

Fingerprint Recognition II

COMP 388-002/488-002 Biometrics

Daniel Moreira
Fall 2023



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UNIVERSITY CHICAGO

Today you will...

Get to know
Fingerprint acquisition and enhancement.



Today's attendance

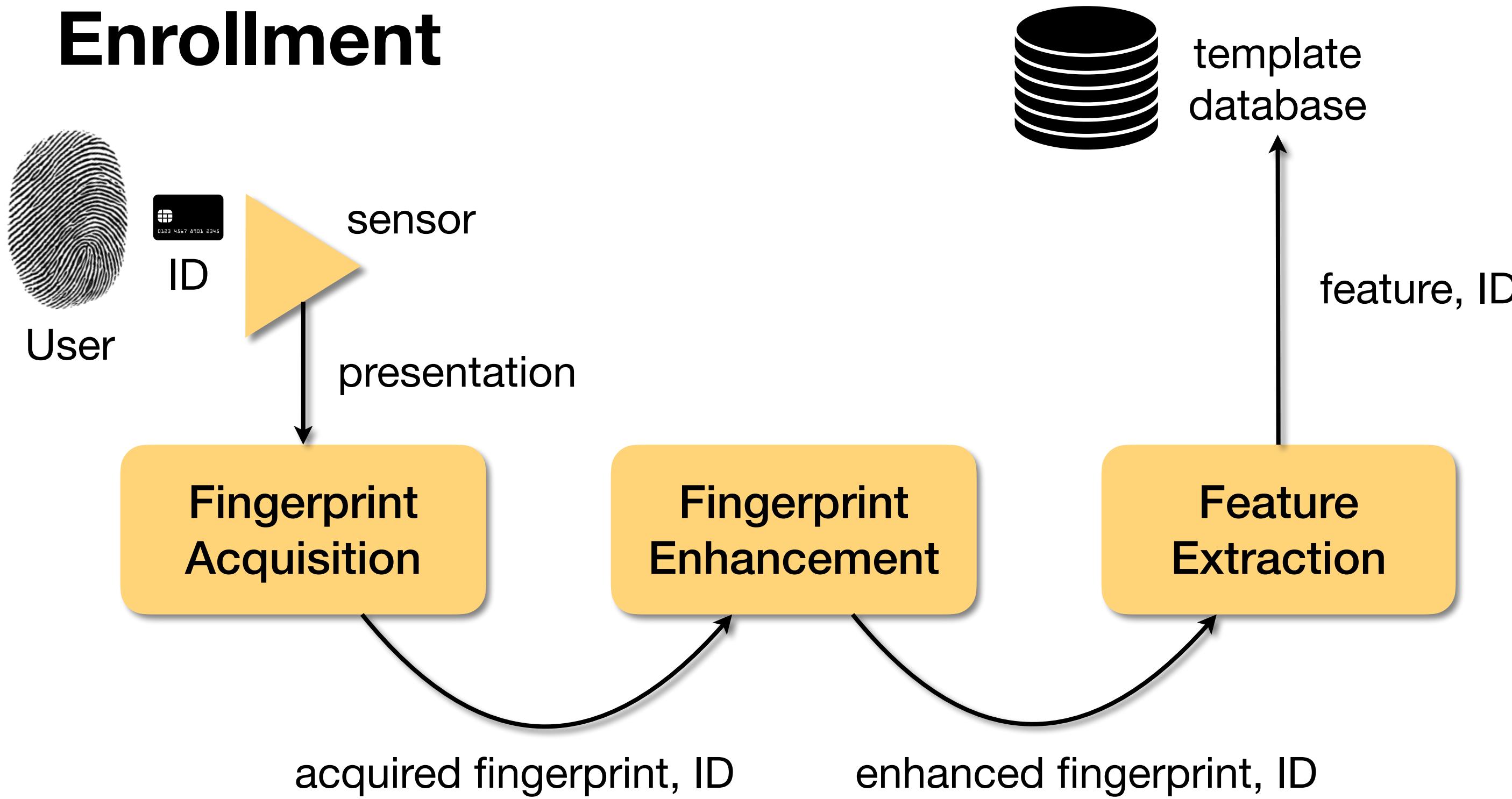
Please fill out the form

<https://forms.gle/j5A7J7GmoHro4ohh8>



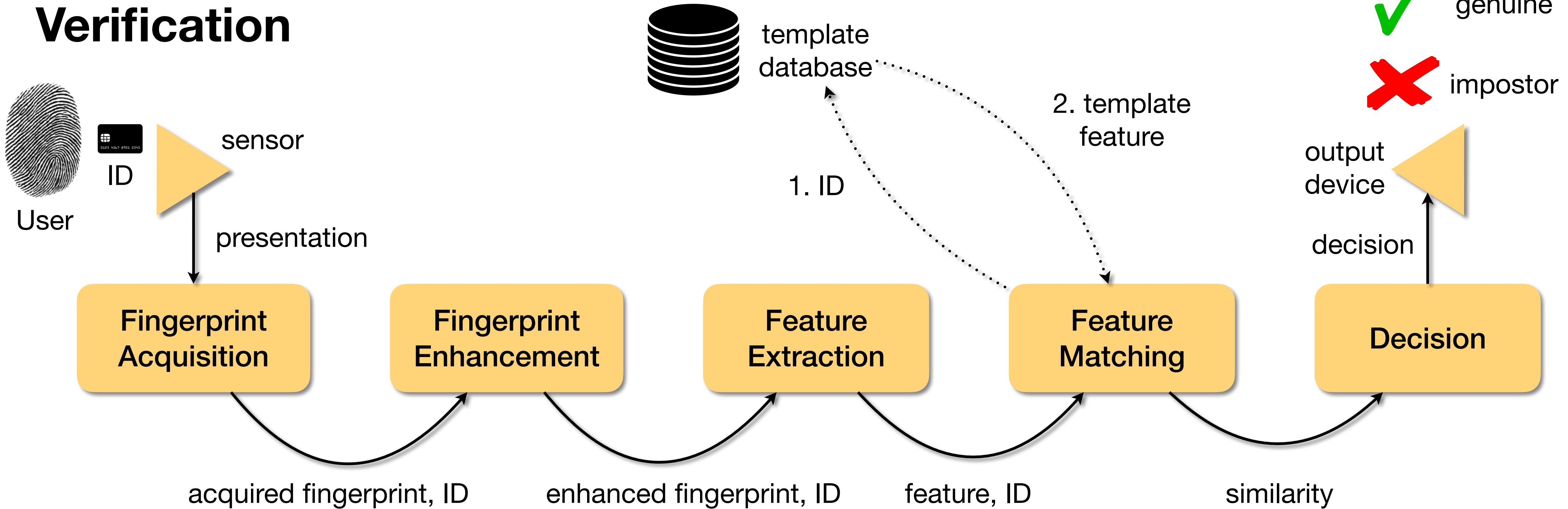
Fingerprint Recognition

Enrollment



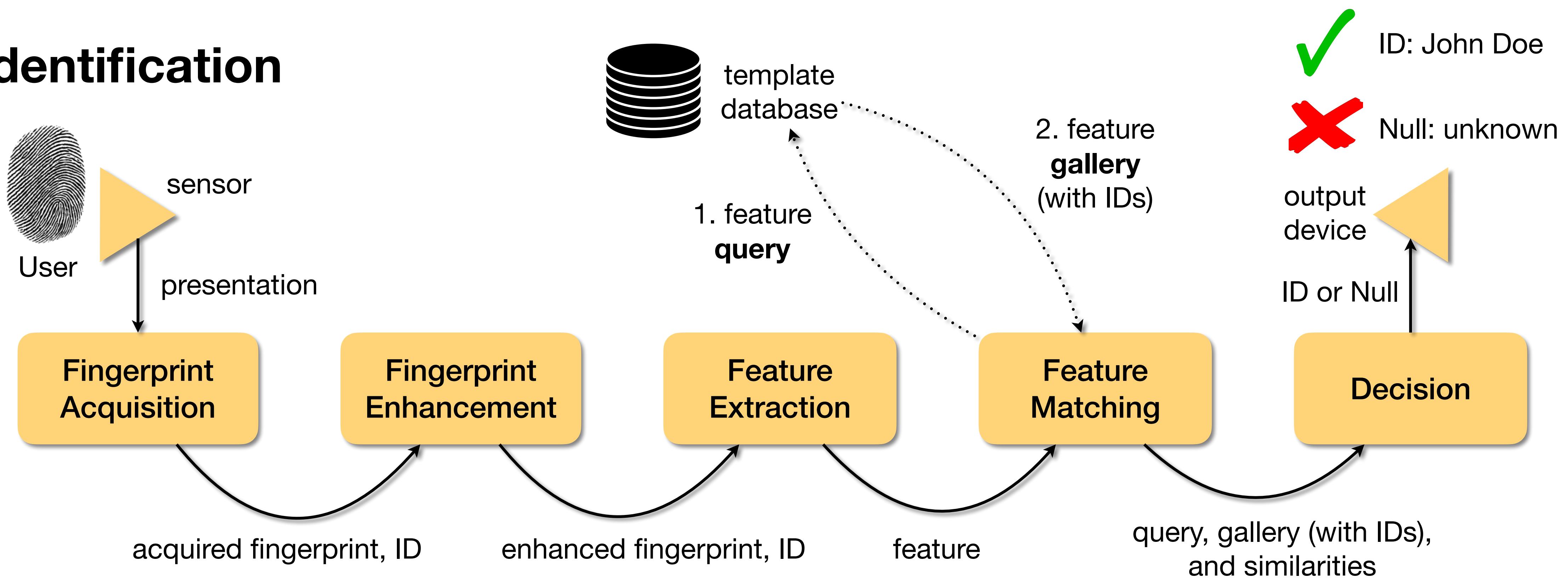
Fingerprint Recognition

Verification

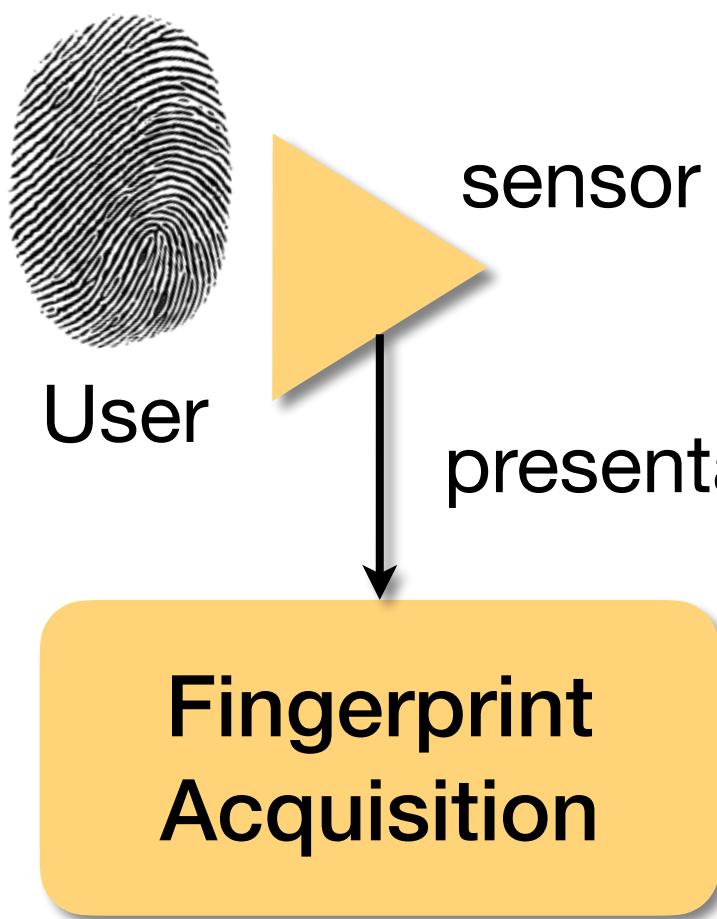


Fingerprint Recognition

Identification

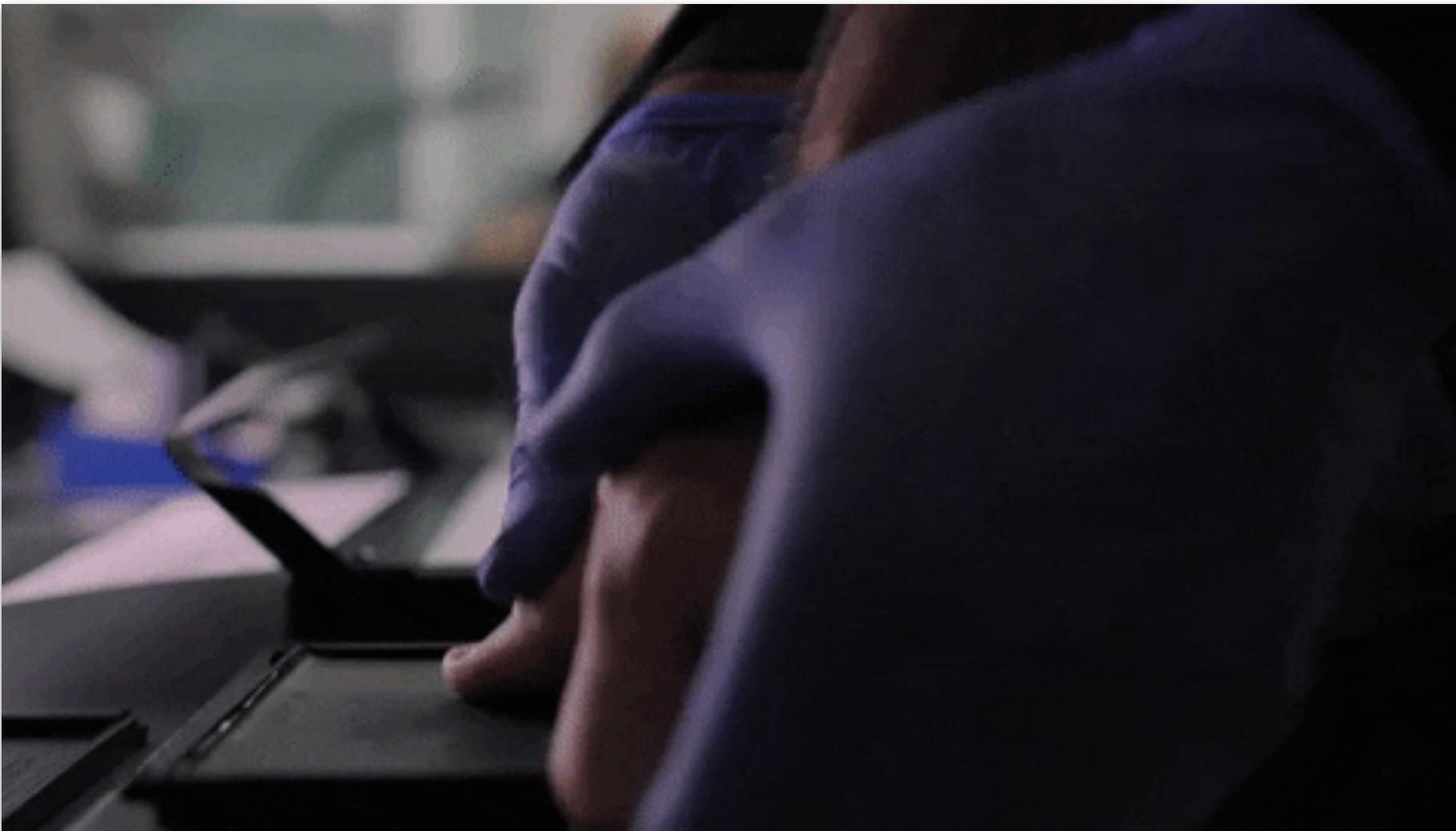


Fingerprint Recognition



Acquisition

Off-line versus On-line



Acquisition

Off-line Acquisition

Same fingerprint.



rolled inked fingerprint



slap inked fingerprint



latent fingerprint

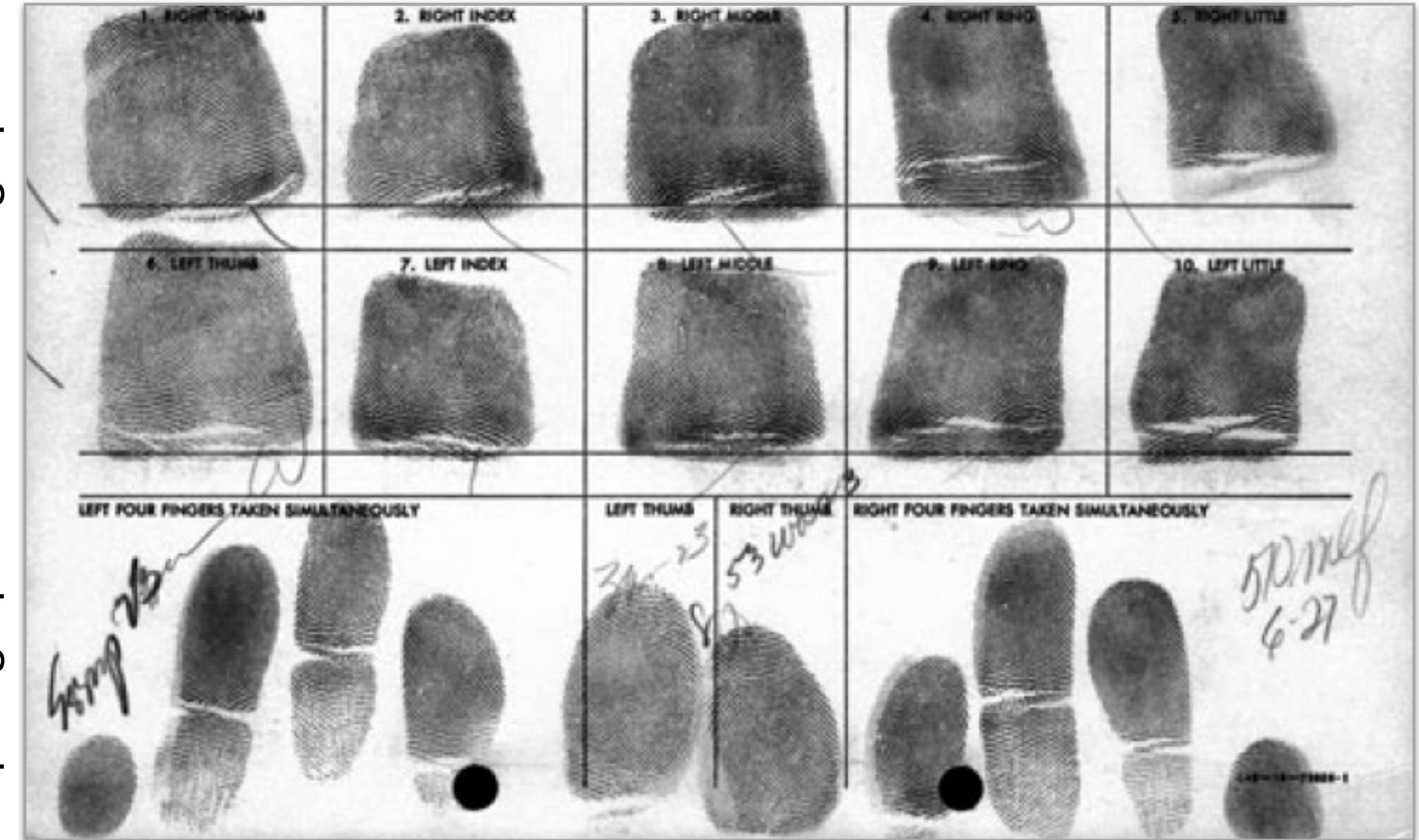
