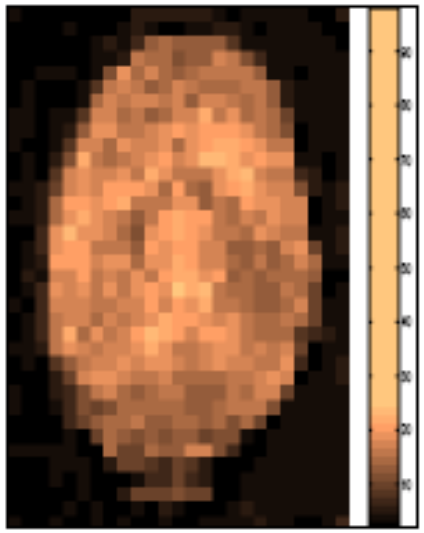
Segmentation

Original



Variance image

Segmented image

Segmentation is the process of isolating foreground from background:

- Image block (16x16 pixels) decomposition
- Thresholding using variance of gradient for each block

Segmentation

- Separating FP from background
- Straited patterns: no thresholding, striped and oriented pattern & isotropic pattern without orientation
- **Segmentation Methods (16x16 block)**
  - Variance orthogonal to the ridge direction **[Ratha95]**
    - Assumption: fingerprint area will exhibit high variance, where as the background and noisy regions will exhibit low variance.
    - Variance can also be used as the quality parameter of the regions.
      - High variance (high contrast): good quality
      - Low variance (low contrast): poor quality
    - Average magnitude of gradient in blocks
      - **Fp1 = segmentimage(Fp1);**