

Fingerprint Recognition II

CSE 40537/60537 Biometrics

Daniel Moreira
Spring 2020



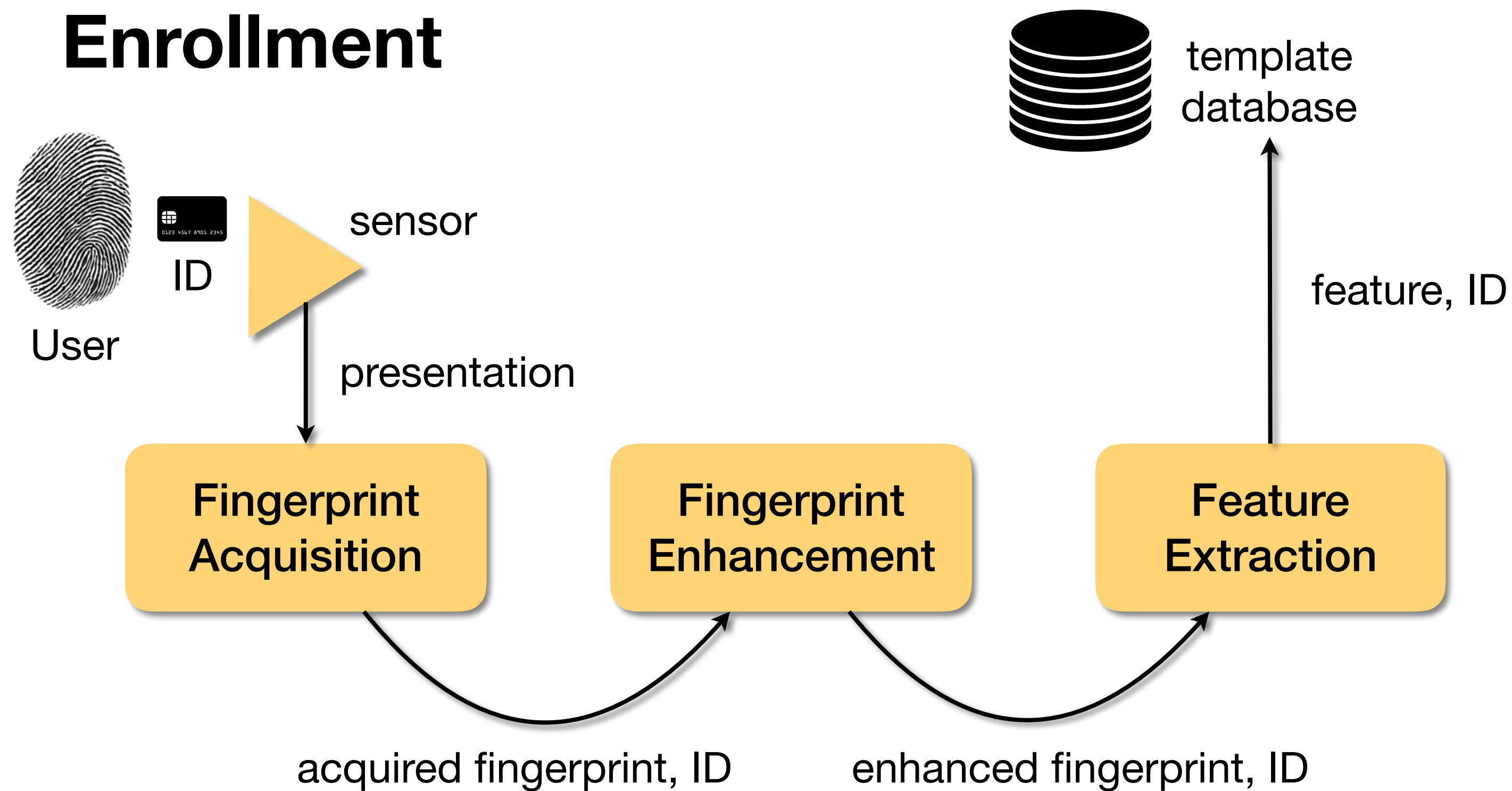
Today you will...

Get to know

Fingerprint acquisition and enhancement.

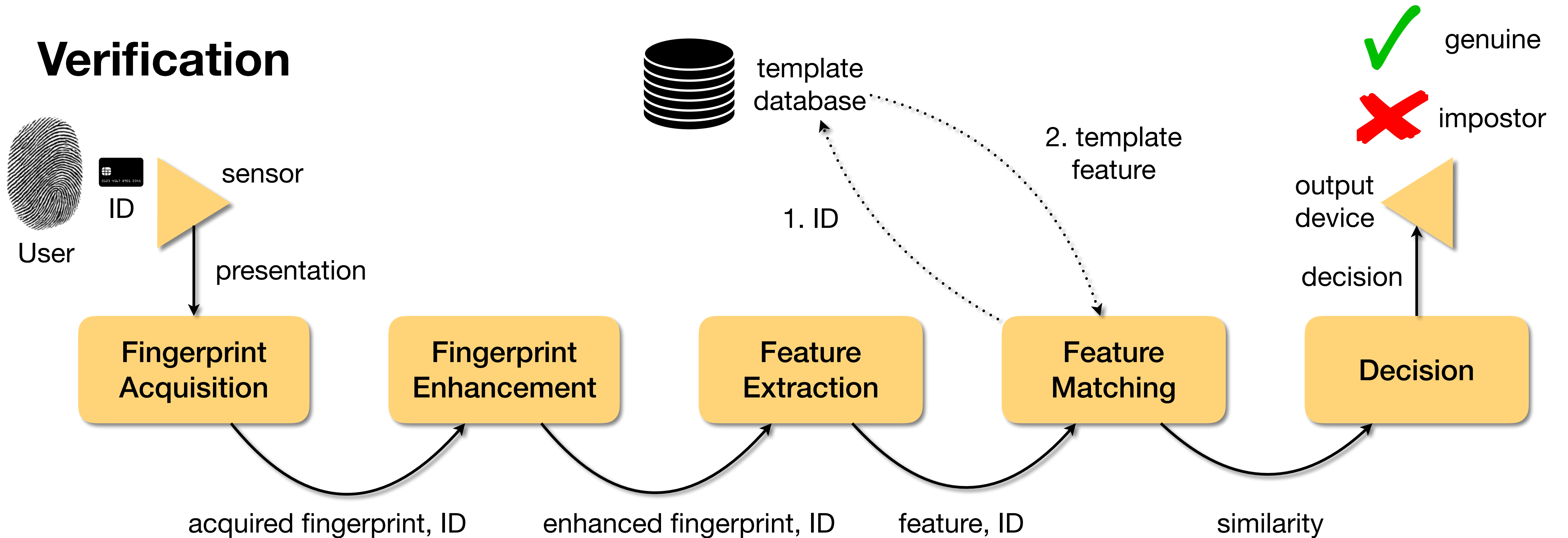
Fingerprint Recognition

Enrollment



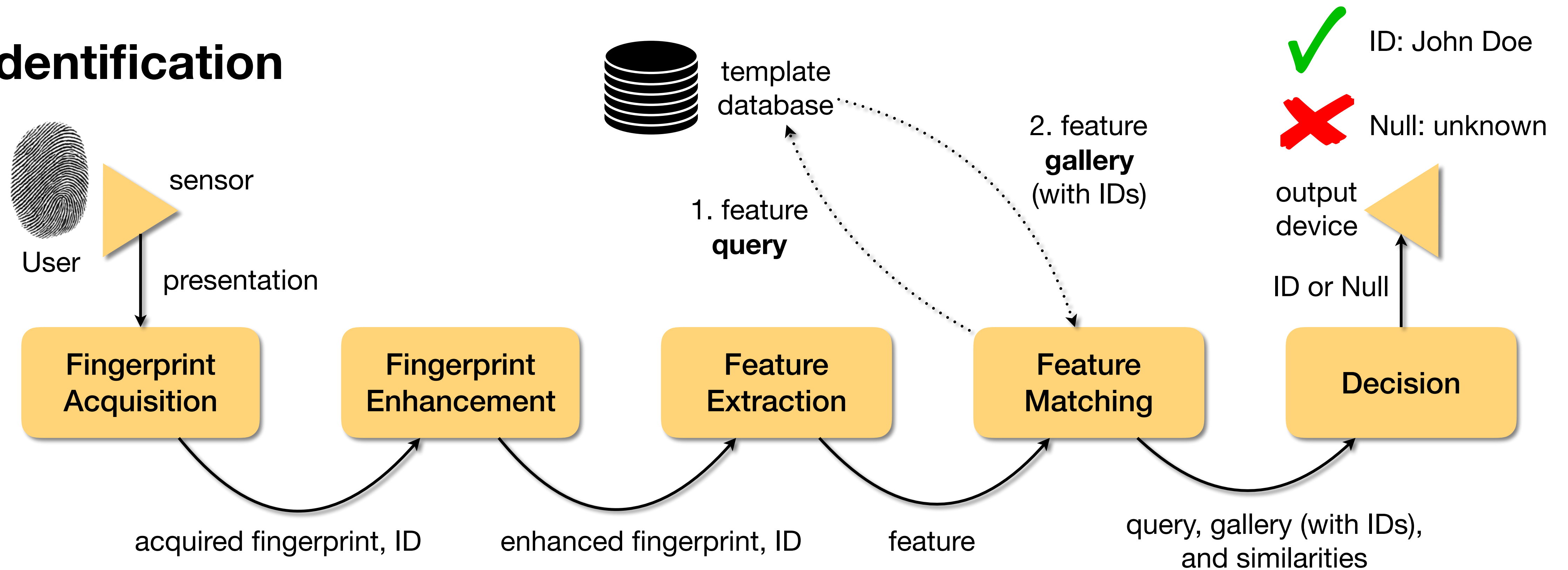
Fingerprint Recognition

Verification

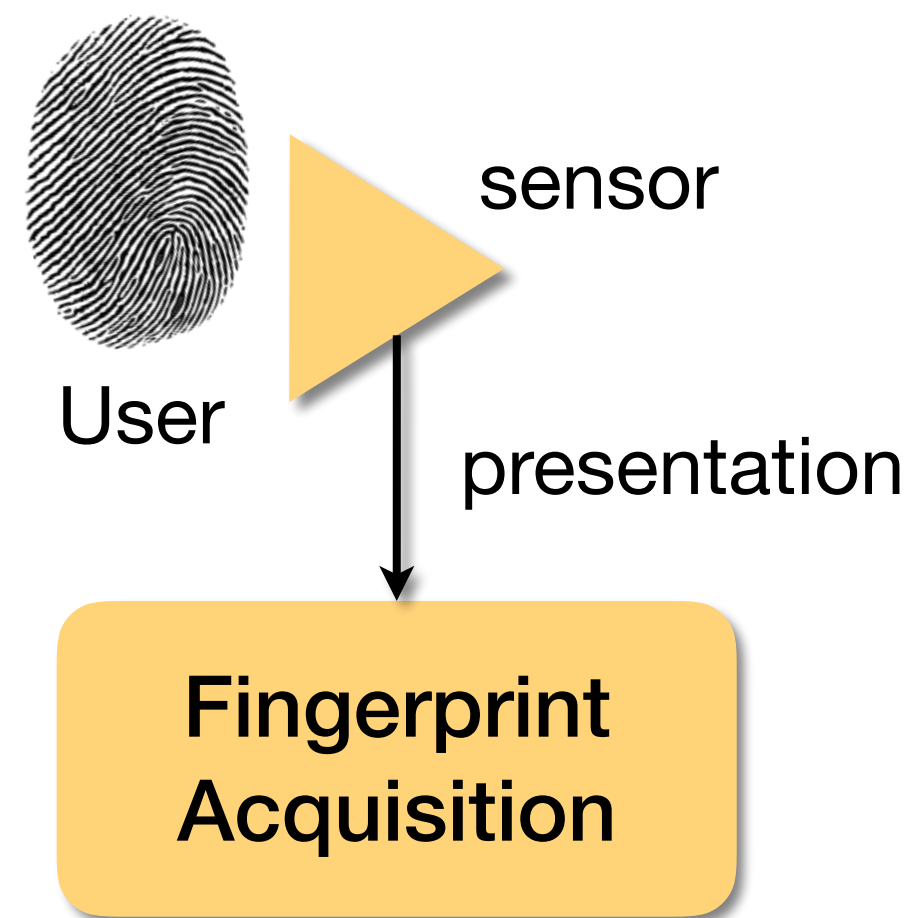


Fingerprint Recognition

Identification



Fingerprint Recognition



Acquisition

Off-line versus On-line



Acquisition

Off-line Acquisition Same fingerprint.