Jain, Ross, and Nadakumar
Introduction to Biometrics
Springer Books, 2011

Acquisition

Off-line Acquisition

Scanning of dactyloscopy cards.

slap fingerprints
rolled fingerprints



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

Acquisition

Off-line Acquisition

Photographing of latent fingerprints.



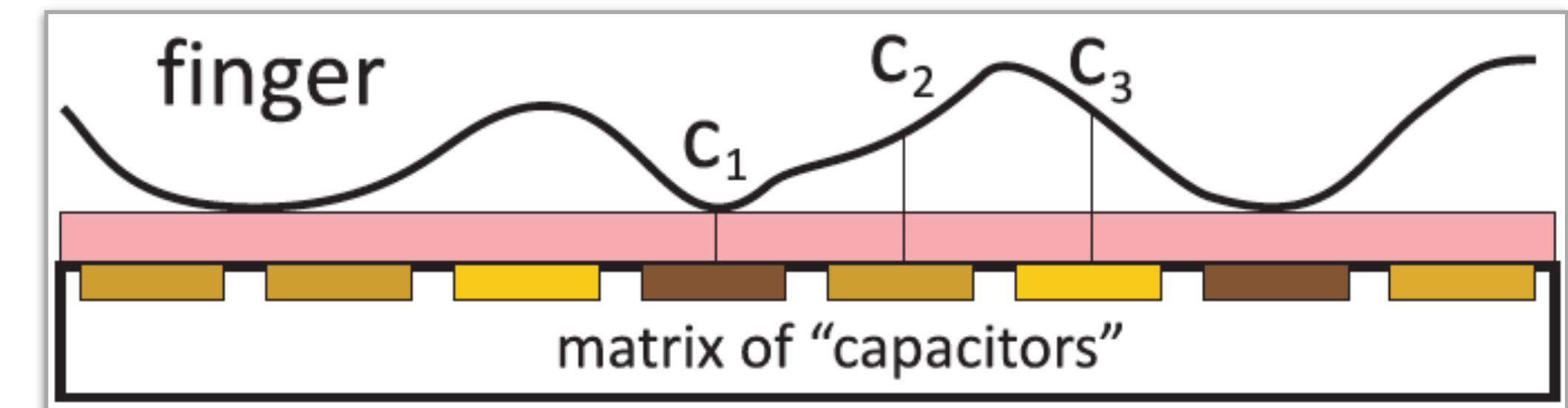
Source: Dr. Adam Czajka

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 moisture.

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/>

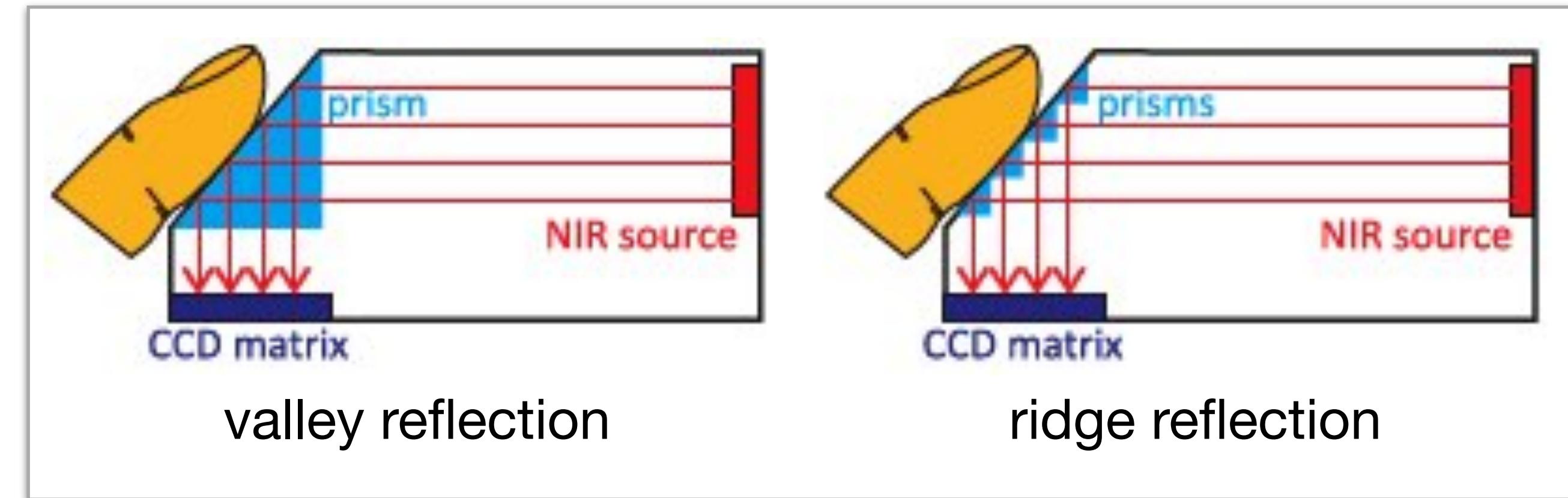
Acquisition

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.

Source: Dr. Adam Czajka



Typical resolution: 400-1000 dpi.

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



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Acquisition

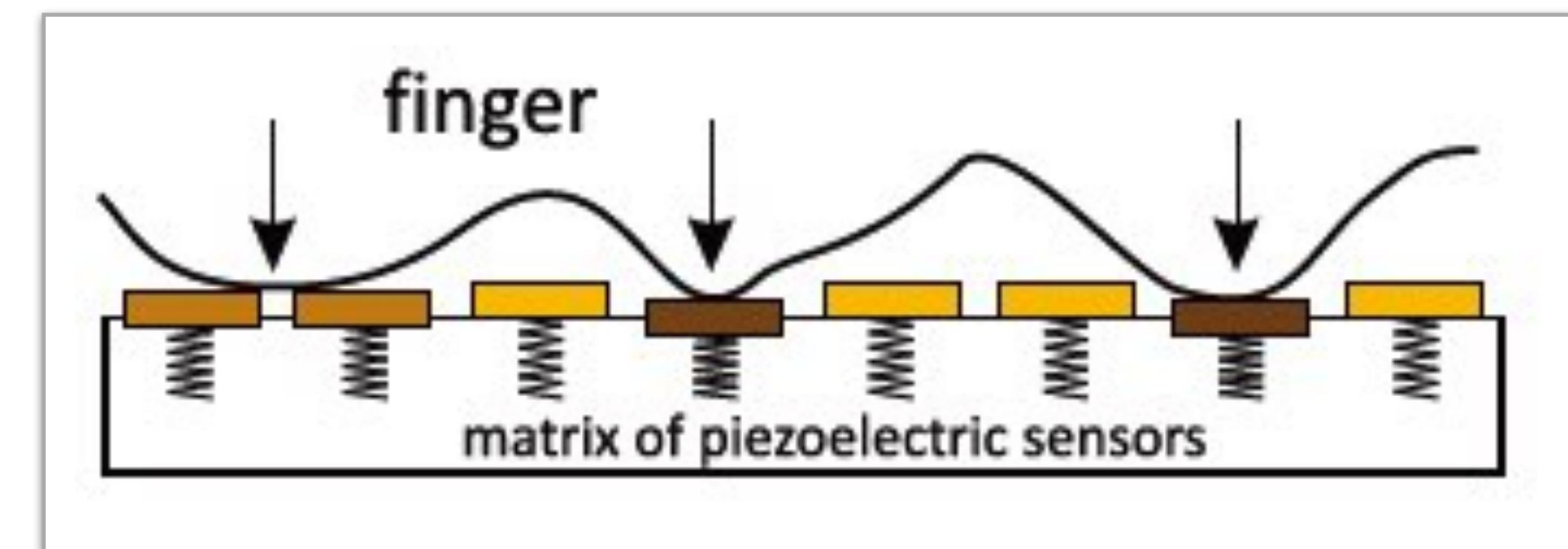
On-line Acquisition

Pressure sensors (3/6)

Also known as piezoelectric.

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

Source: Dr. Adam Czajka



Robust to moisture.

Typical resolution: 400 dpi.

Acquisition

On-line Acquisition

Pressure sensors (3/6)

Device and sample.



BMF/Hitachi
Source: Dr. Adam Czajka



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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

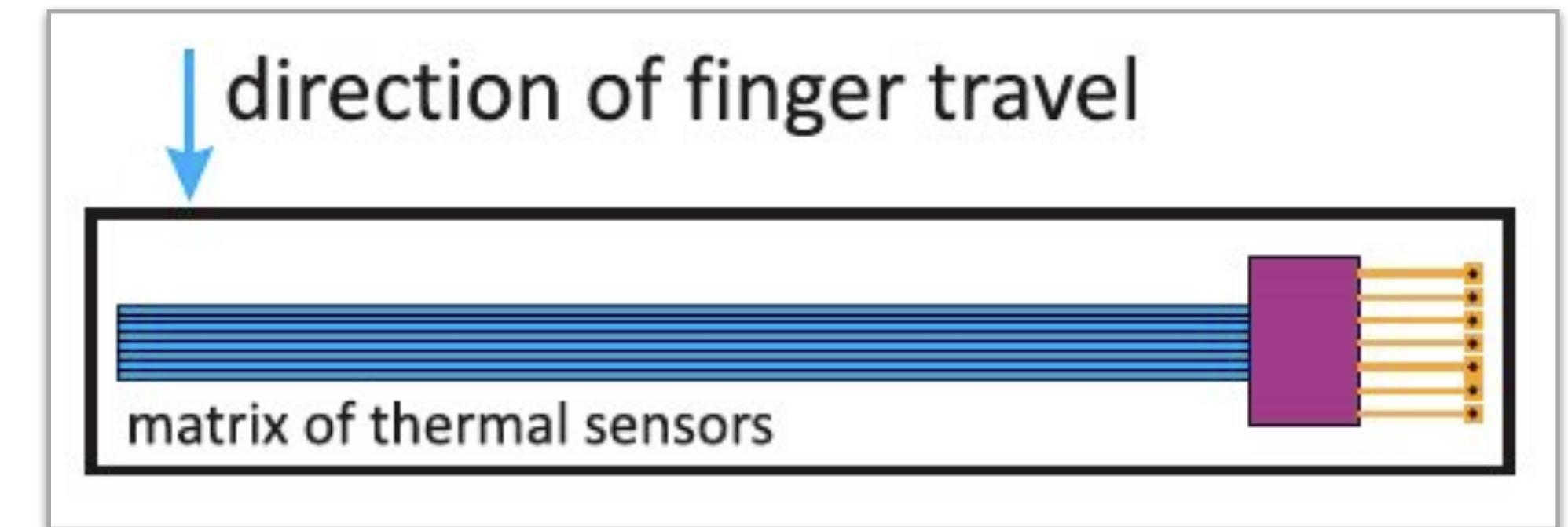
Thermal sensors (4/6)

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.



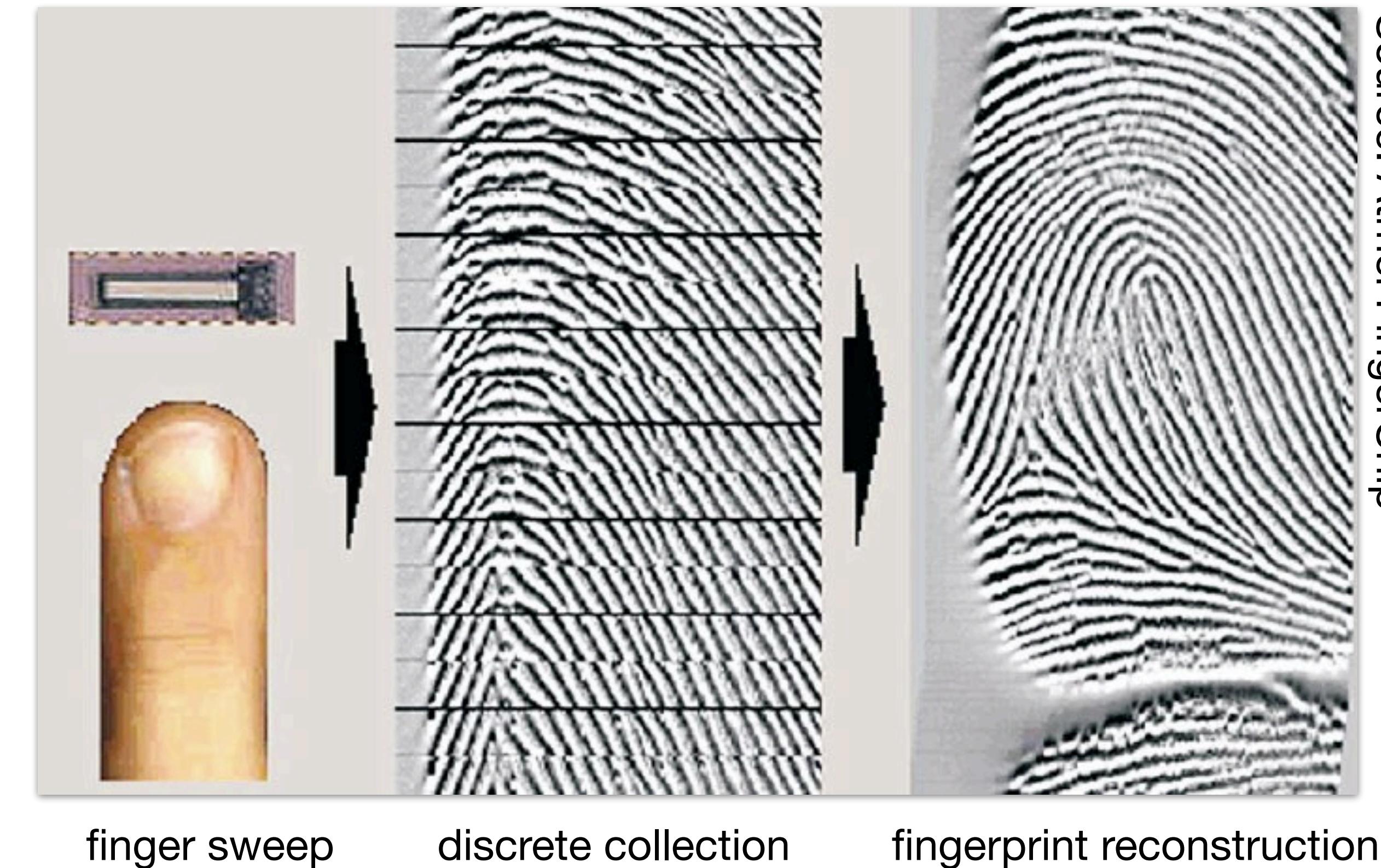
Source: Dr. Adam Czajka

Acquisition

On-line Acquisition

Thermal sensors (4/6)

Example: Atmel FingerChip
Sample generation.



Source: Atmel FingerChip

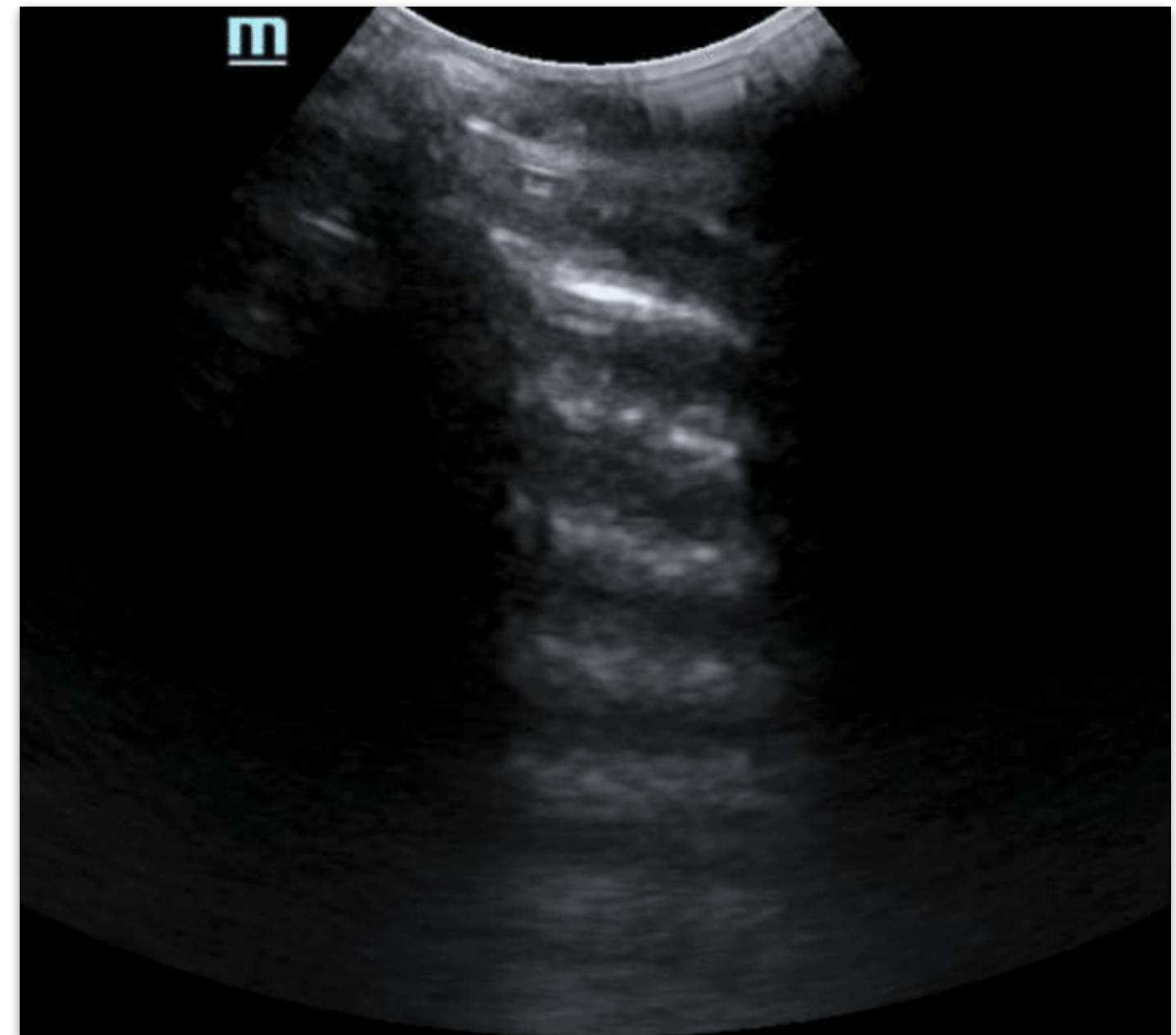
Acquisition

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.