Jain, Ross, and Nadakumar
Introduction to Biometrics
Springer Books, 2011



rolled inked fingerprint



slap inked fingerprint

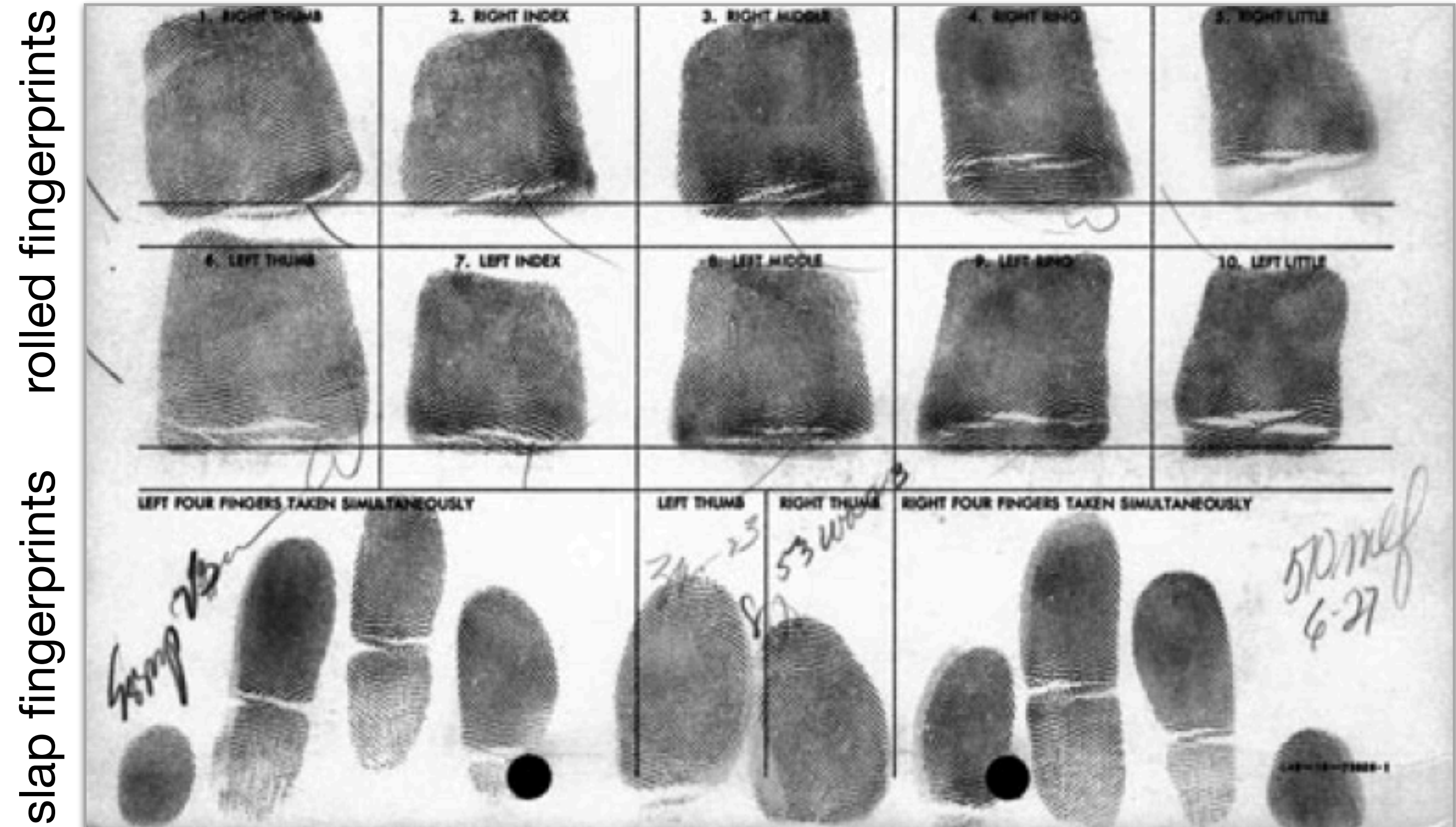


latent fingerprint

Acquisition

Off-line Acquisition

Scanning of
dactyloscopy cards.

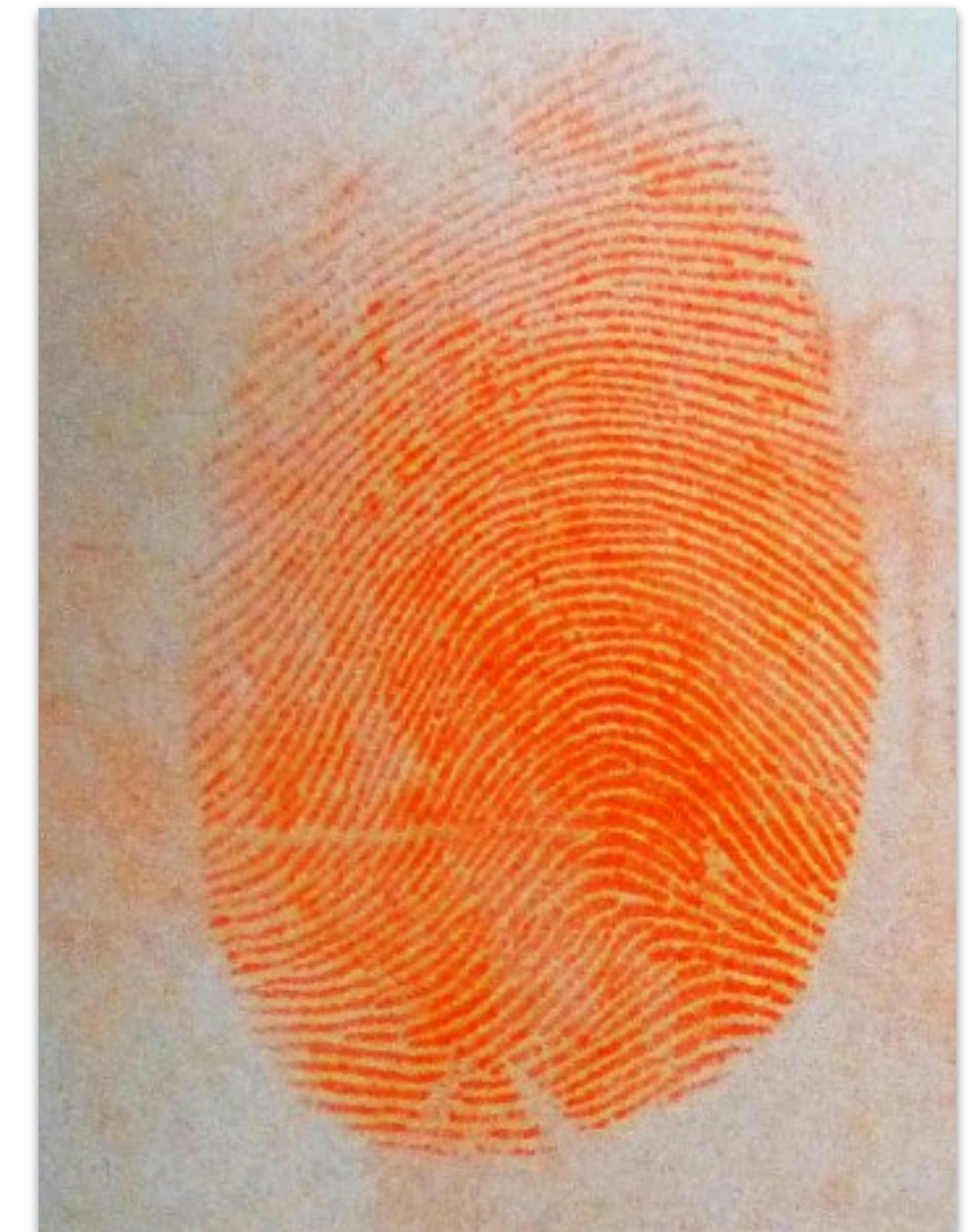


Jain, Ross, and Nadakumar
Introduction to Biometrics
Springer Books, 2011

Acquisition

Off-line Acquisition

Photographing of latent fingerprints.



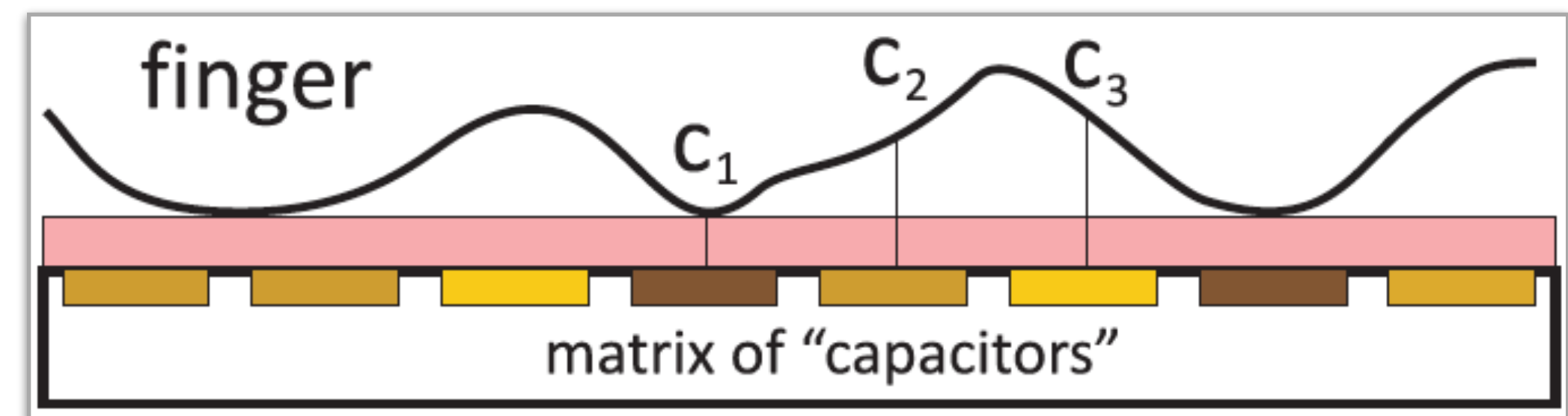
Source: Dr. Adam Czajka

Acquisition

On-line Acquisition

Capacitive sensors (1/6)

Ridges and valleys will generate different charges C_n , which will form different image segments.



Source: Dr. Adam Czajka

Low cost, but sensitive to dirt and moistness.

Typical resolution: 300 dpi (dots per inch).

Acquisition

On-line Acquisition

Capacitive sensors (1/6) Device and sample.



Precise Biometrics
Source: Dr. Adam Czajka



Source: <http://bias.csr.unibo.it/fvc2002/>

Acquisition

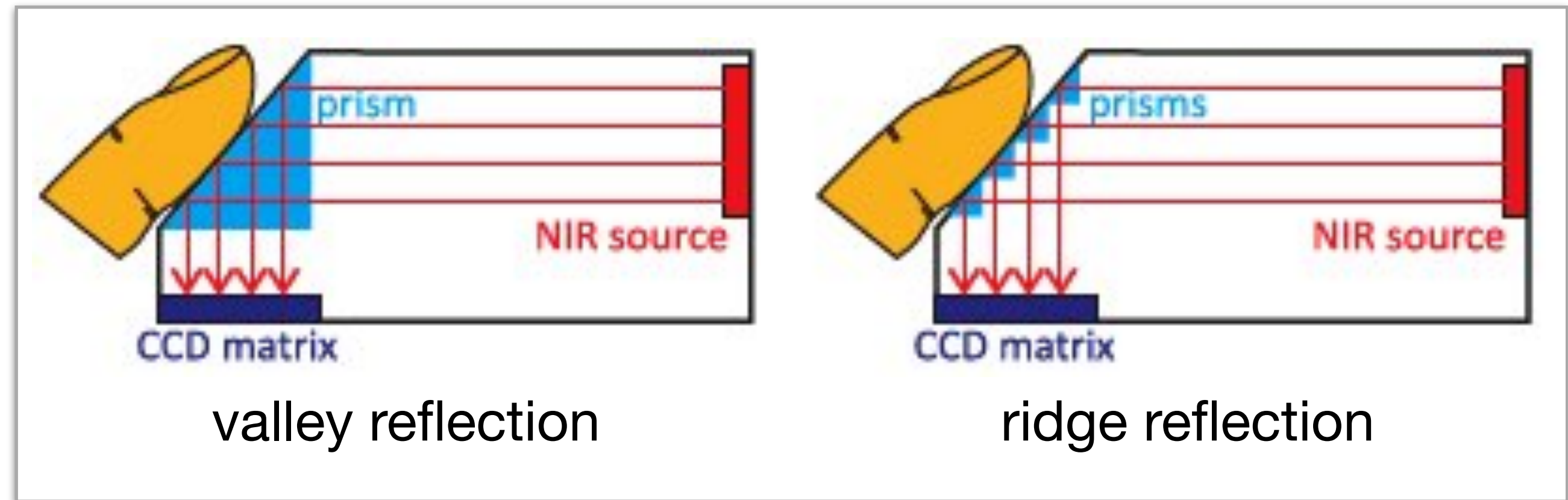
On-line Acquisition

Optical sensors (2/6)

Ridges won't be reflected on charge-coupled device (CCD) matrix, contrary to valleys, leading to darker image segments.

Typical resolution: 400-1000 dpi.

Source: Dr. Adam Czajka



Acquisition

On-line Acquisition

Optical sensors (2/6) Devices.



Identix

Source: Dr. Adam Czajka



Guardian

Acquisition

On-line Acquisition

Optical sensors (2/6) - Samples.