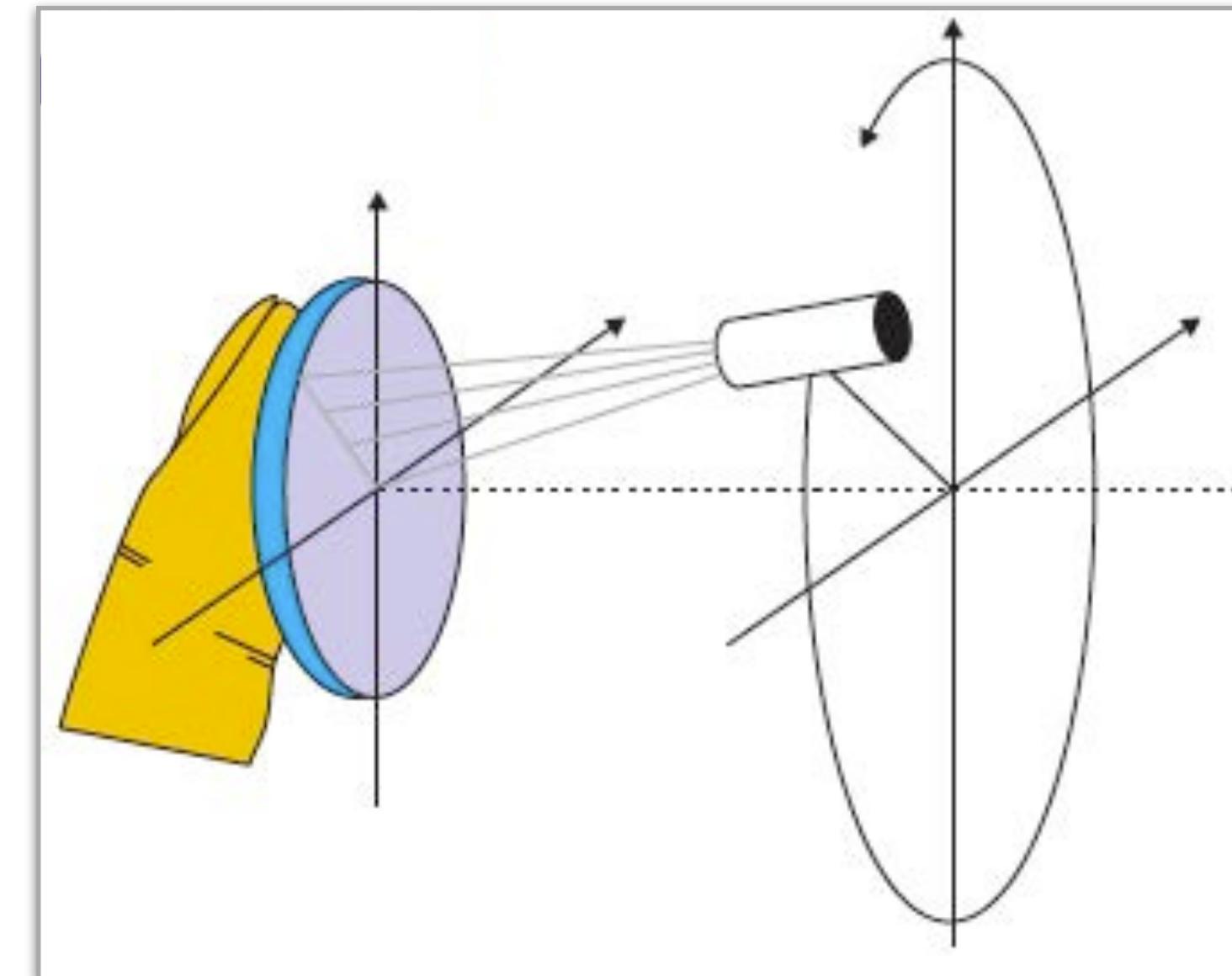
Acquisition

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

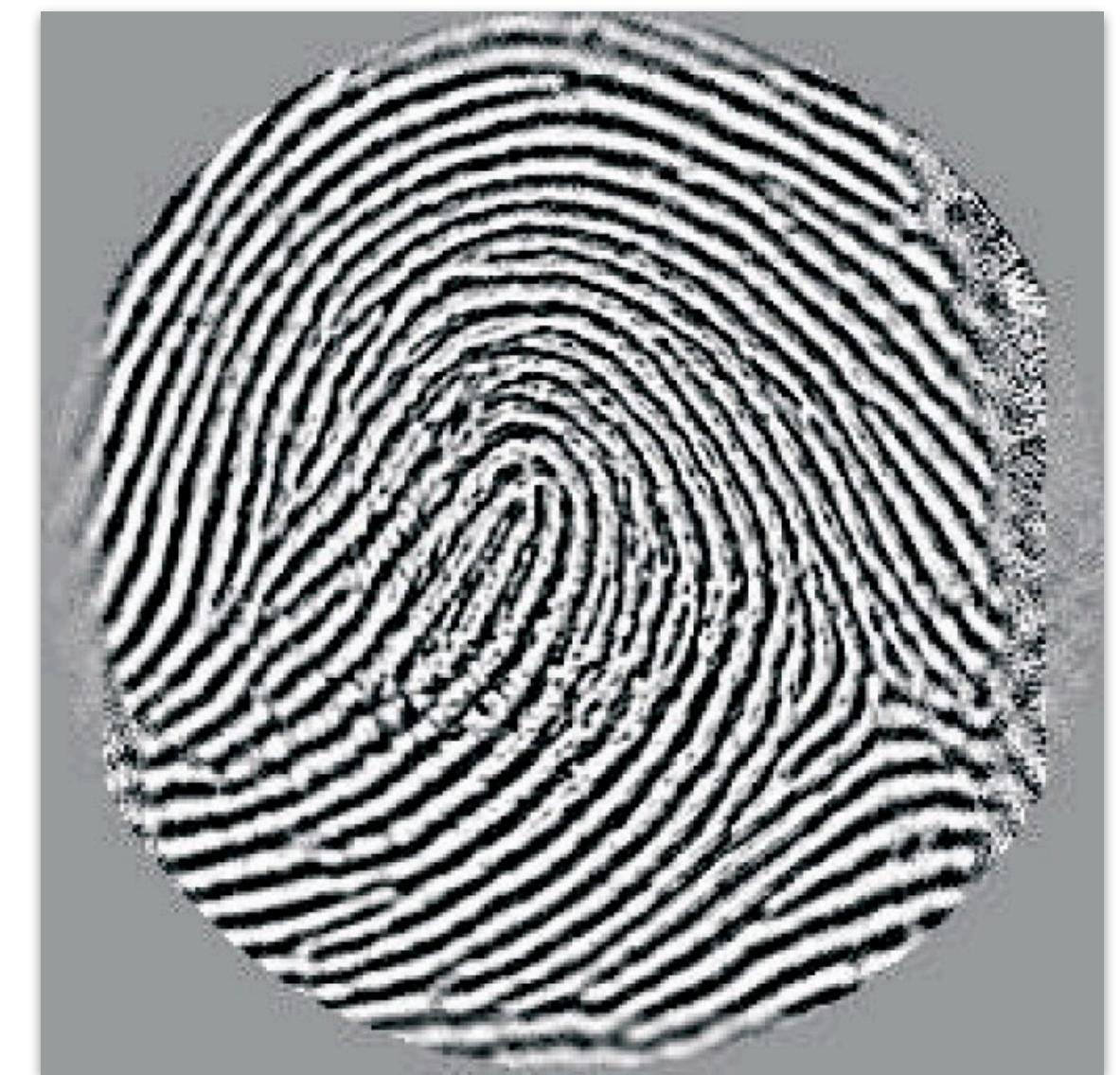
More expensive. Typical resolution: 250 dpi.
Harder to be spoofed (due to ultrasounds penetration).

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



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Acquisition

On-line Acquisition

Touchless sensor (6/6)

3D imaging with CCD sensor.

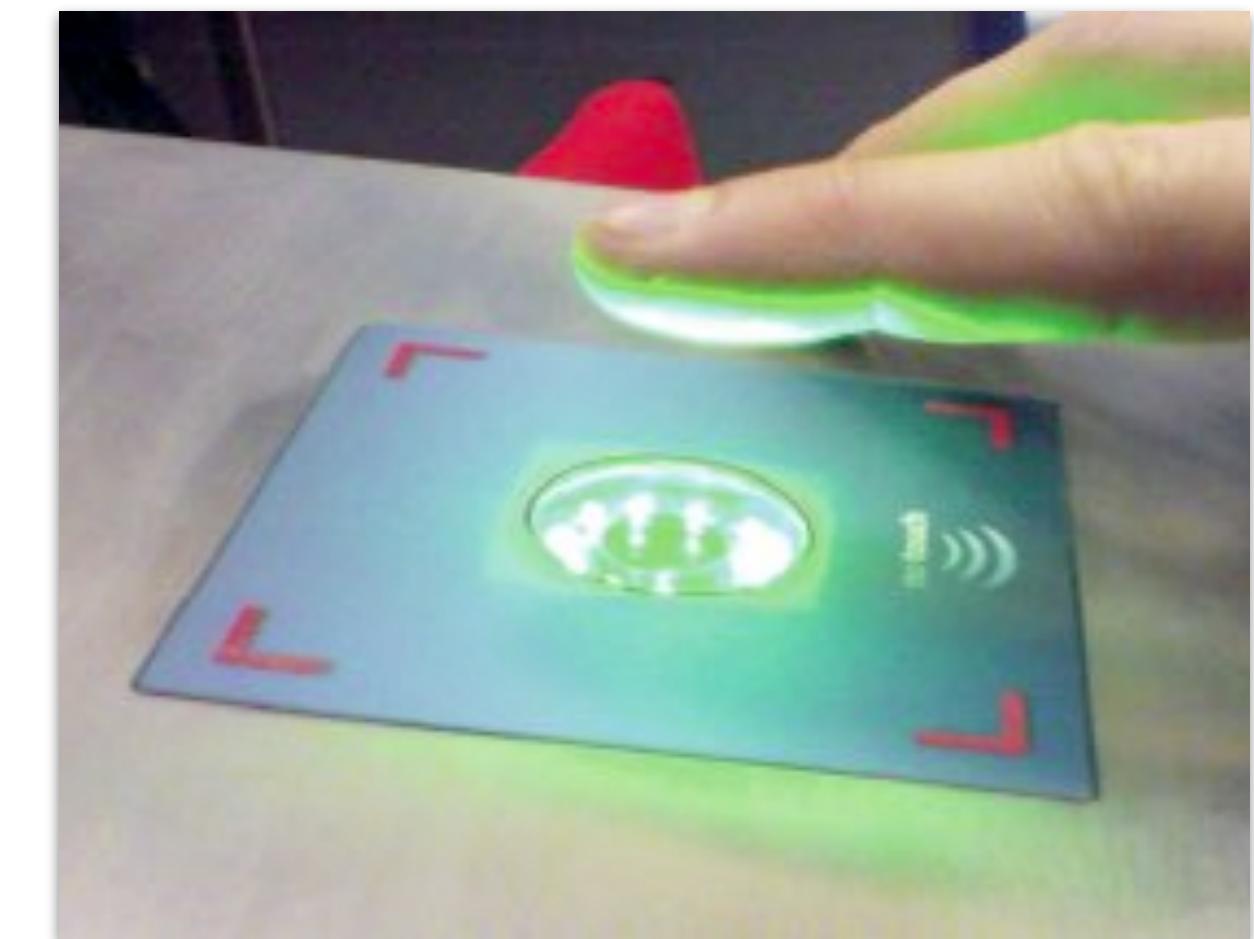
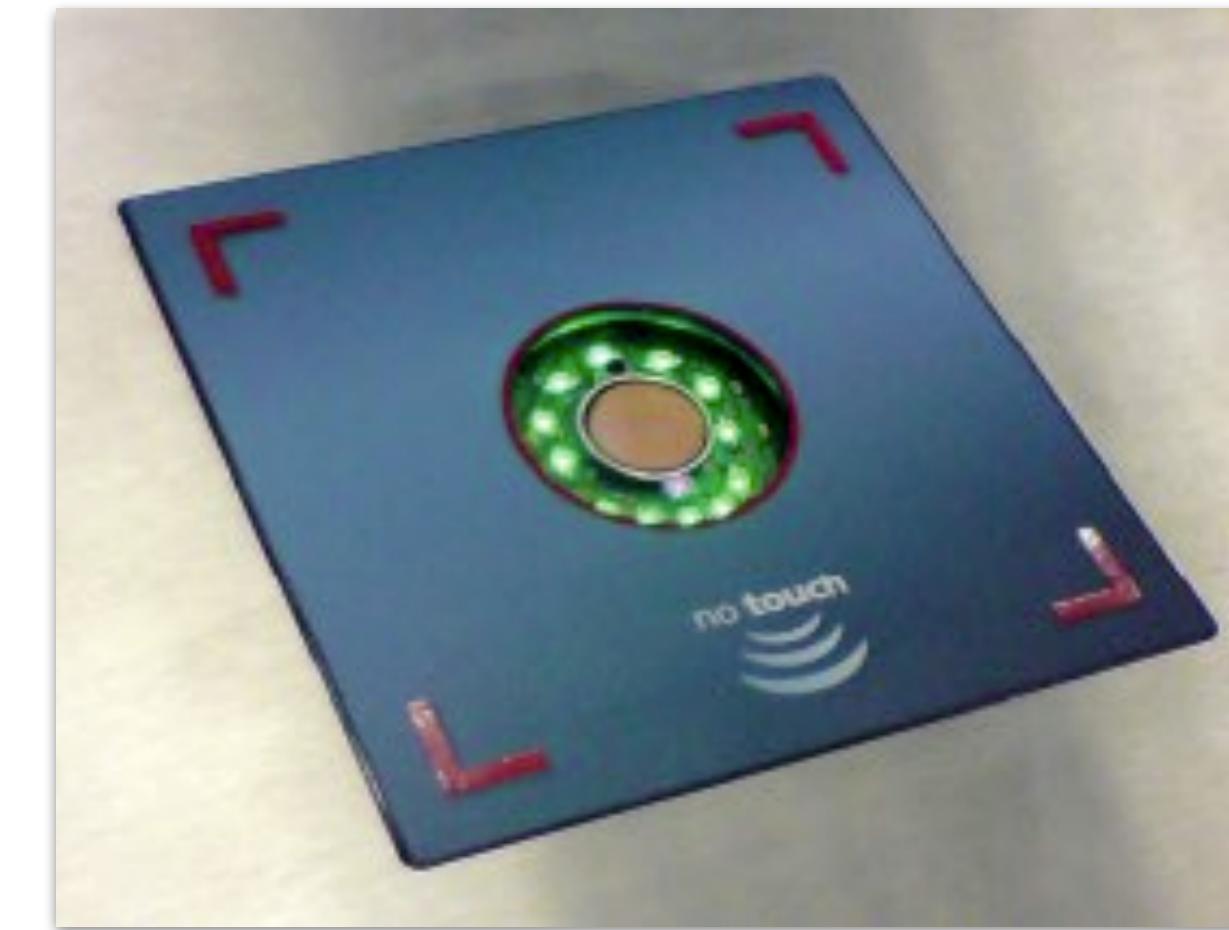


Acquisition

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/>

Smithsonian
MAGAZINE

SUBSCRIBE SMARTNEWS HISTORY SCIENCE INGENUITY ARTS & CULTURE TRAVEL

Adermatoglyphia: The Genetic Disorder Of People Born Without Fingerprints

The extremely rare disease causes no problems—apart from occasional difficulties with the authorities



The finger pads of a person with adermatoglyphia are entirely smooth. (Photo by Sprecher et. al.)

By Joseph Stromberg
SMITHSONIANMAG.COM
JANUARY 14, 2014

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.



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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?

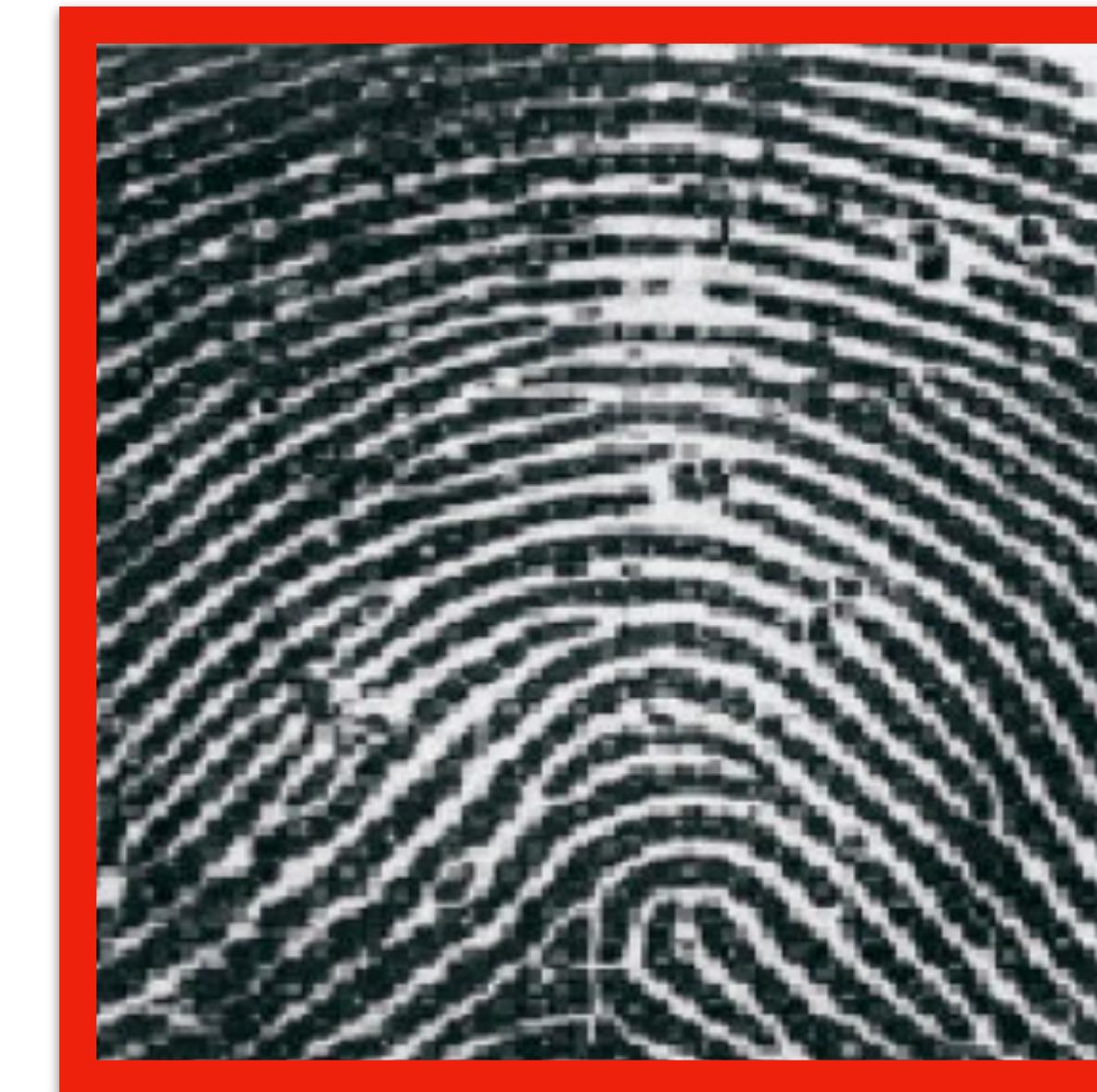
From capacitive sensor

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



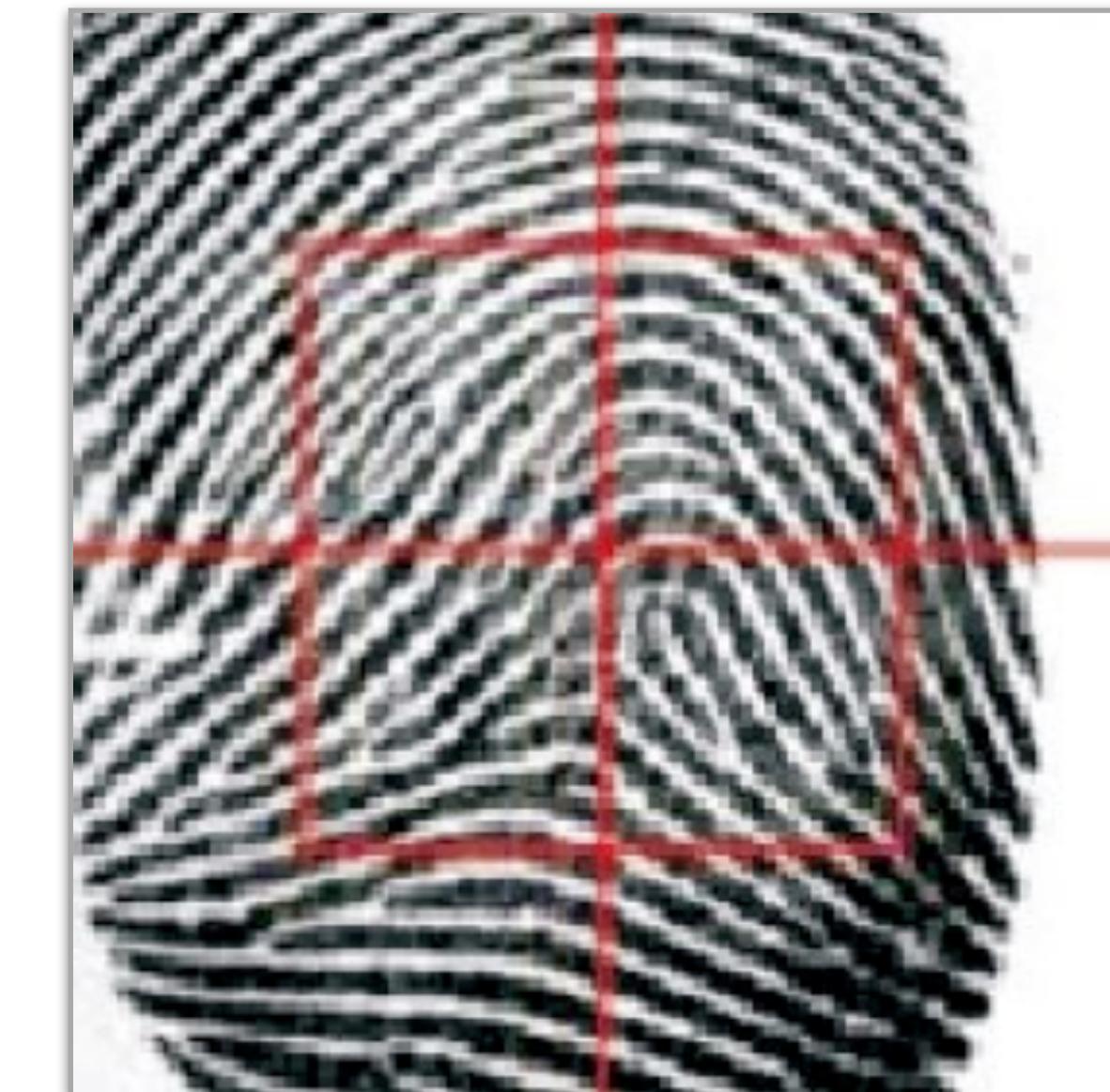
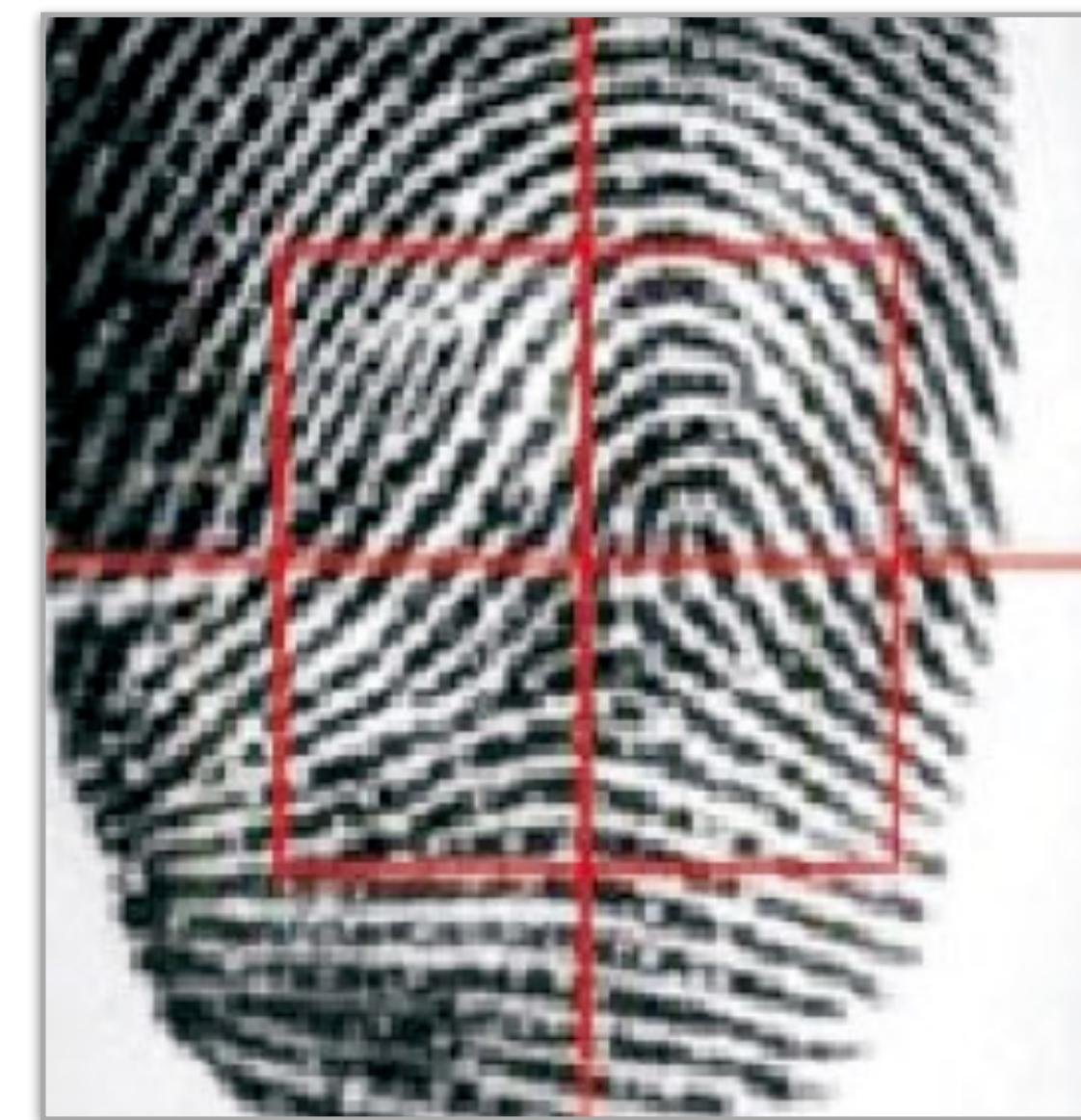
authentic



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?

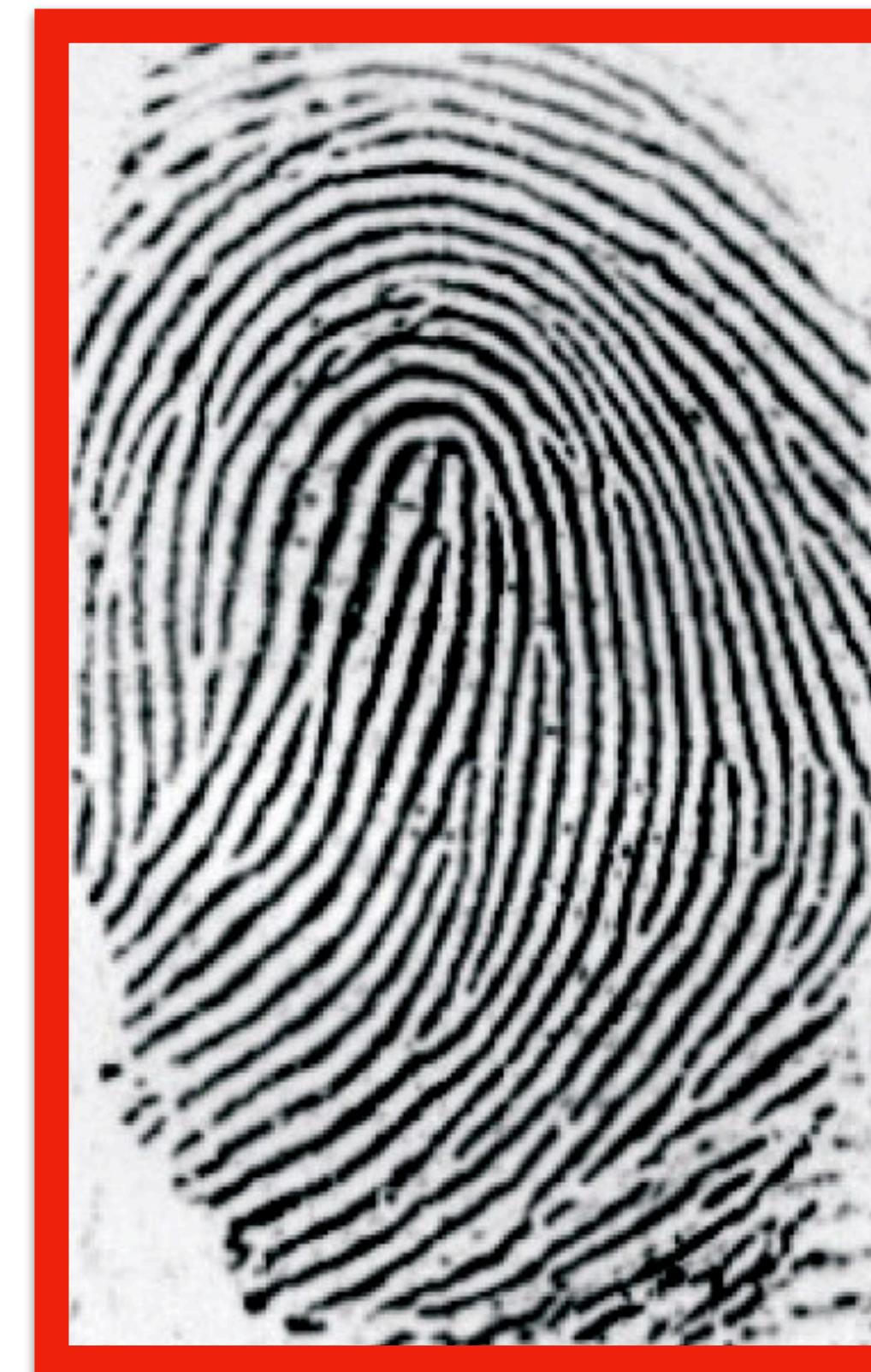
From optical sensor



Fake or authentic?