Source: Dr. Adam Czajka



slap
Biometrika FX2000



rolled
CrossMatch LS320



thumbs
L1 TP4100



little, ring, middle, and index
L1 TP4100

Acquisition

On-line Acquisition

Pressure sensors (3/6)

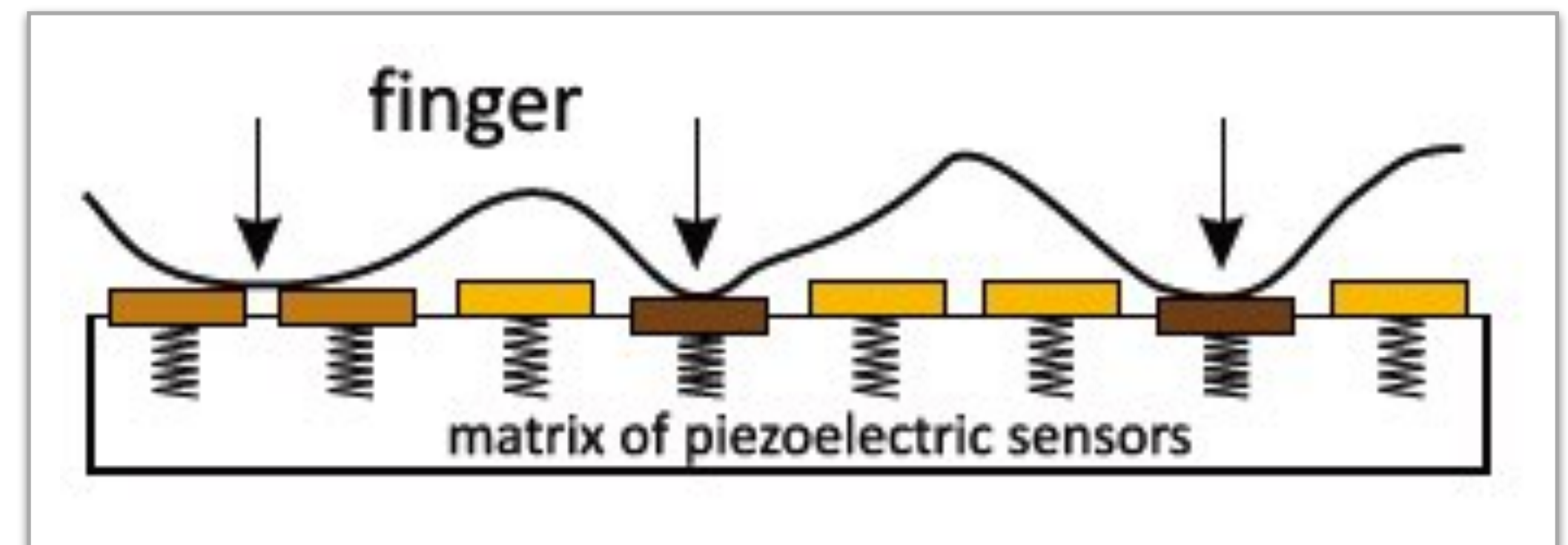
Also known as piezoelectric.

Ridges will cause stronger pressure than valleys, forming different image segments.

Robust to moistness.

Typical resolution: 400 dpi.

Source: Dr. Adam Czajka



Acquisition

On-line Acquisition

Pressure sensors (3/6)
Device and sample.

Source: Dr. Adam Czajka



BMF/Hitachi

Source: Dr. Adam Czajka



Acquisition

On-line Acquisition

Thermal sensors (4/6)

Based on surface temperature.

Ridges will transfer a different amount of heat when compared to valleys, leading to different image segments.



Acquisition

On-line Acquisition

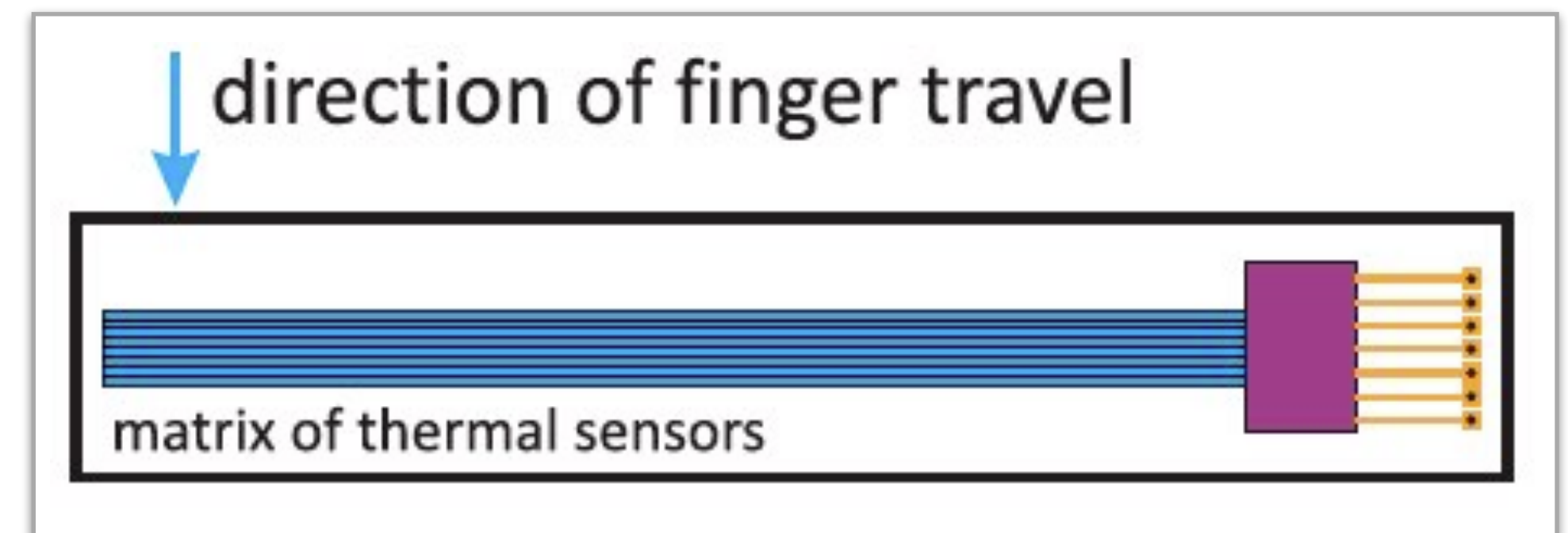
Thermal sensors (4/6)

Example: Atmel FingerChip

Finger is swept onto the sensor.

Thin sensor but high resolution
(typically 500 dpi).

While finger is swept, temperature is collected
at discrete time intervals.



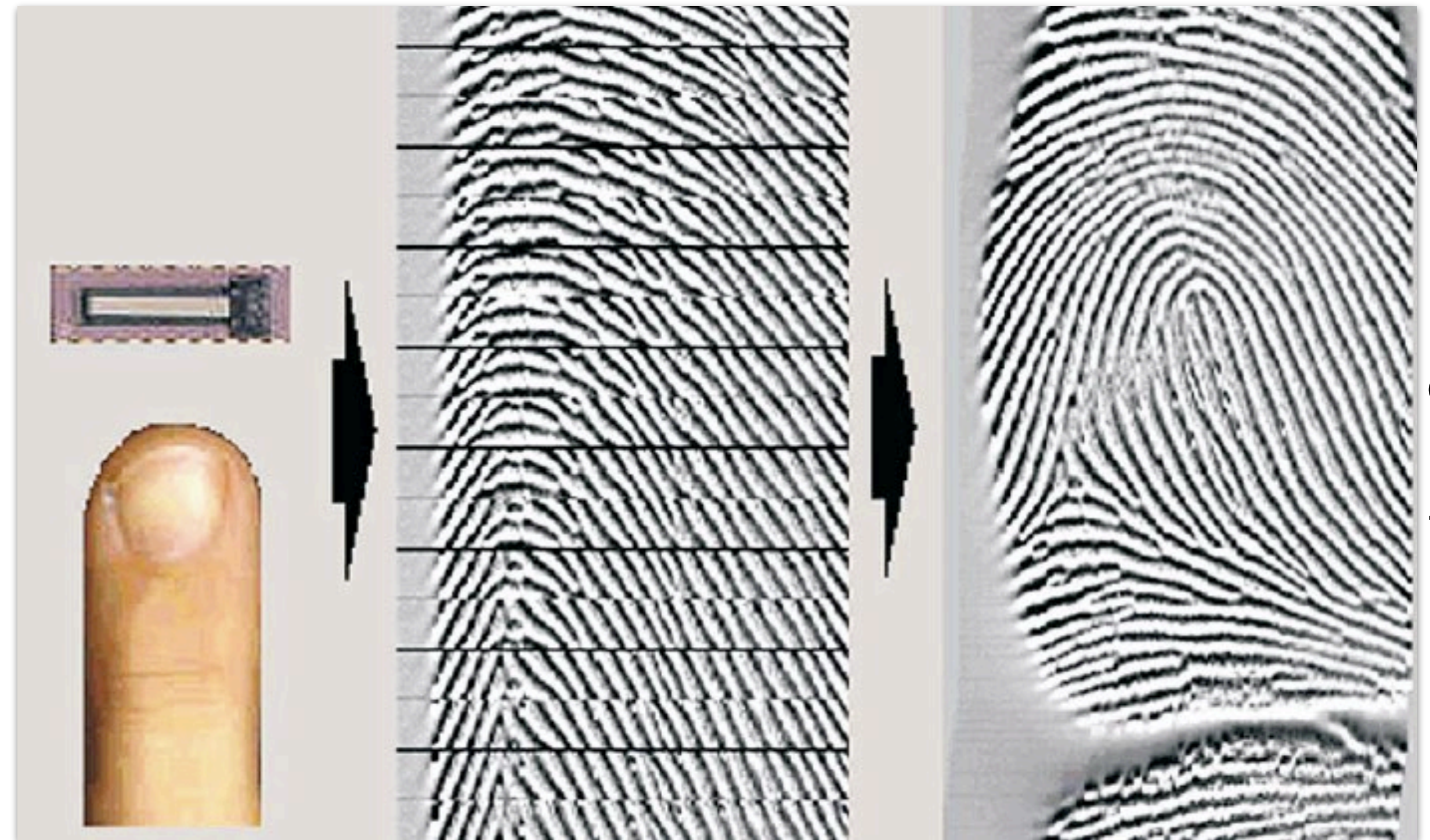
Source: Dr. Adam Czajka

Acquisition

On-line Acquisition

Thermal sensors (4/6)

Example: Atmel FingerChip
Sample generation.



Source: Atmel FingerChip

finger sweep

discrete collection

fingerprint reconstruction

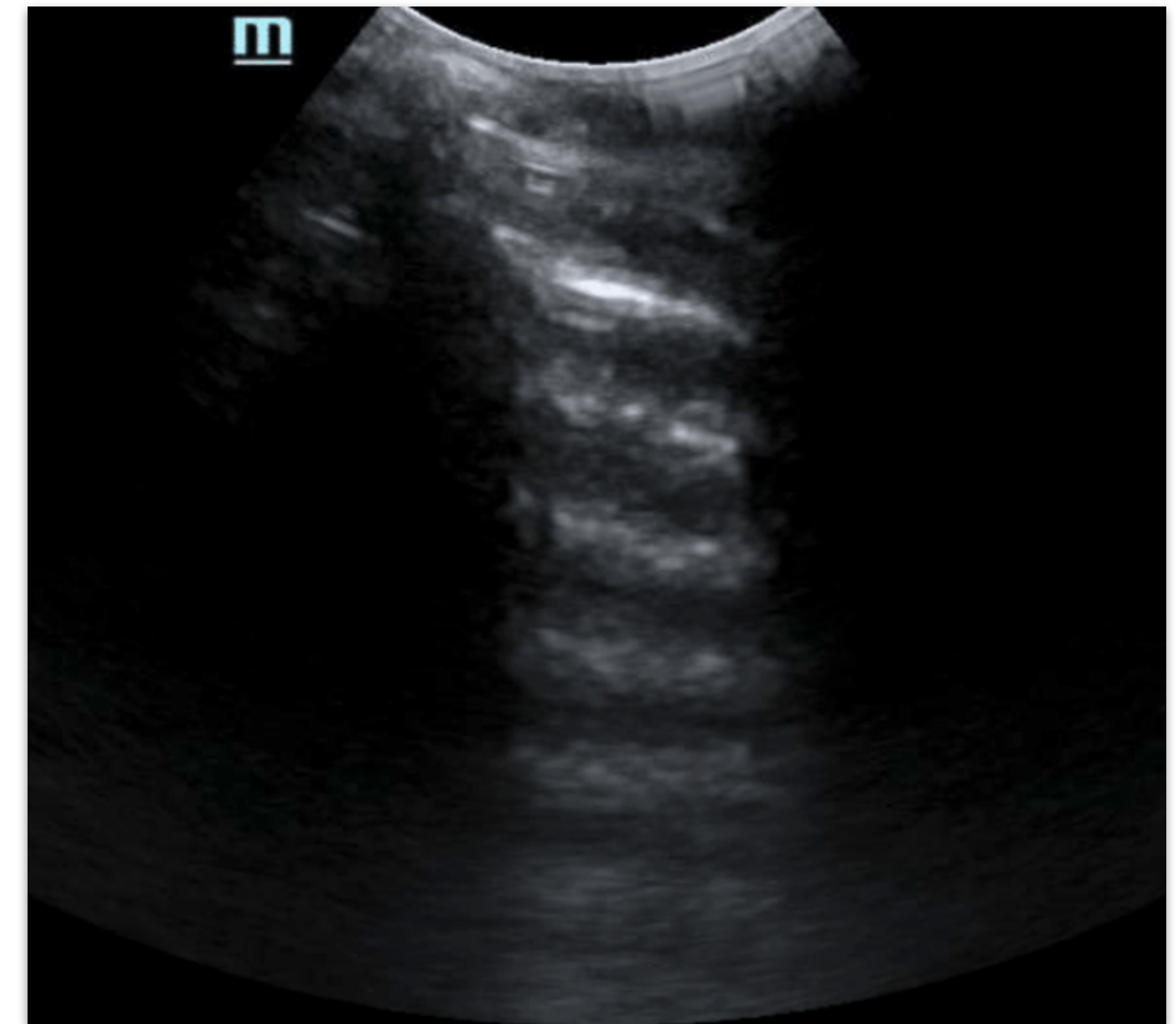
Acquisition

On-line Acquisition

Ultrasound sensors (5/6)

Measures the scattering of sound waves over the finger surface.

Ridges and valleys will produce different scattering, leading to different image segments.