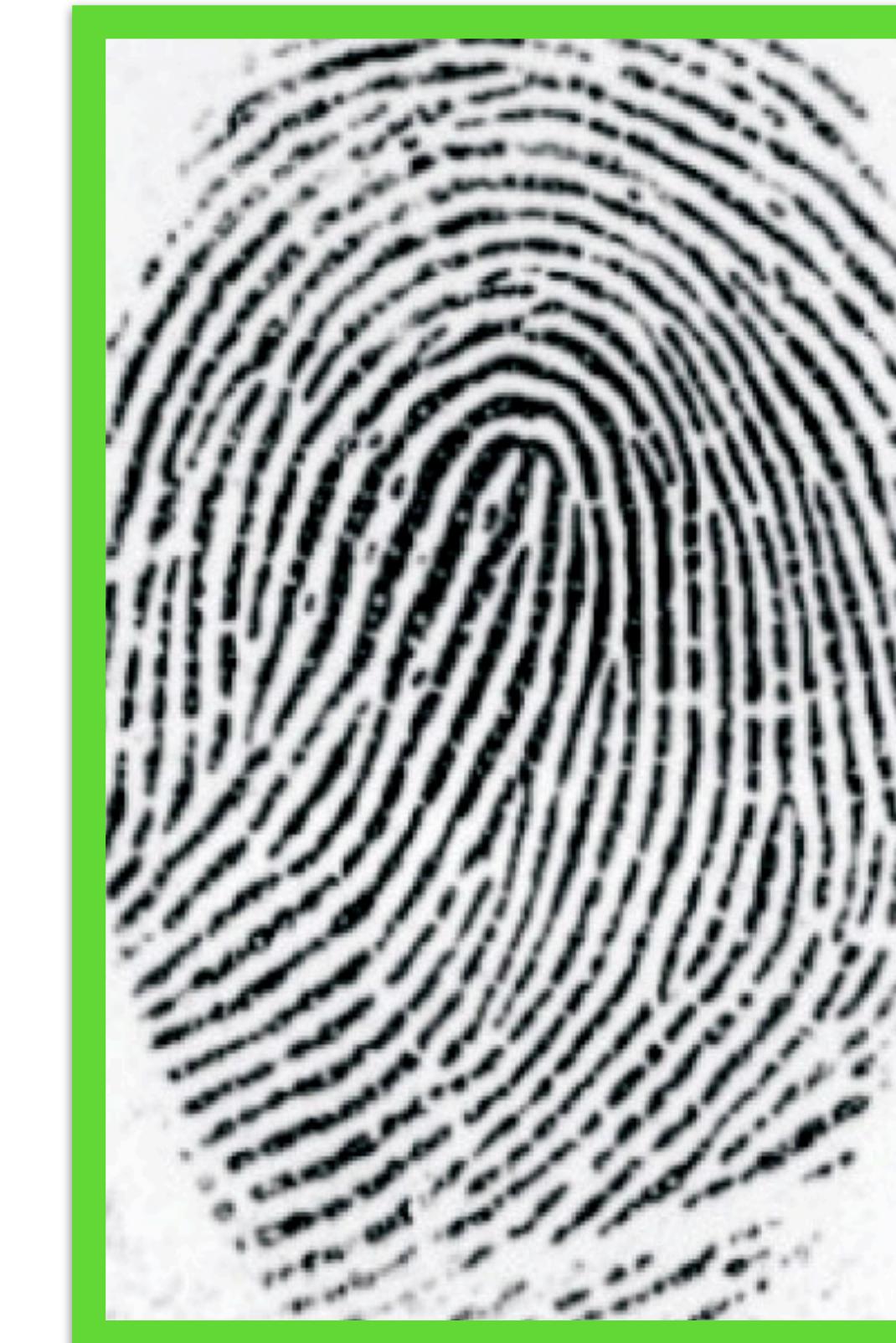
From optical sensor

wood glue

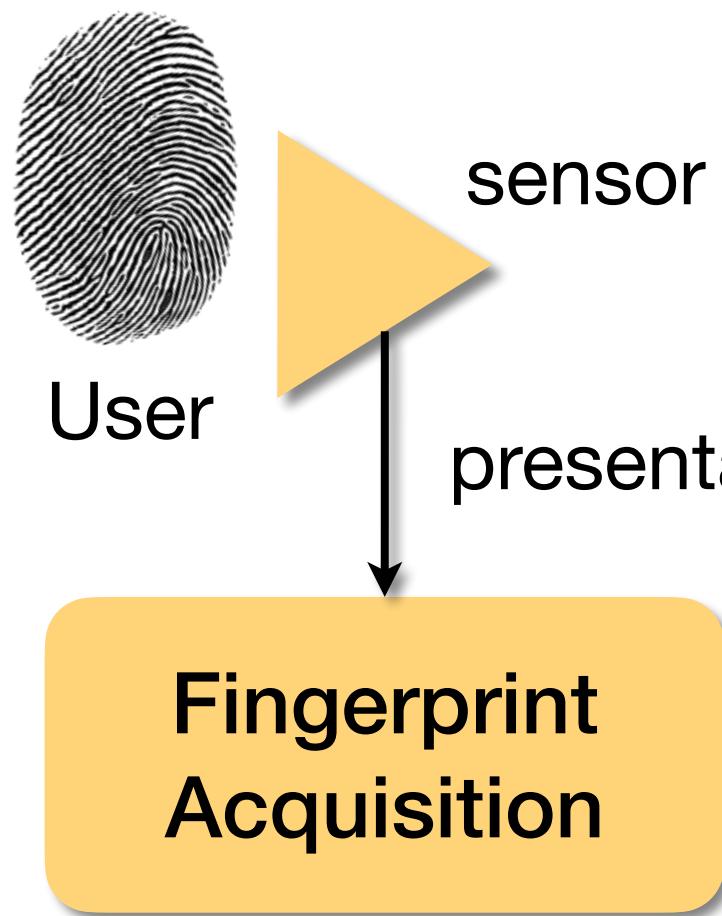


Source: Dr. Adam Czajka

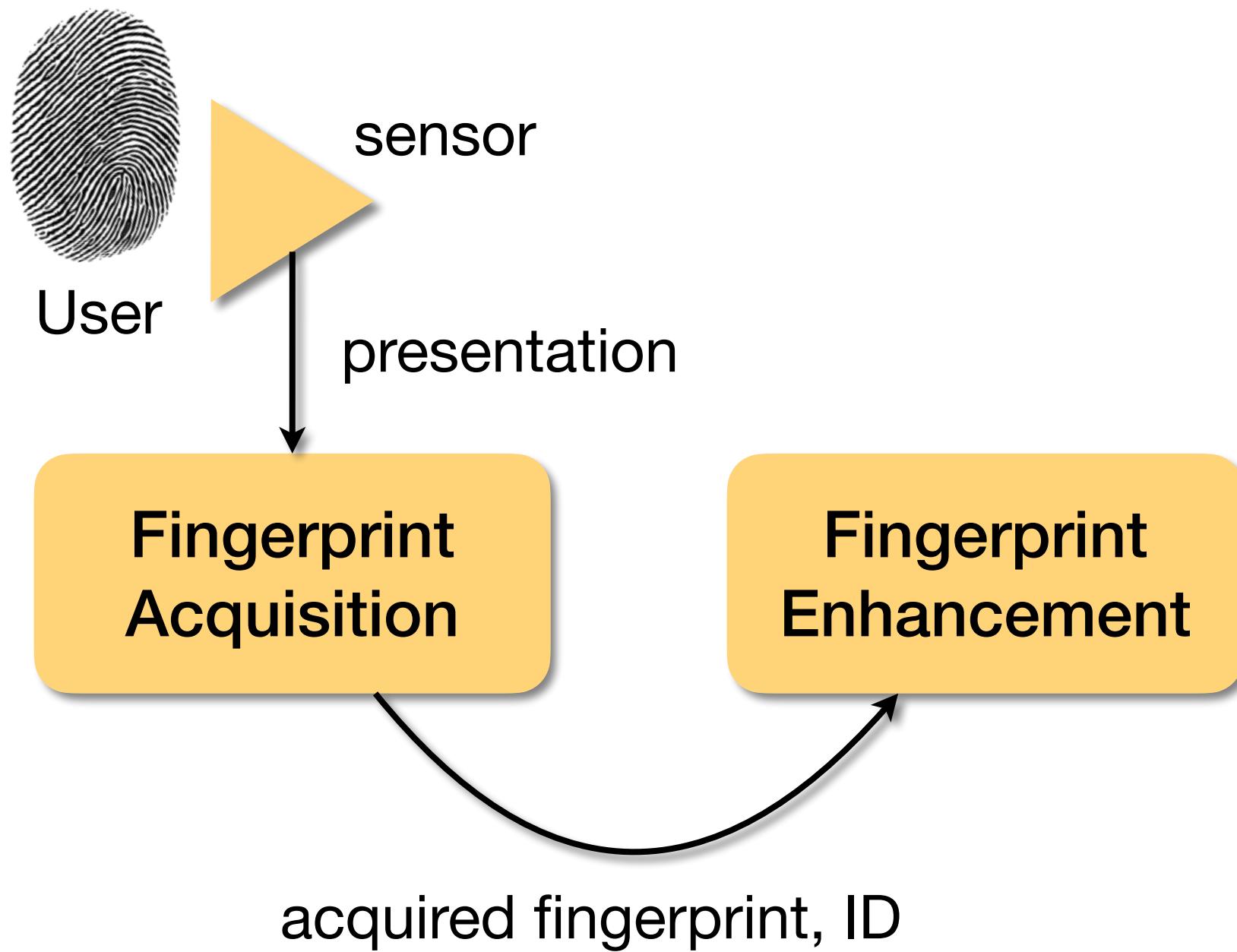
authentic



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

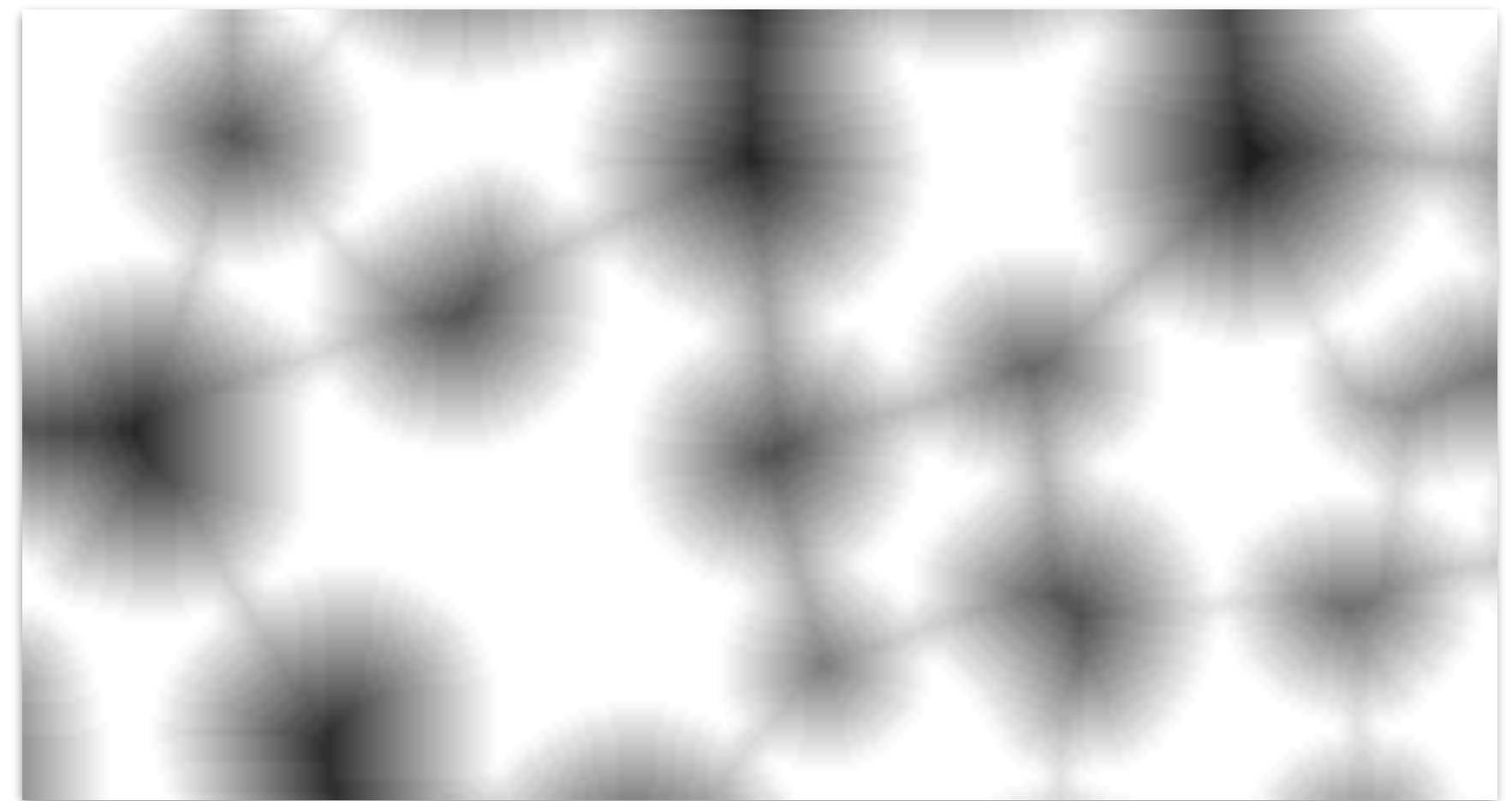
Tasks

Enhancement of image contrast.