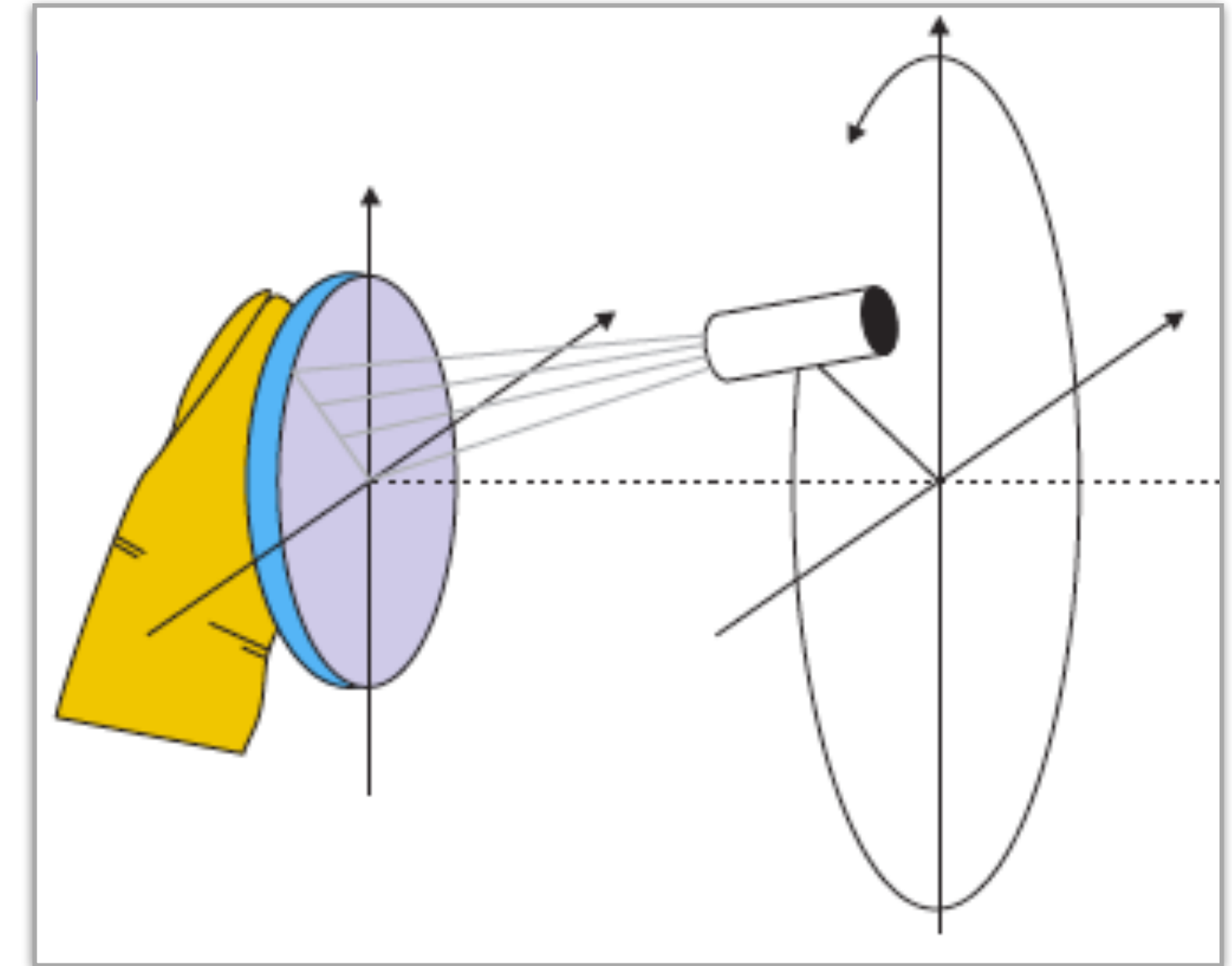
Acquisition

On-line Acquisition

Ultrasound sensors (5/6)

Example: Optel

Transducer moves along a circular trajectory whose central axis is perpendicular to the fingertip.



Source: Dr. Adam Czajka

More expensive. Typical resolution: 250 dpi.
Harder to be spoofed (due to ultrasounds penetration).

Acquisition

On-line Acquisition

Ultrasound sensors (5/6)

Example: Optel
Device and sample.



Source: www.optel.com.pl

Acquisition

On-line Acquisition

Ultrasound sensor (5/6)

Example: Qualcomm Fingerprint

Sensor embedded into the device display.



Source: mashable.com

Acquisition

On-line Acquisition

Touchless sensor (6/6)

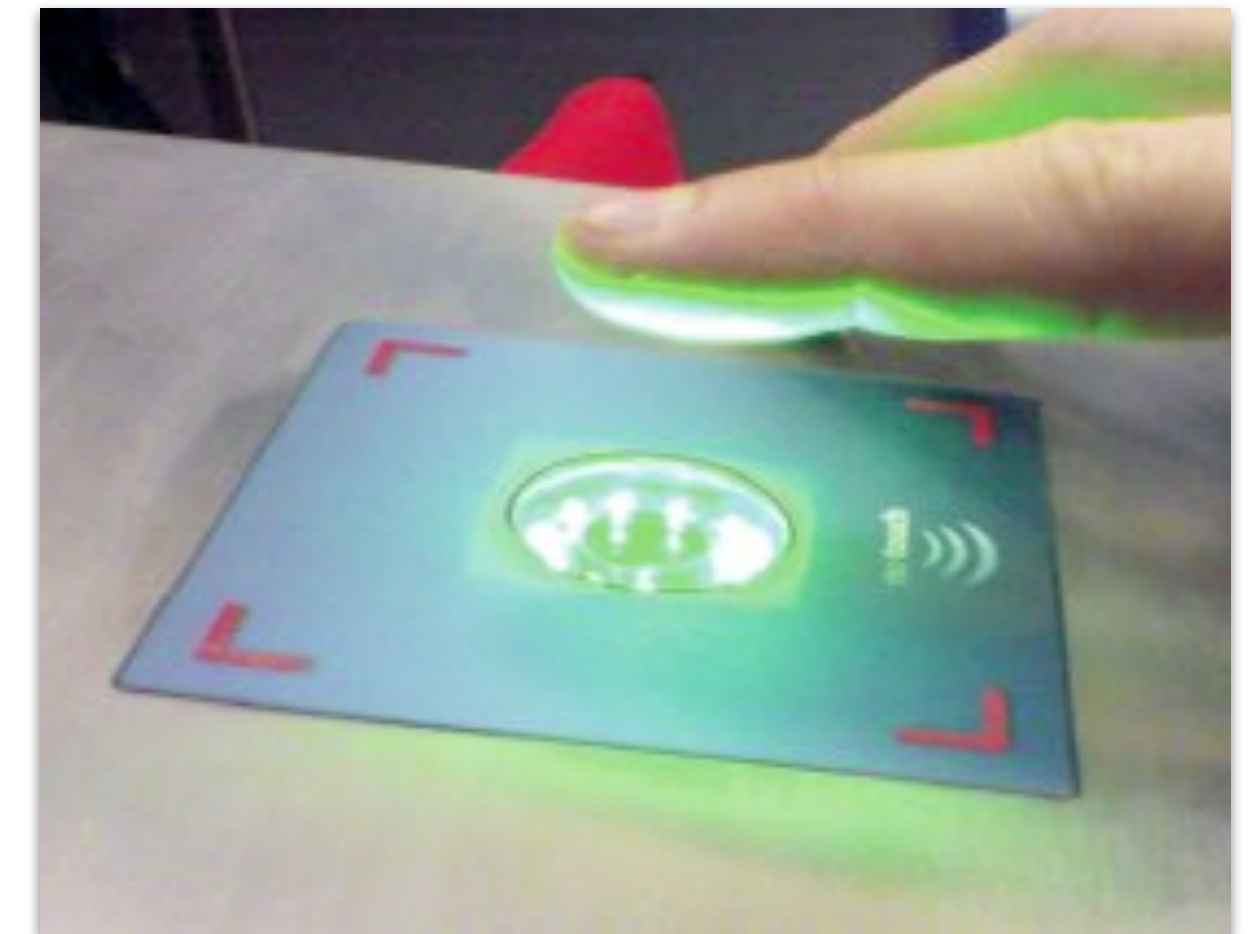
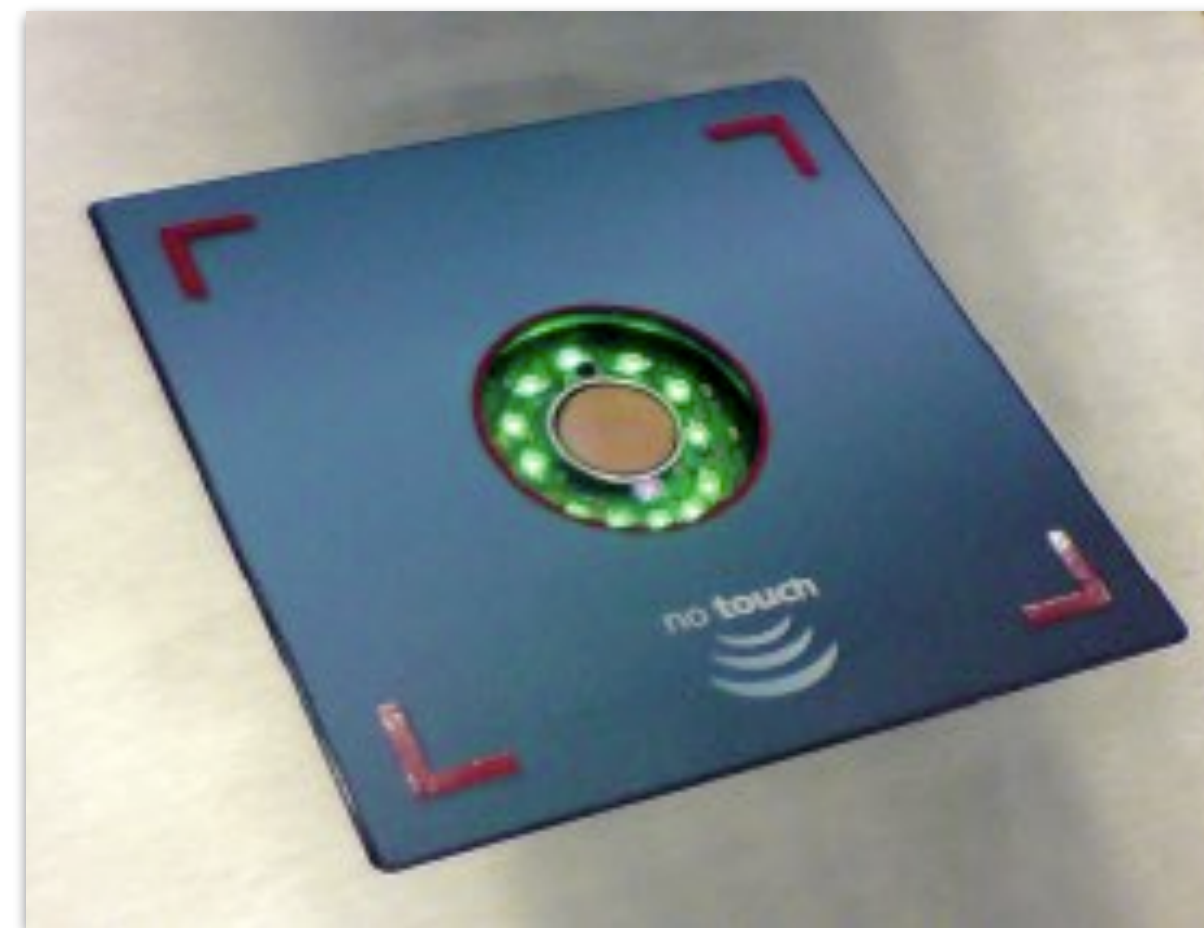
3D imaging with CCD sensor.



Acquisition

On-line Acquisition

Touchless sensor (6/6)
Example: TST Biometrics Device.



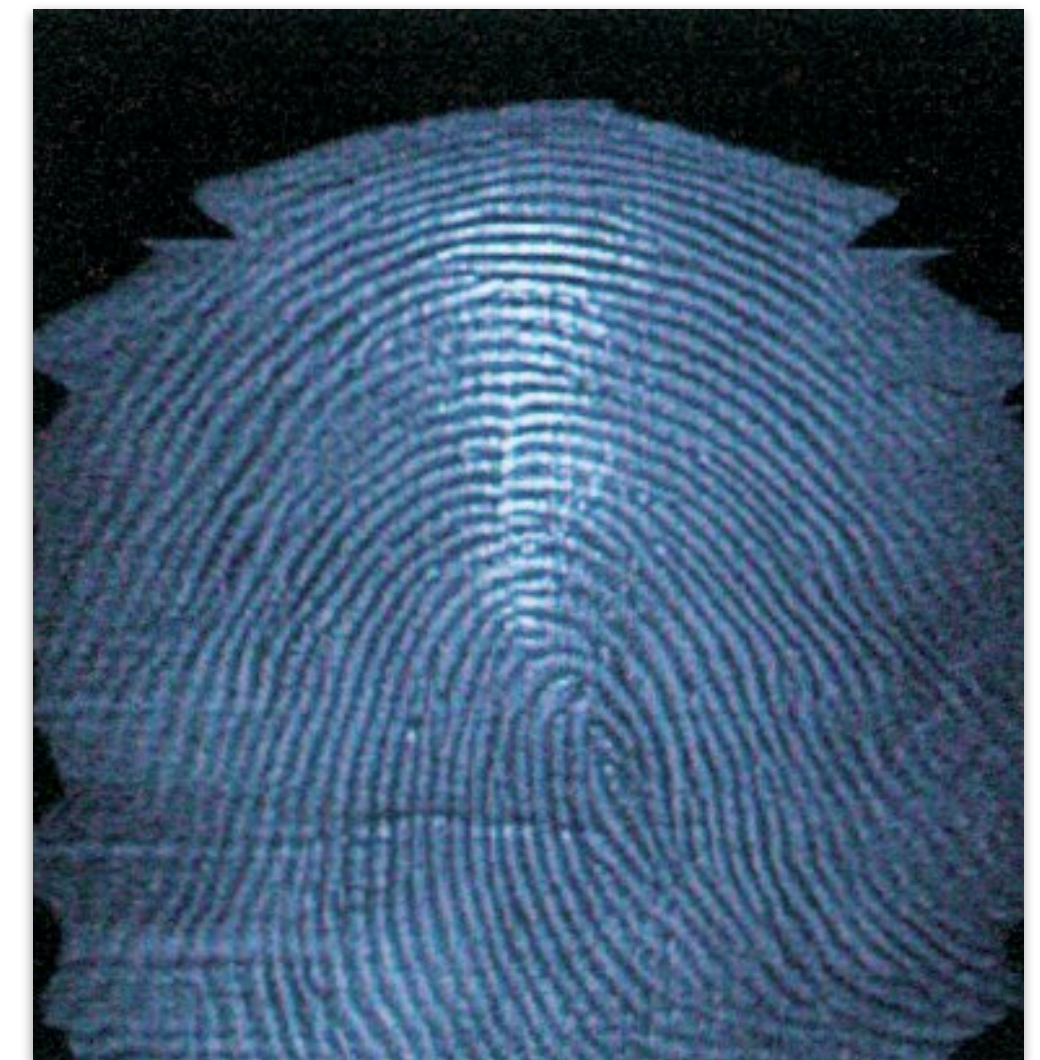
Source: Dr. Adam Czajka

Acquisition

On-line Acquisition

Touchless sensor (6/6)

Example: MorphoWave Device and sample.



Source: Dr. Adam Czajka

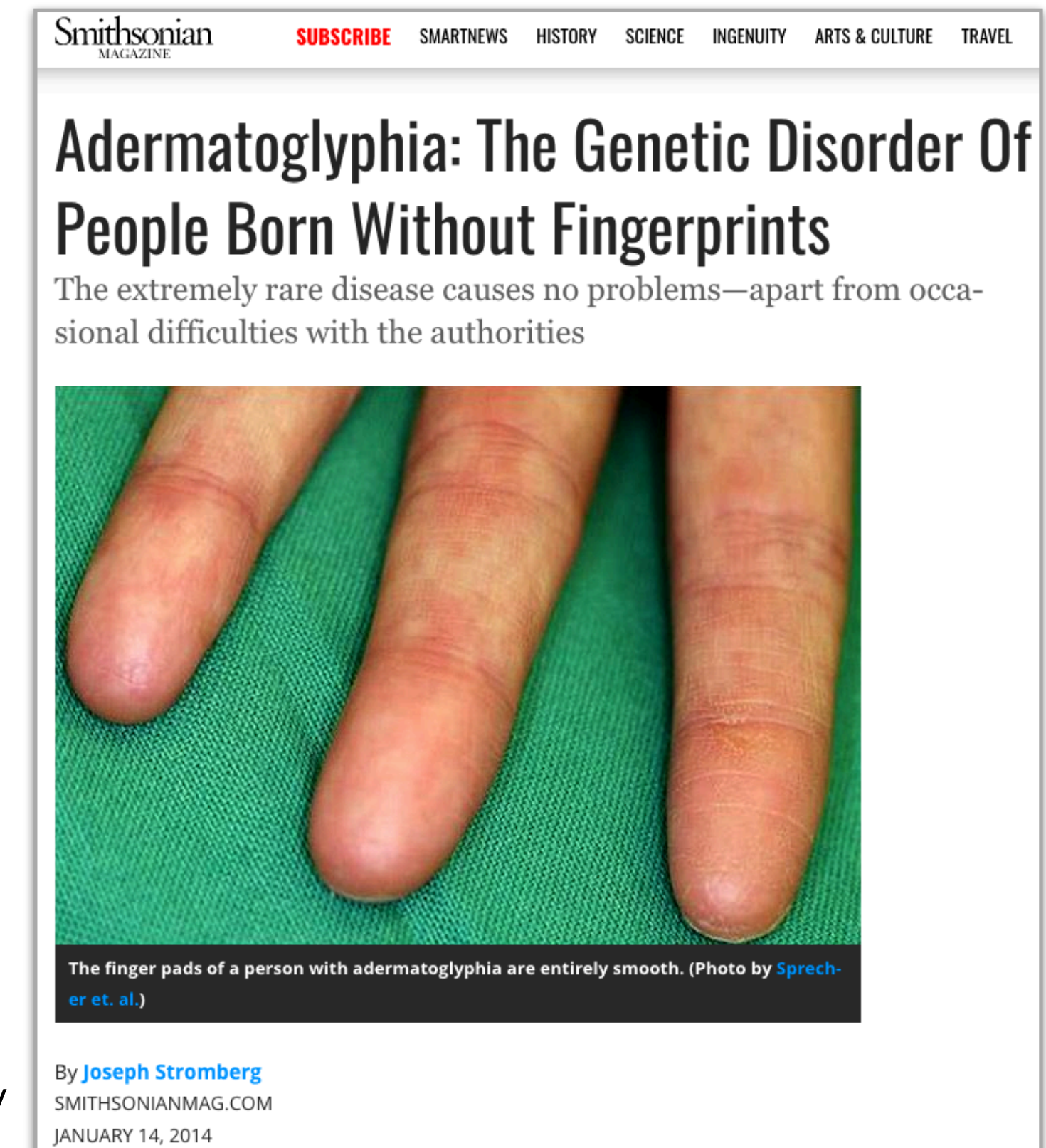
Acquisition

Problems

Adermatoglyphia

Leads to failure to acquire (FTA)
and failure to enroll (FTE).

<https://www.smithsonianmag.com/science-nature/adermatoglyphia-genetic-disorder-people-born-without-fingerprints-180949338/>



Acquisition

Problems

Presentation Attack

Techniques to generate fake fingerprints:

- Paper printouts.

- Clay or latex molds, plus wood-glue, gelatin, or silicone mold filling.



Source: Dr. Adam Czajka

Objectives: spoofing and obfuscation.

Faking Fingerprints



Available at: <https://www.youtube.com/watch?v=KdycMYILTr0>

Acquisition

Problems

Presentation Attack

How robust might be the different sensors?

Capacitive, Pressure, and Thermal

May be fooled, if synthetic material presents similar skin properties.
Not enough resolution for level-3 features.

Optical

May be fooled, including paper printout.
Larger resolution will allow the use of level-3 features.

Acquisition

Problems

Presentation Attack

How robust might be the different sensors?

Ultrasound

May be robust if ultrasound penetration is used.

Touchless

Flat fake samples may not work due to 3D detection.

Acquisition

Problems

Presentation Attack

How about humans?



Fake or authentic?

From capacitive sensor



Fake or authentic?

From capacitive sensor

Matsumoto, T.
*Importance of Open Discussion on Adversarial Analyses for Mobile
Security Technologies---A Case Study for User Identification---*
ITU-T Workshop on Security, Seoul, 2002



authentic



gelatin

Fake or authentic?

From optical sensor



Fake or authentic?

From optical sensor



authentic



silicone



gelatin

Matsumoto, T.
*Importance of Open Discussion on Adversarial Analyses for Mobile
Security Technologies---A Case Study for User Identification---*
ITU-T Workshop on Security, Seoul, 2002

Fake or authentic?

From optical sensor



Fake or authentic?

From optical sensor

Source: Dr. Adam Czajka

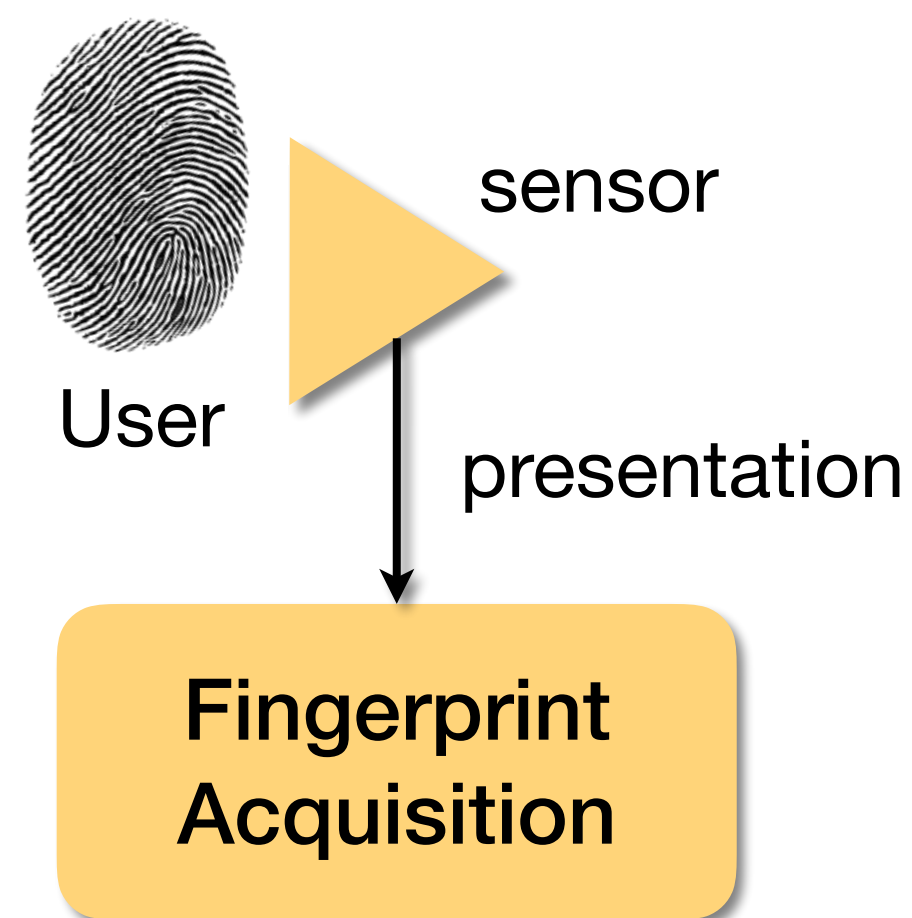
wood glue



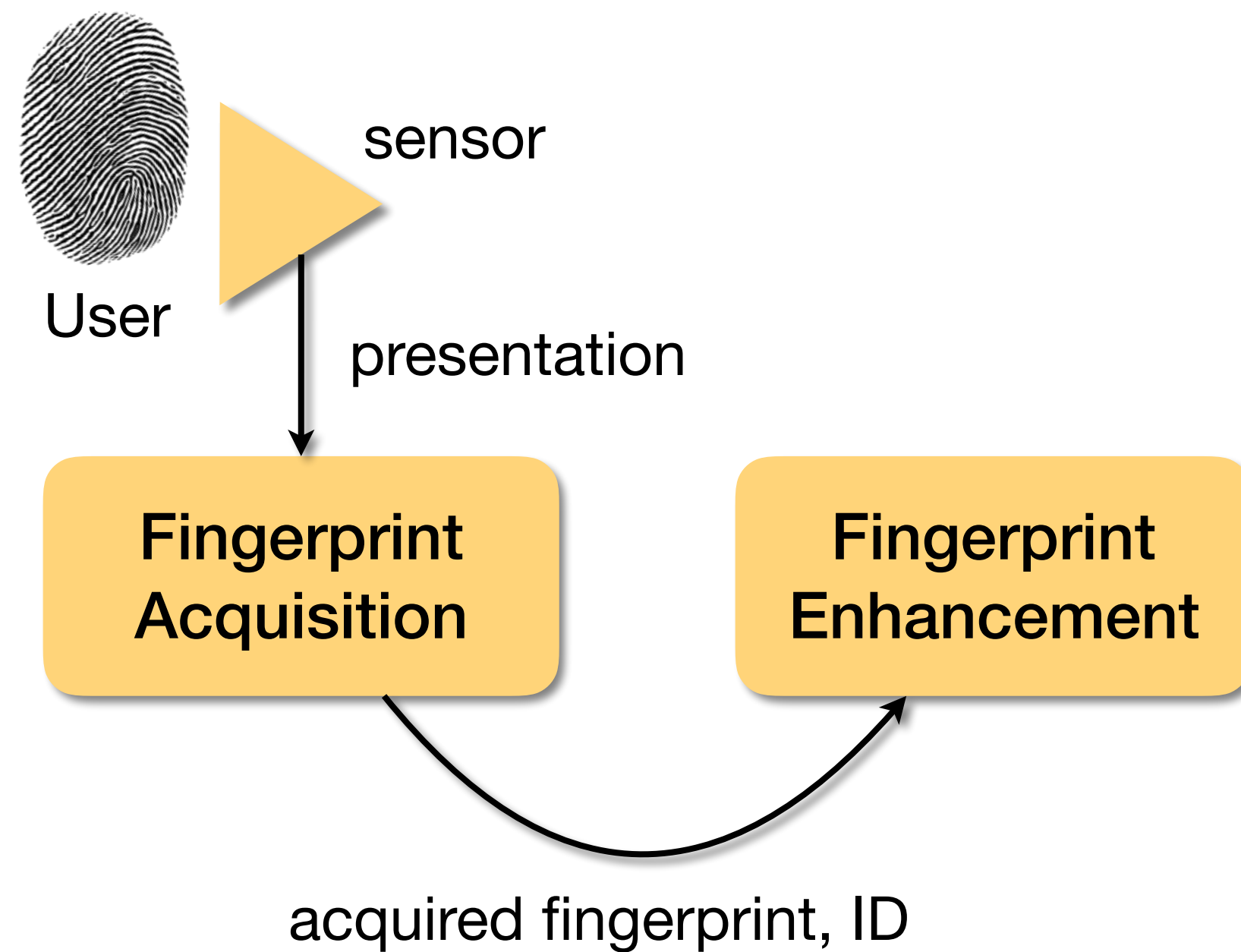
authentic



Fingerprint Recognition



Fingerprint Recognition



Enhancement

Objectives

Noise removal.