Enhancement of ridges and valleys.

Content segmentation.

Others.



Enhancement

Image Processing Solutions

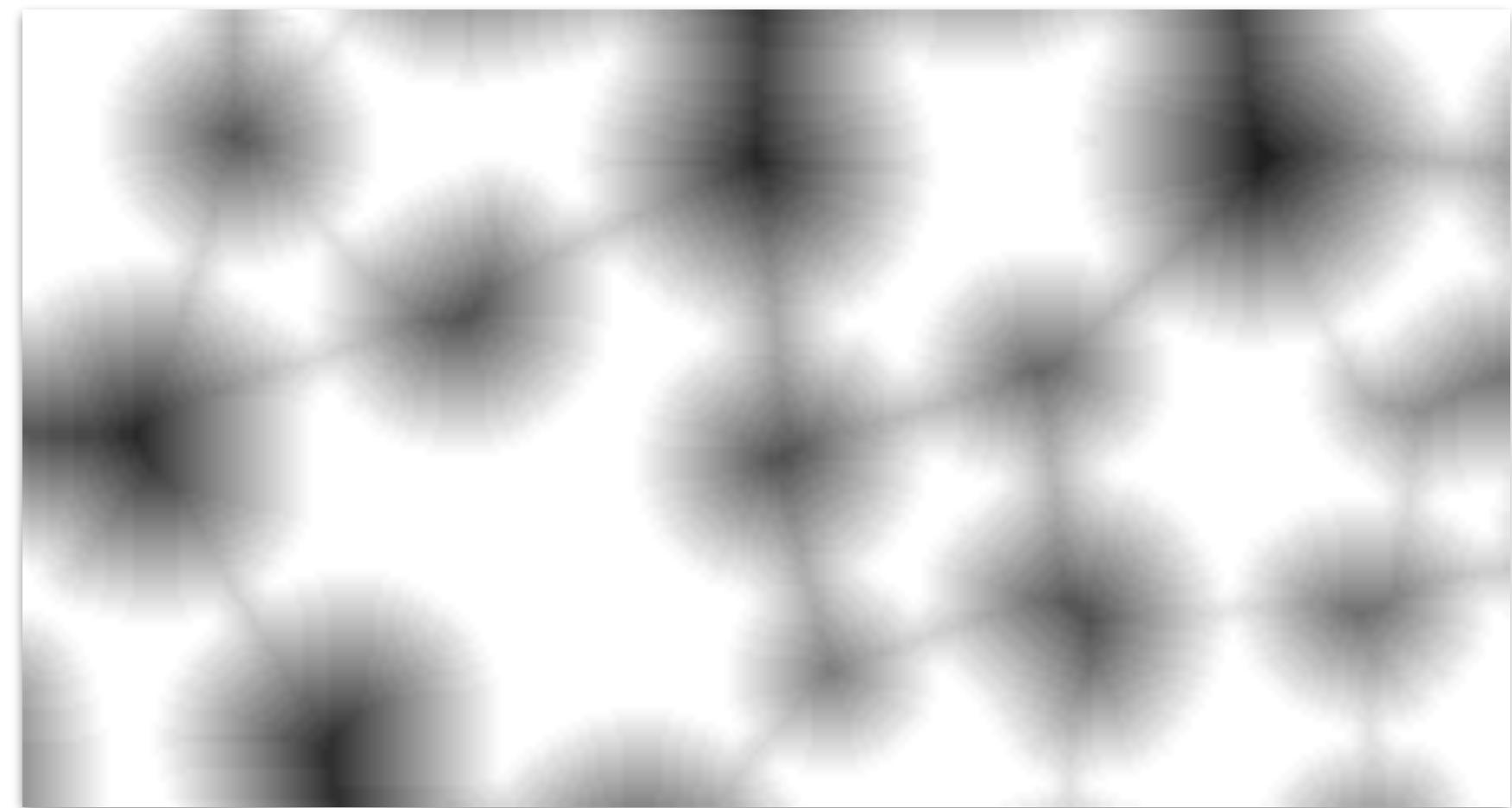
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Enhancement

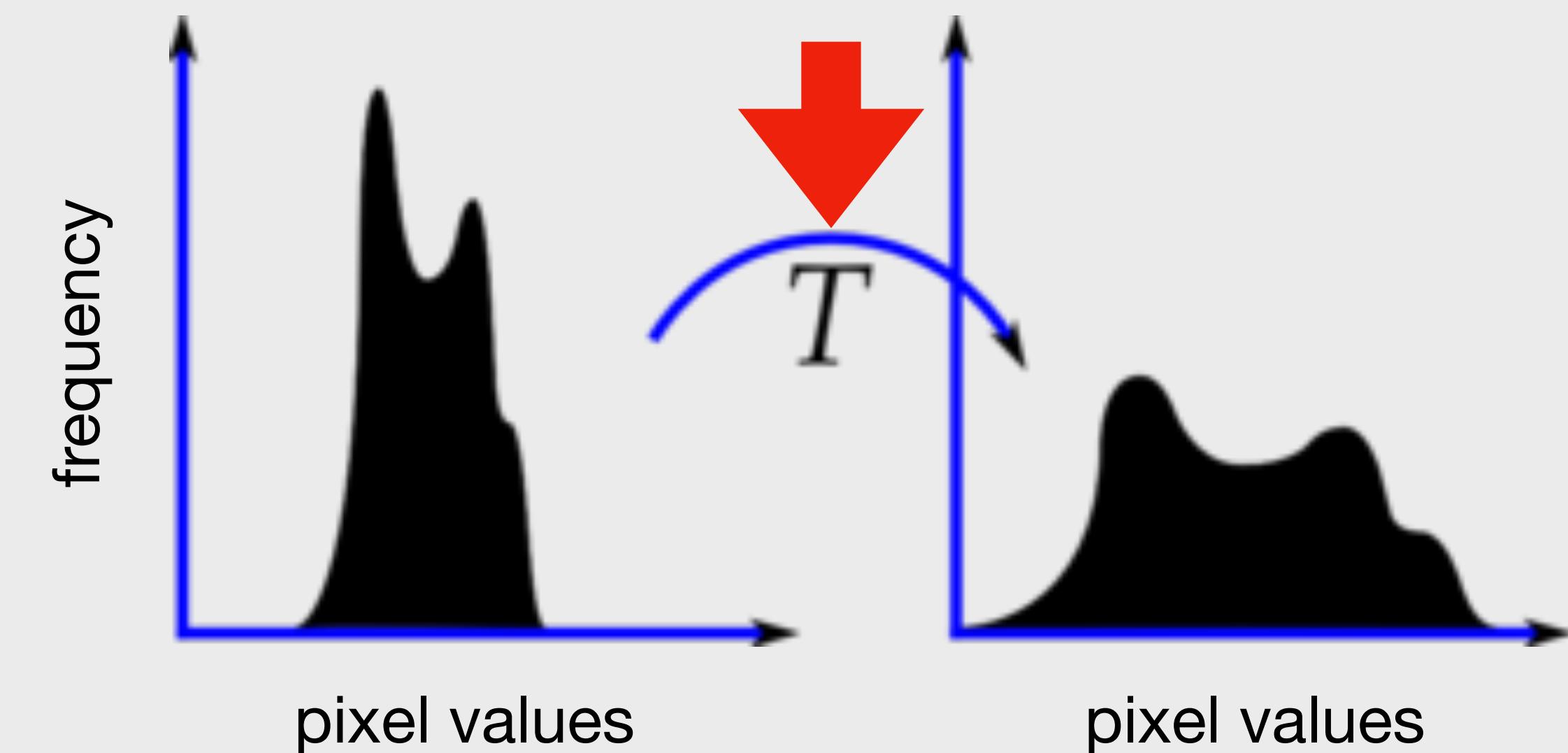
Image Contrast

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.

For a target image...



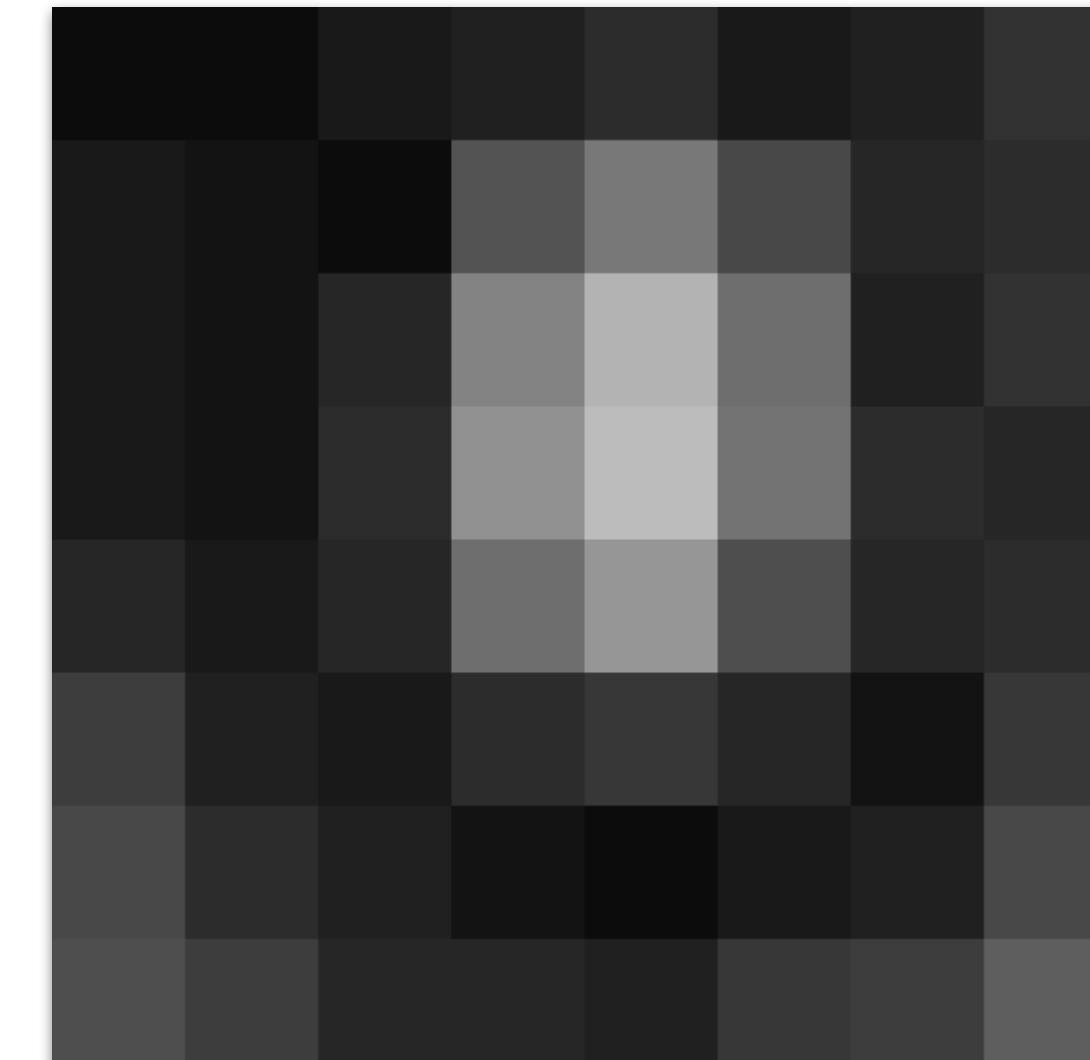
Enhancement

Color Histogram Equalization

Simple implementation

Toy Case

52	55	61	59	79	61	76	61
62	59	55	104	94	85	59	71
63	65	66	113	144	104	63	72
64	70	70	126	154	109	71	69
67	73	68	106	122	88	68	68
68	79	60	70	77	66	58	75
69	85	64	58	55	61	65	83
70	87	69	68	65	73	78	90



Source: https://en.wikipedia.org/wiki/Histogram_equalization

Enhancement

Color Histogram Equalization

Simple implementation

Toy Case

1. Compute cumulative distribution function (CDF)

52	55	61	59	79	61	76	61
62	59	55	104	94	85	59	71
63	65	66	113	144	104	63	72
64	70	70	126	154	109	71	69
67	73	68	106	122	88	68	68
68	79	60	70	77	66	58	75
69	85	64	58	55	61	65	83
70	87	69	68	65	73	78	90

color histogram

Value	Count								
52	1	64	2	72	1	85	2	113	1
55	3	65	3	73	2	87	1	122	1
58	2	66	2	75	1	88	1	126	1
59	3	67	1	76	1	90	1	144	1
60	1	68	5	77	1	94	1	154	1
61	4	69	3	78	1	104	2		
62	1	70	4	79	2	106	1		
63	2	71	2	83	1	109	1		