Keep only essential information.

Reduce intra-class variation.

Why do we need to enhance?

Poor illumination conditions.

Careless fingerprint presentation.

Limited sensor accuracy.

Sensor dirtiness.

Skin condition.



Enhancement

Capture Condition



too bright



too dark

Enhancement

Skin Condition

Maltoni et al.
Handbook of Fingerprint Recognition
Springer Books, 2009



normal



dry



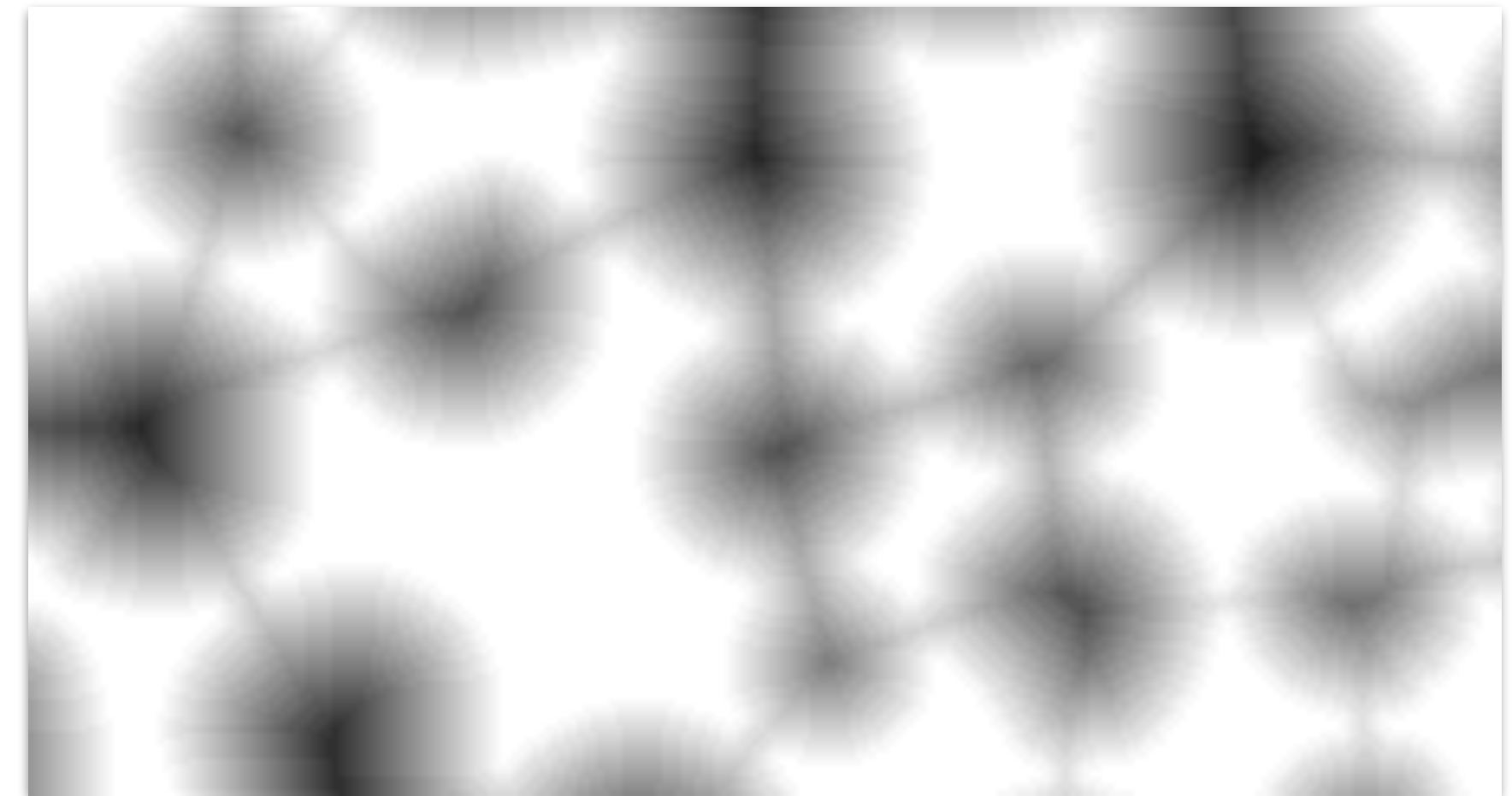
wet

Enhancement

Image Processing Solutions

Tasks

Enhancement of image contrast.
Enhancement of ridges and valleys.
Content segmentation.

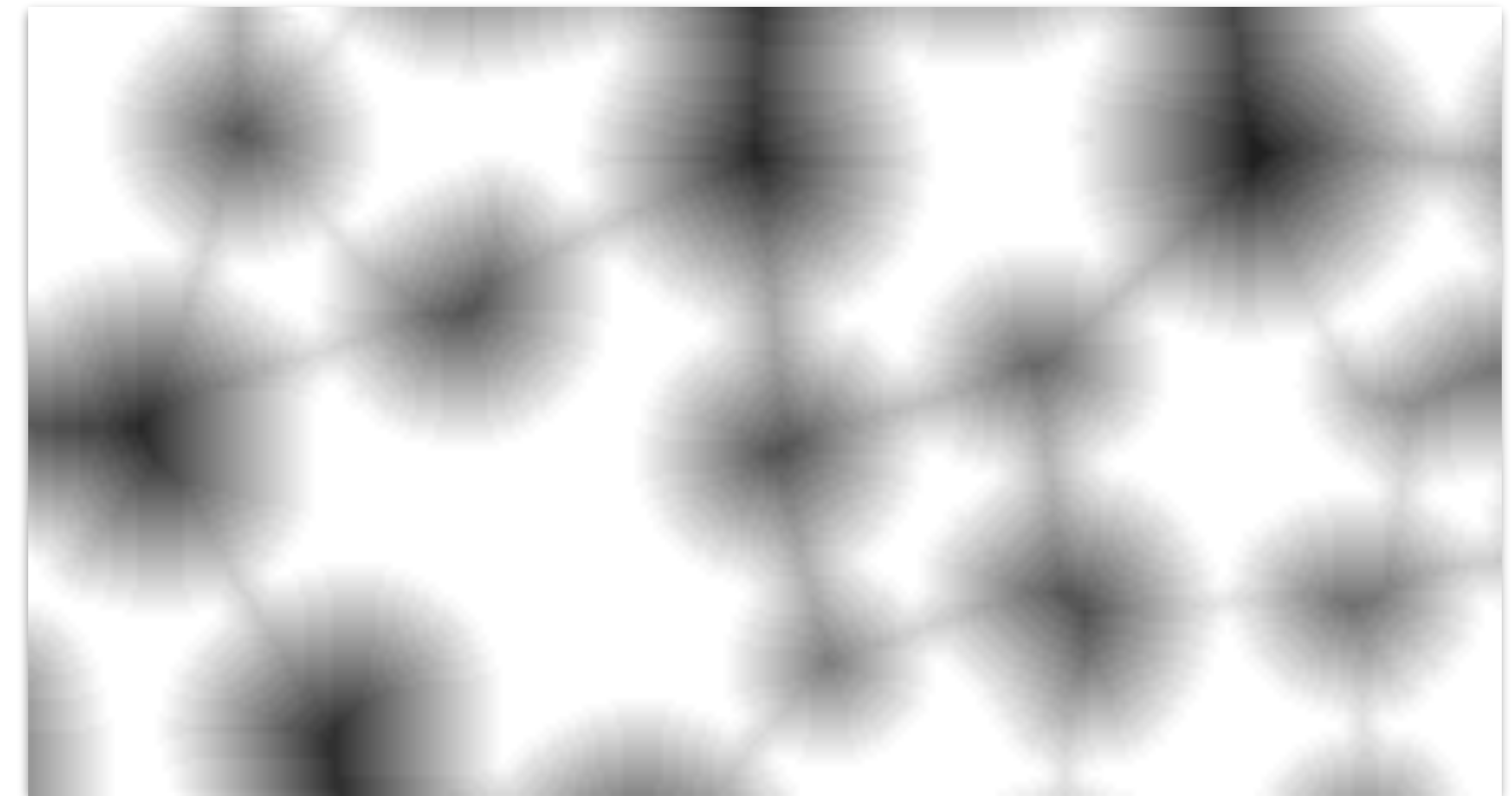


Enhancement

Image Processing Solutions

Tasks

Enhancement of image contrast.
Enhancement of ridges and valleys.
Content segmentation.



Enhancement

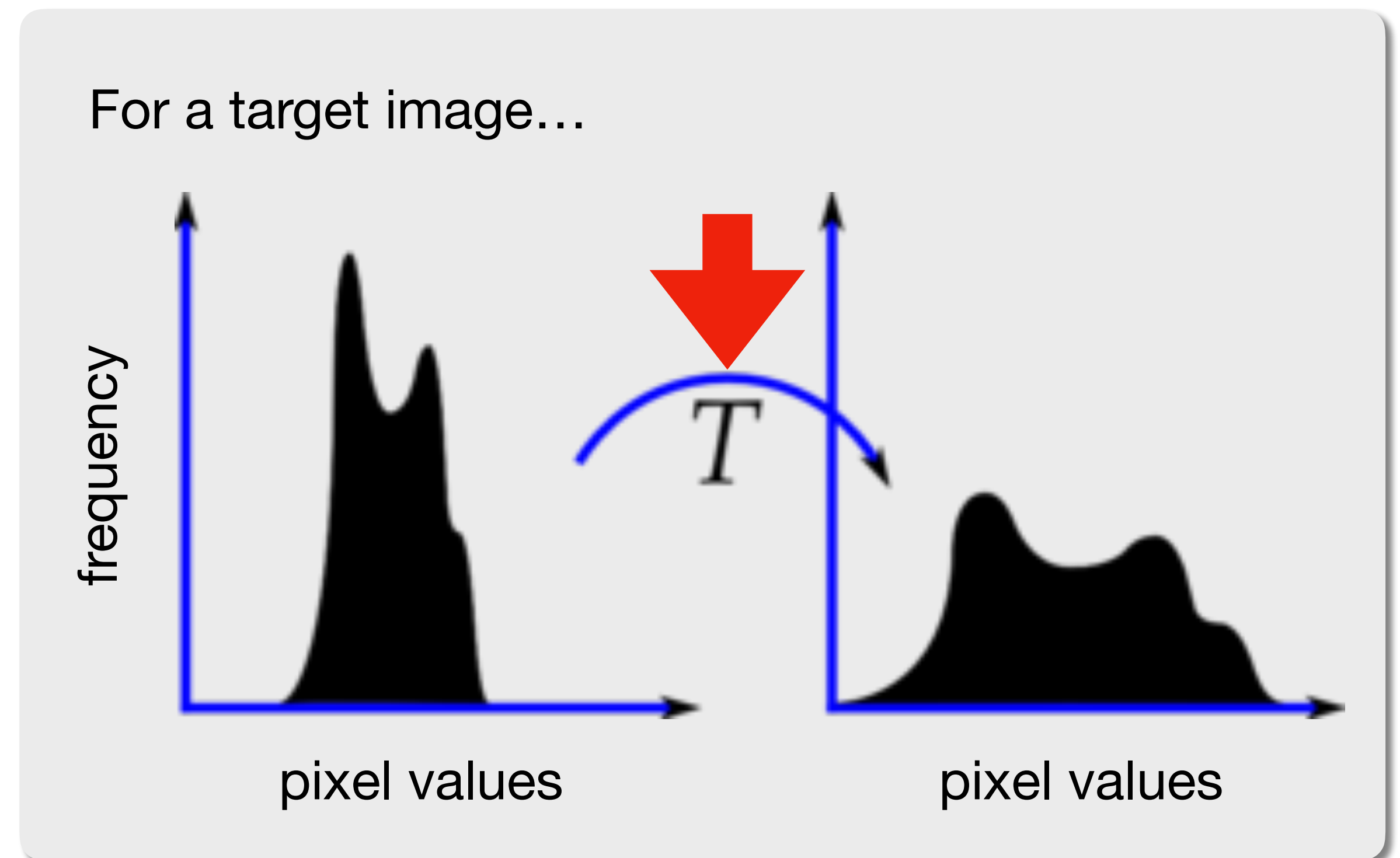
Image Contrast

Example:

Color histogram equalization.

Useful when pixel values are confined to a specific range (too bright or too dark images).

Stretching the color histogram will improve the contrast.



Enhancement

Image Contrast

Example:
Color histogram equalization.

Example: too bright capture.



before



after

Enhancement

Image Contrast

Example:
Color histogram equalization.

Example: too dark capture.



before



after

Enhancement

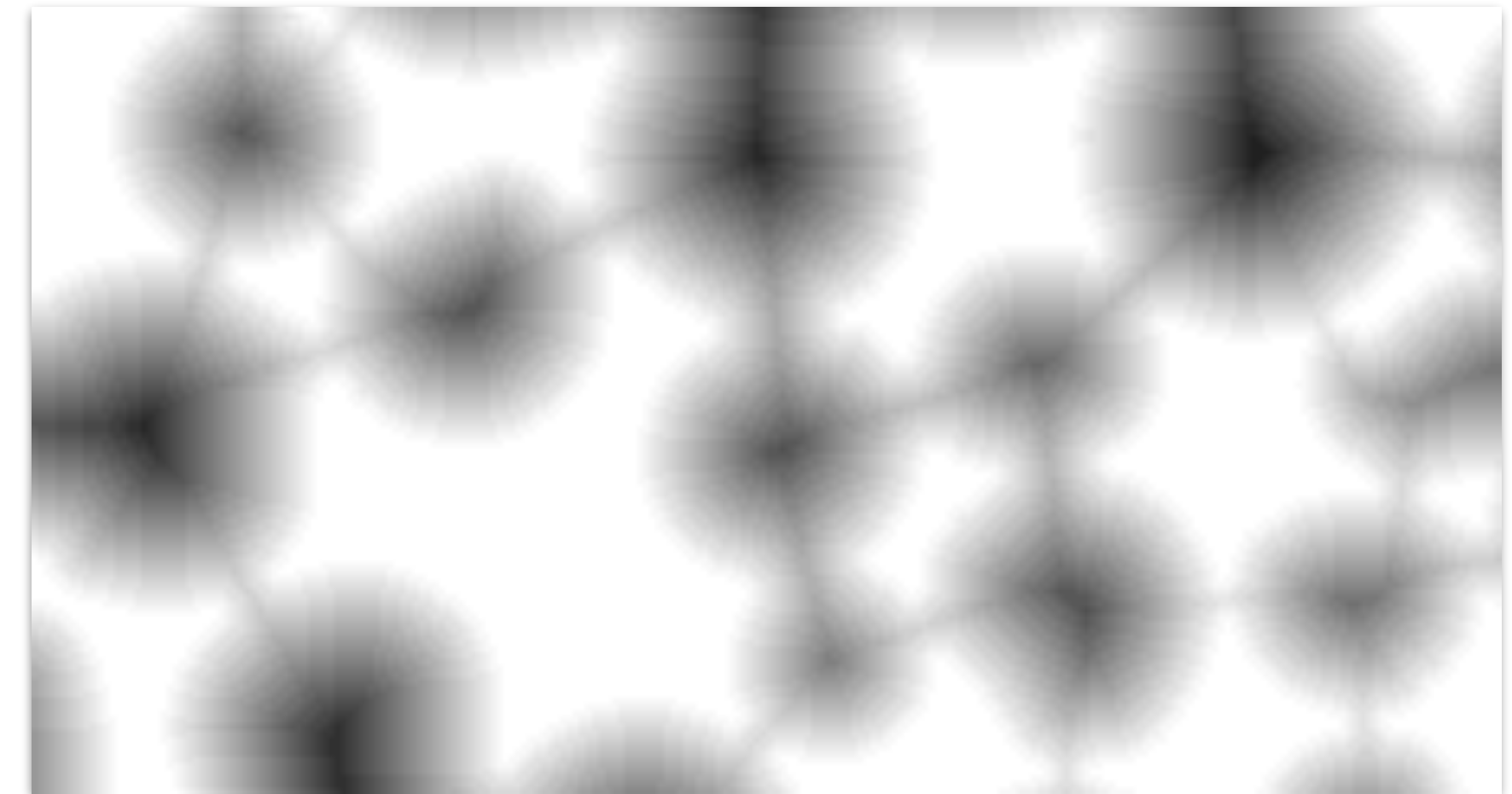
Image Processing Solutions

Tasks

Enhancement of image contrast.

Enhancement of ridges and valleys.

Content segmentation.



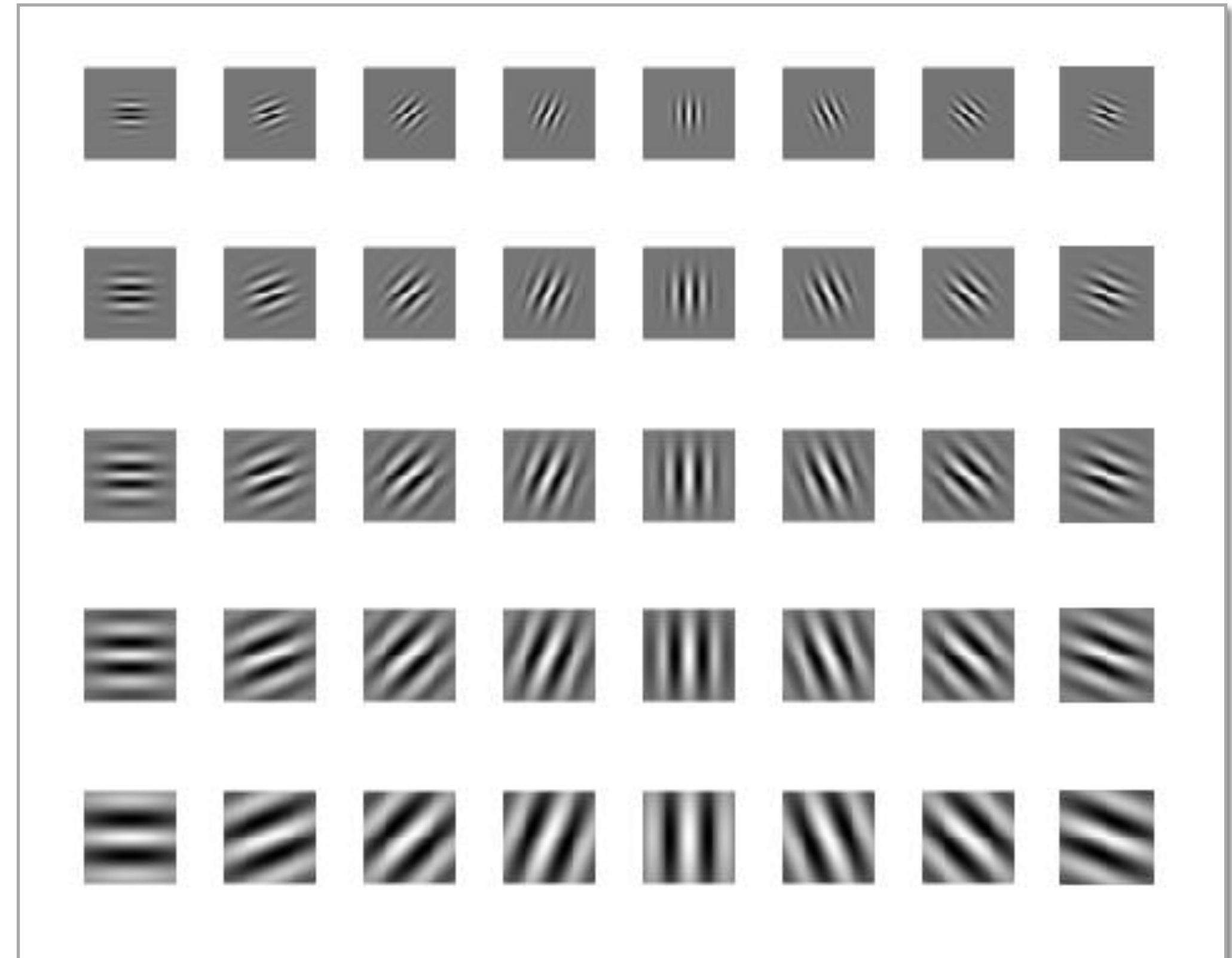
Enhancement

Ridges and Valleys

Example:

Image filtering with
Gabor filters.

Ridges and valleys may become
more prominent when a fingerprint
image is filtered by Gabor filters.



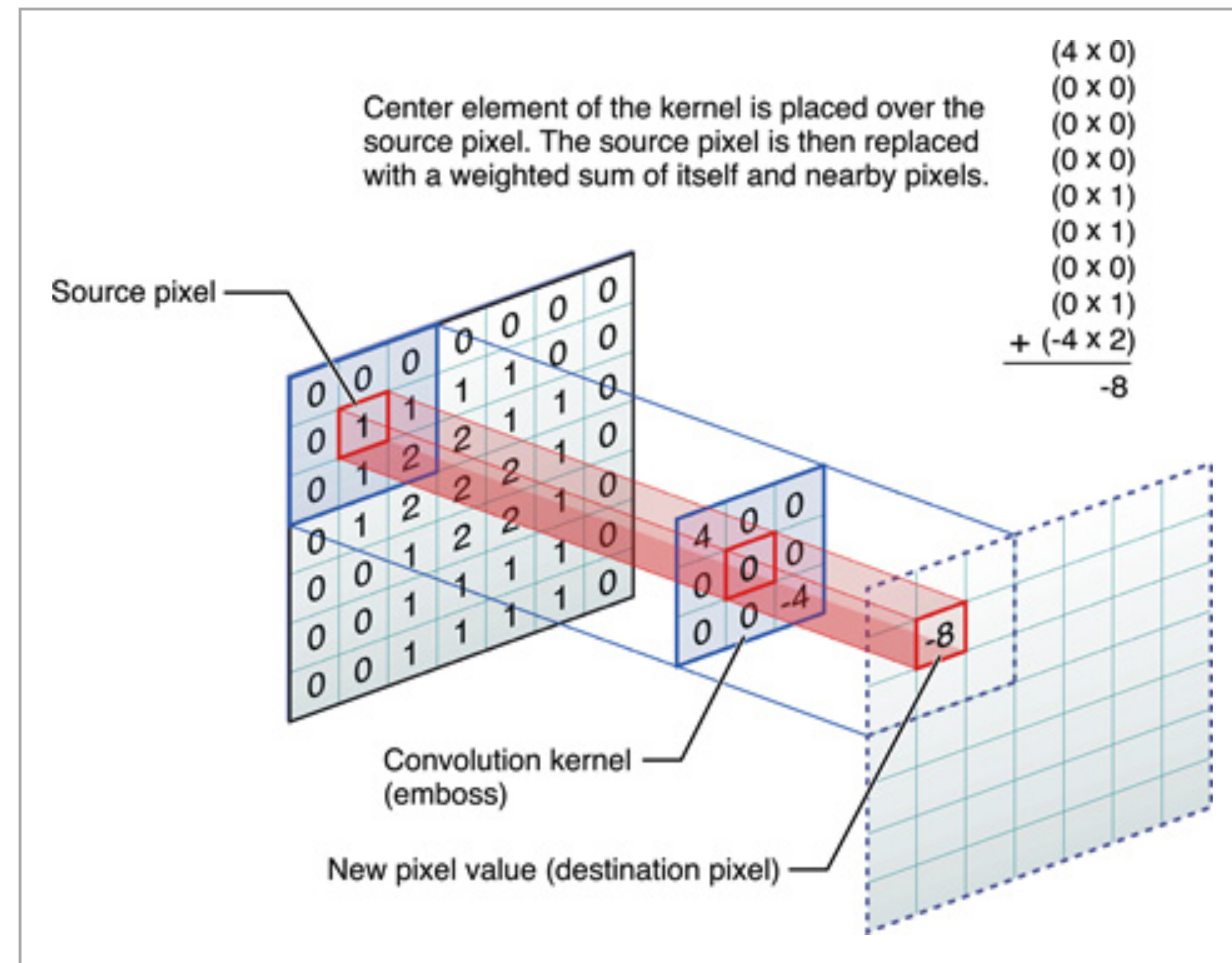
Enhancement

Ridges and Valleys

Example:

Image filtering with
Gabor filters.

Gabor filters may be
applied to an image
through convolutions.



Source: <https://developer.apple.com/library/archive/documentation/Performance/Conceptual/vimage/ConvolutionOperations/ConvolutionOperations.html>

Enhancement

Ridges and Valleys

Example:
Image filtering with
Gabor filters.

Maltoni et al.
Handbook of Fingerprint Recognition
Springer Books, 2009



before



after

Enhancement

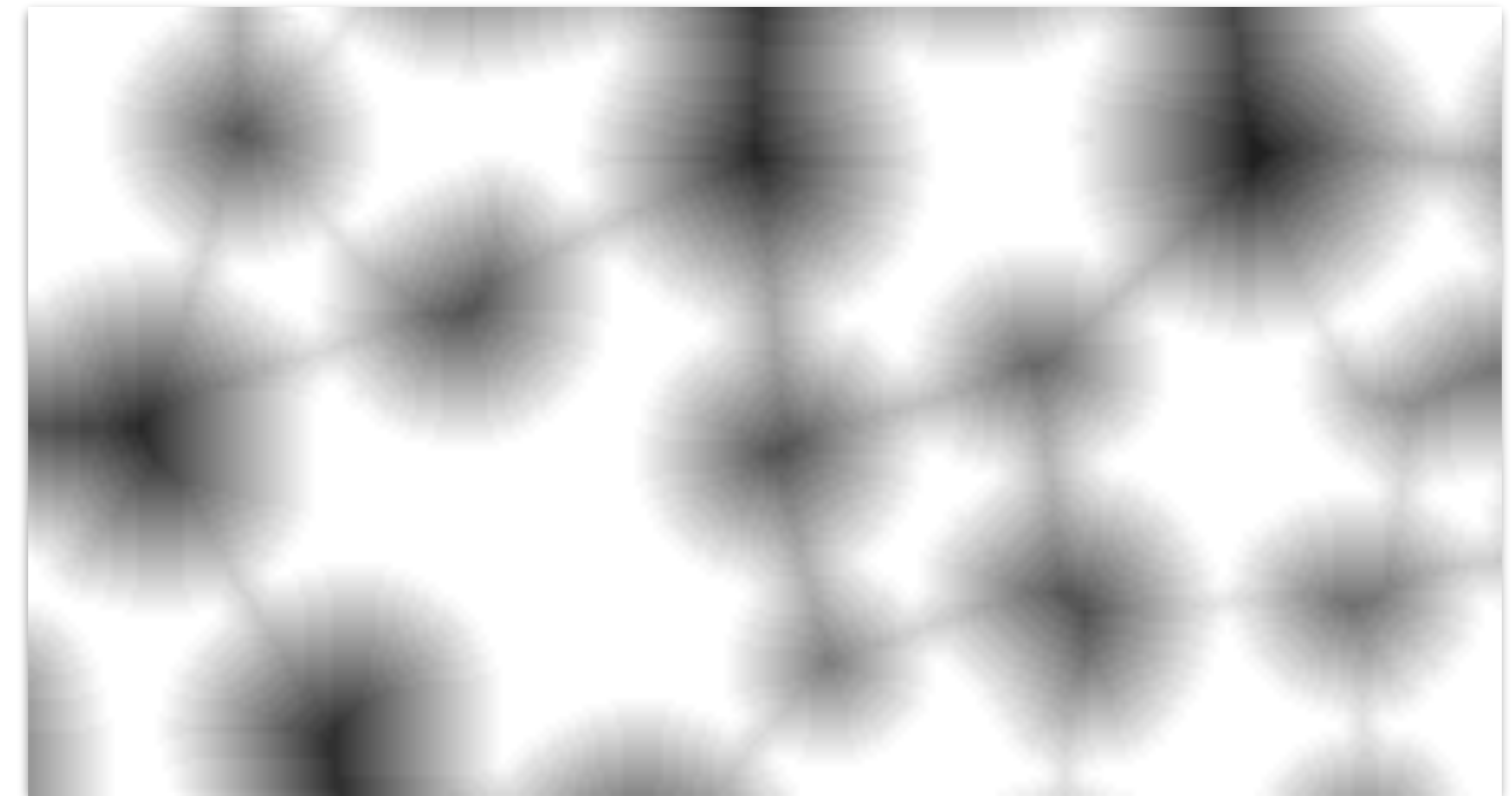
Image Processing Solutions

Tasks

Enhancement of image contrast.

Enhancement of ridges and valleys.

Content segmentation.



Enhancement

Segmentation

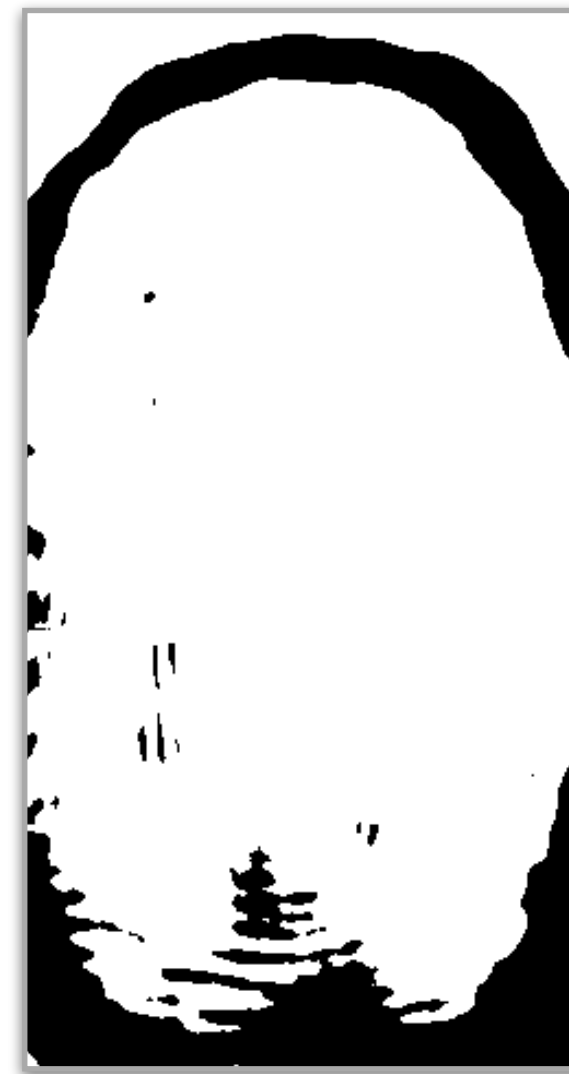
Example: blurring, thresholding, and morphological operations.



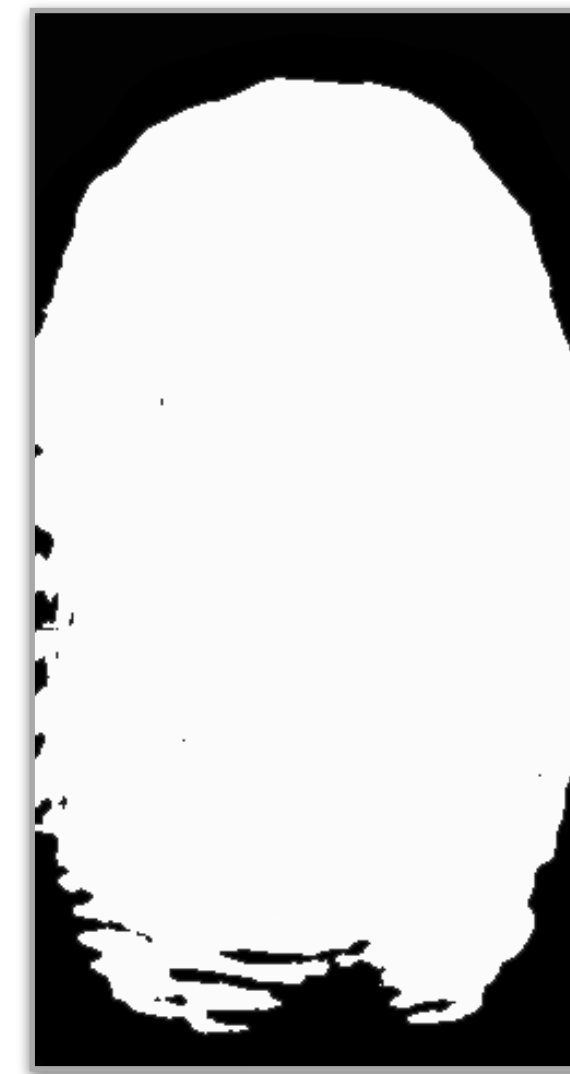
before



blur



threshold



open



after

Enhancement

Image Processing Solutions

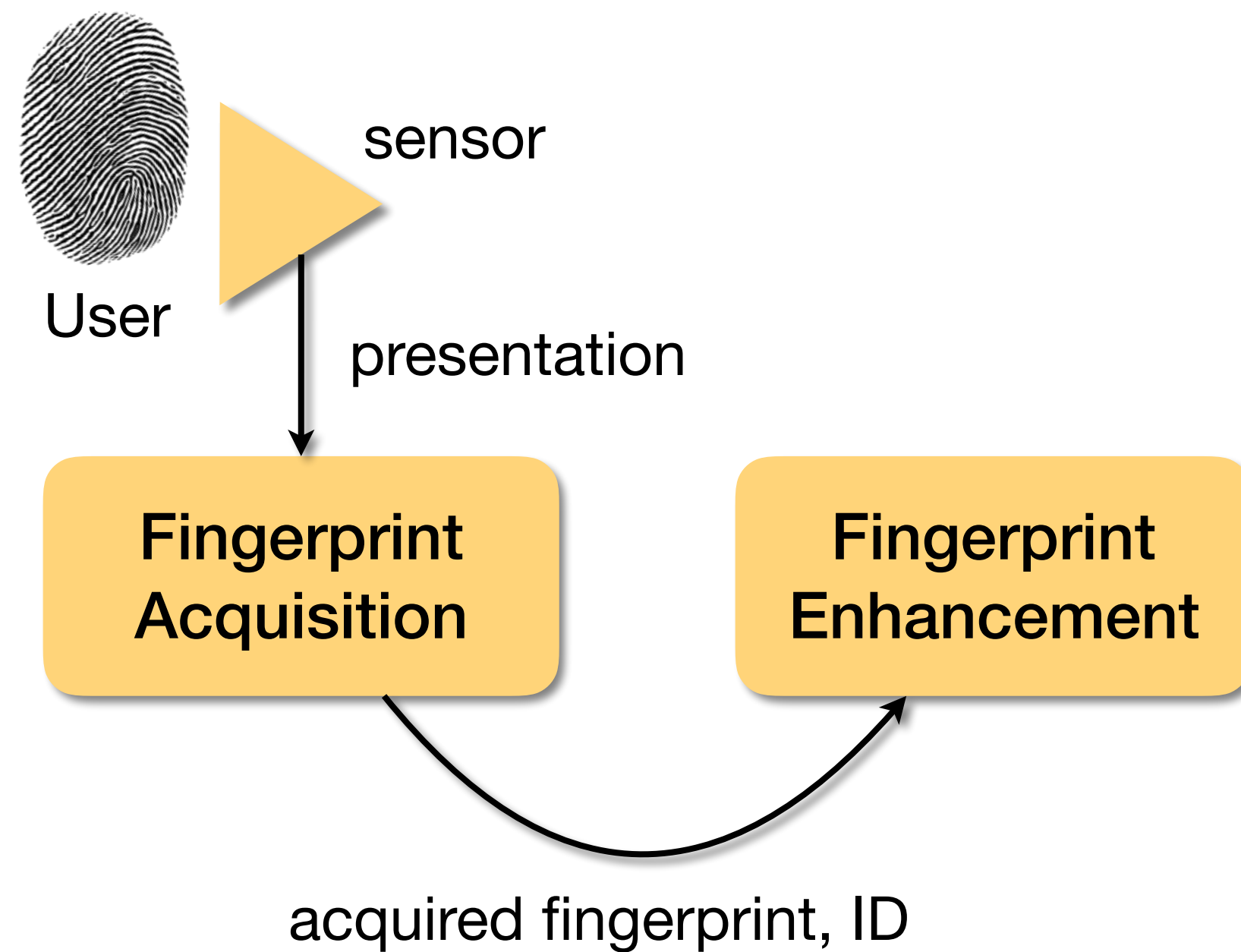
Be Aware

Besides the aforementioned techniques, there are much more sophisticated and effective ones.

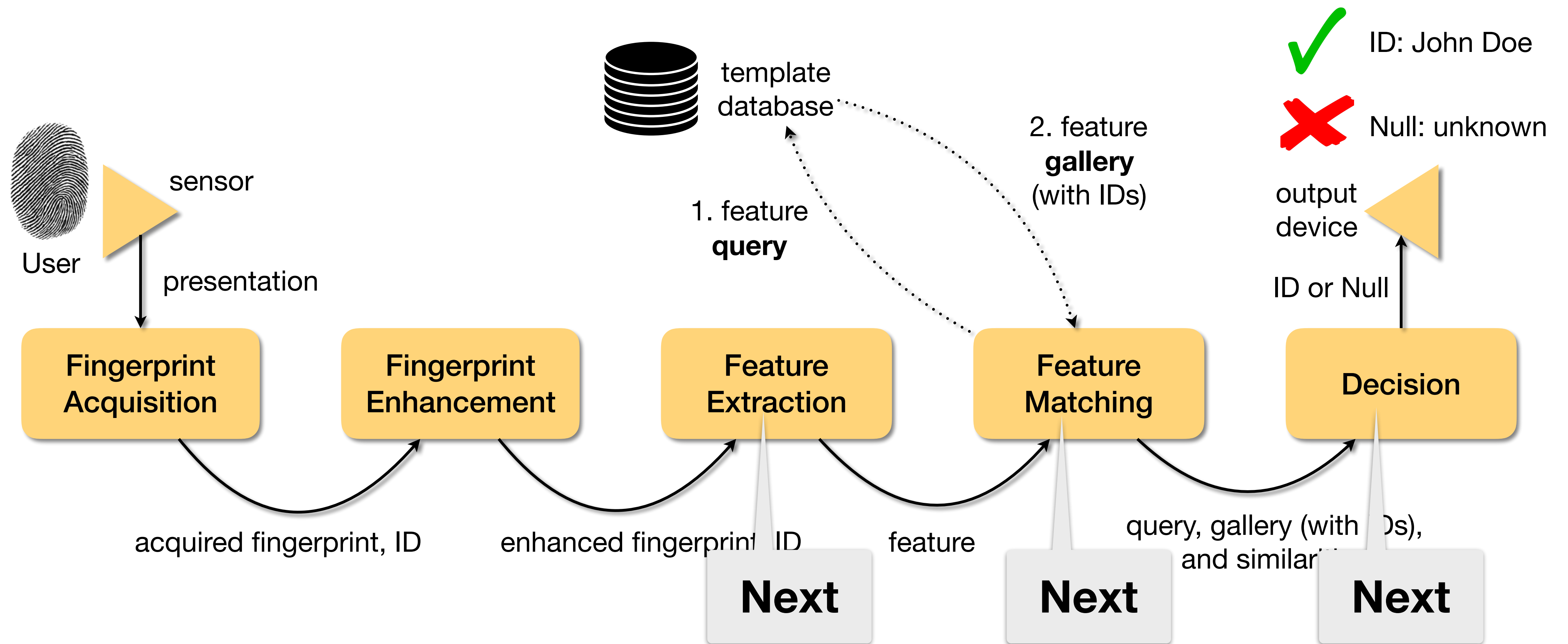
We'll see some of them in practice and with more details during our next coding class.



Fingerprint Recognition



Fingerprint Recognition



S'up Next?

Even more about fingerprints

Fingerprint feature extraction methods.

Fingerprint matching methods.

Visit to see fingerprint sensors.



Acknowledgments

This material is heavily based on
Dr. Adam Czajka's and Dr. Walter Scheirer's courses.
Thank you, professors, for kindly allowing me to use your material.

<https://engineering.nd.edu/profiles/aczajka>
<https://www.wjscheirer.com/>