Source: https://en.wikipedia.org/wiki/Histogram_equalization

Enhancement

Color Histogram Equalization

Simple implementation

Toy Case

1. Compute cumulative distribution function (CDF)

52	55	61	59	79	61	76	61
62	59	55	104	94	85	59	71
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64	70	70	126	154	109	71	69
67	73	68	106	122	88	68	68
68	79	60	70	77	66	58	75
69	85	64	58	55	61	65	83
70	87	69	68	65	73	78	90

v, Pixel Intensity	cdf(v)
52	1
55	4
58	6
59	9
60	10
61	14
62	15
63	17
64	19

Source: https://en.wikipedia.org/wiki/Histogram_equalization

Enhancement

Color Histogram Equalization

Simple implementation

Toy Case

1. Compute cumulative distribution function (CDF)

2. Perform min-max normalization
[0, 255] interval

52	55	61	59	79	61	76	61
62	59	55	104	94	85	59	71
63	65	66	113	144	104	63	72
64	70	70	126	154	109	71	69
67	73	68	106	122	88	68	68
68	79	60	70	77	66	58	75
69	85	64	58	55	61	65	83
70	87	69	68	65	73	78	90

v, Pixel Intensity	cdf(v)	h(v), Equalized v
52	1	0
55	4	12
58	6	20
59	9	32
60	10	36
...		
120	92	241
144	63	251
154	64	255

Source: https://en.wikipedia.org/wiki/Histogram_equalization

Enhancement

Color Histogram Equalization Simple implementation

Toy Case

1. Compute cumulative distribution function (CDF)
2. Perform min-max normalization [0, 255] interval

52	55	61	59	79	61	76	61
62	59	55	104	94	85	59	71
63	65	66	113	144	104	63	72
64	70	70	126	154	109	71	69
67	73	68	106	122	88	68	68
68	79	60	70	77	66	58	75
69	85	64	58	55	61	65	83
70	87	69	68	65	73	78	90

0	12	53	32	190	53	174	53
57	32	12	227	219	202	32	154
65	85	93	239	251	227	65	158
73	146	146	247	255	235	154	130
97	166	117	231	243	210	117	117
117	190	36	146	178	93	20	170
130	202	73	20	12	53	85	194
146	206	130	117	85	166	182	215

Source: https://en.wikipedia.org/wiki/Histogram_equalization

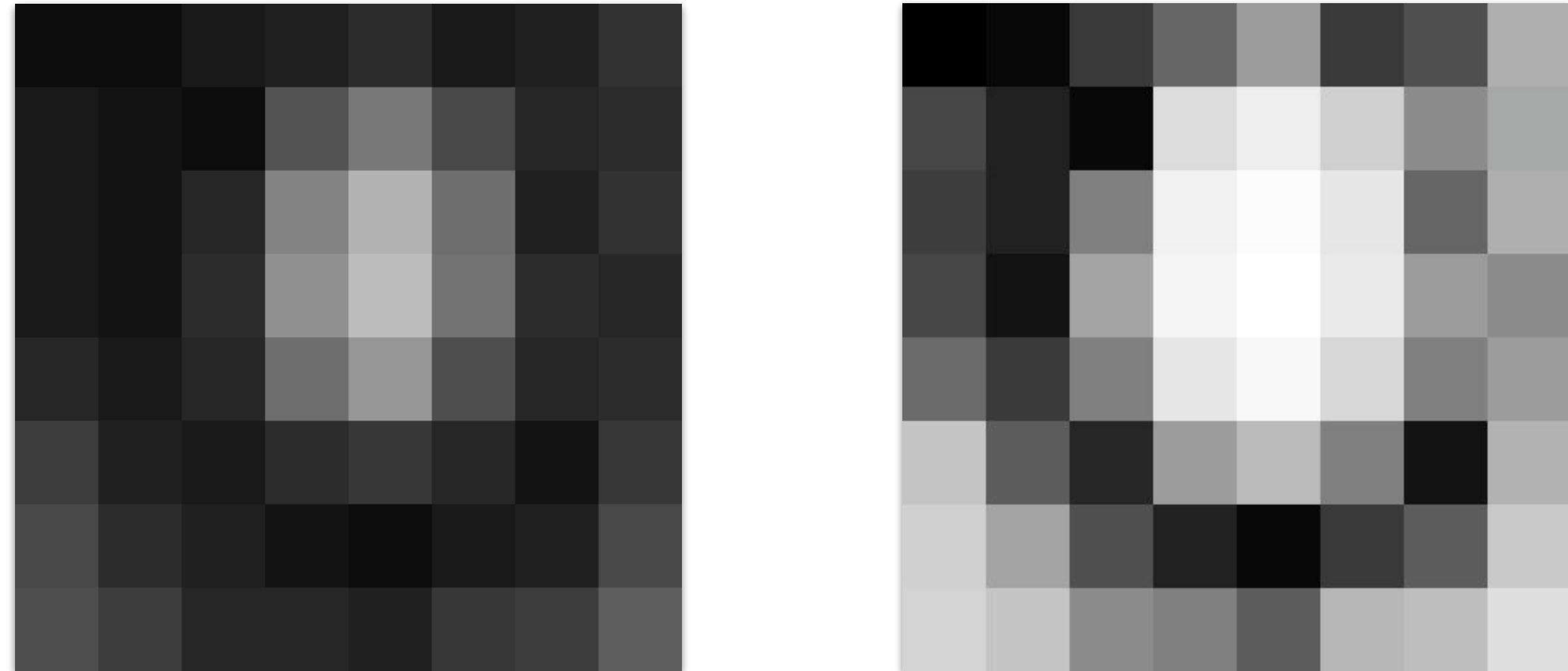
Enhancement

Color Histogram Equalization Simple implementation

Toy Case

1. Compute cumulative distribution function (CDF)

2. Perform min-max normalization
[0, 255] interval



Source: https://en.wikipedia.org/wiki/Histogram_equalization

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

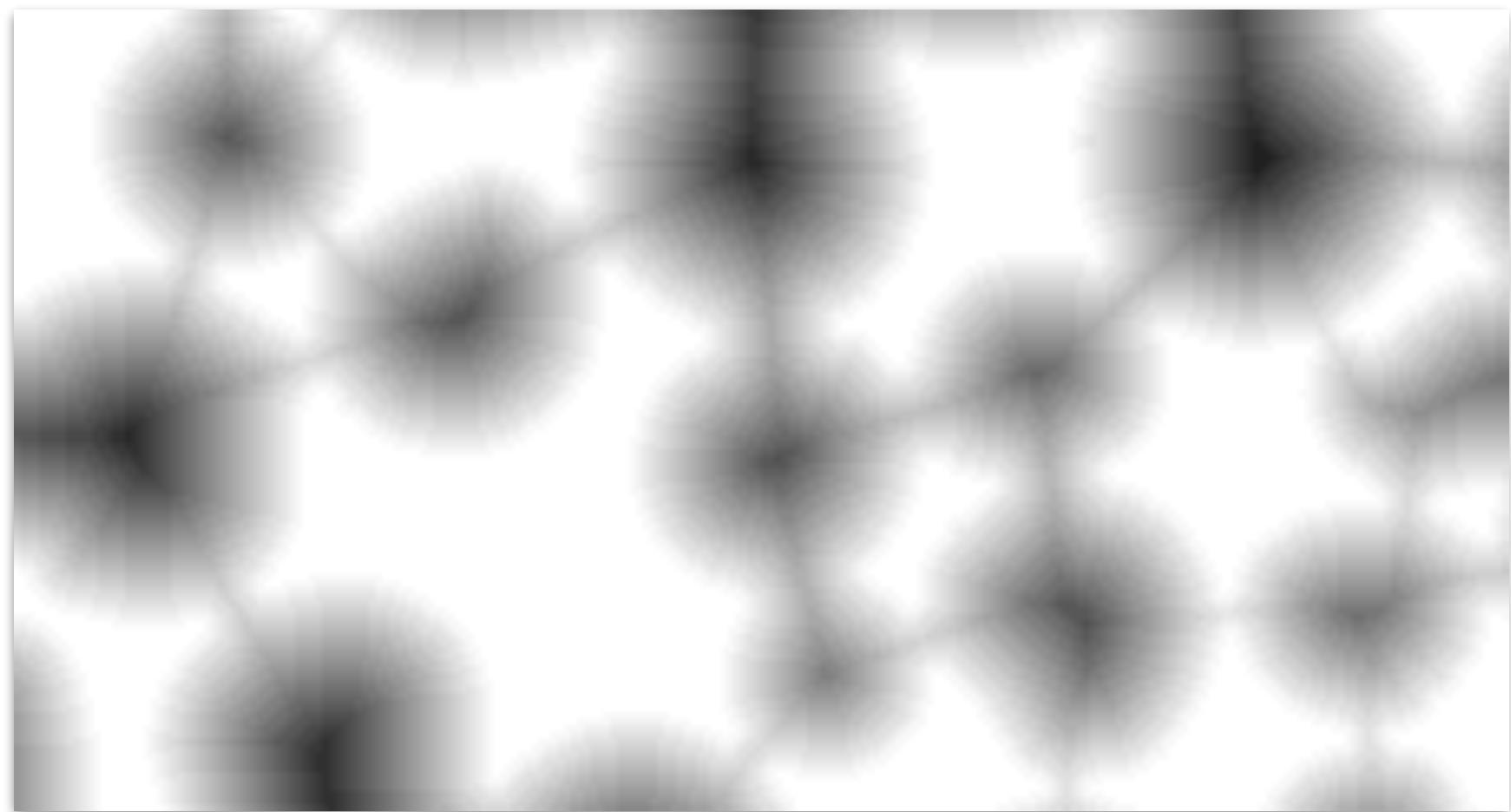
Tasks

Enhancement of image contrast.

Enhancement of ridges and valleys.

Content segmentation.

Others.



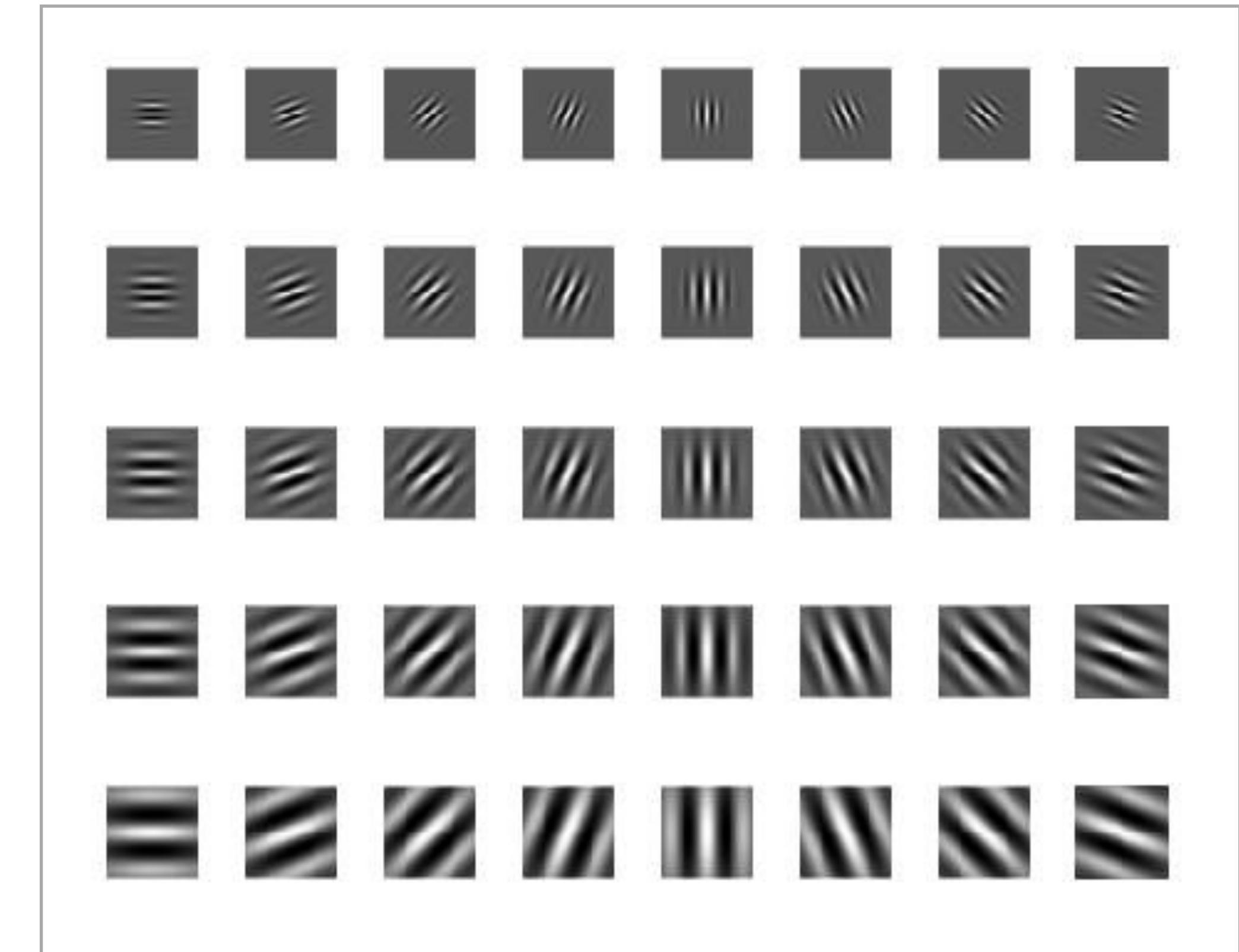
Enhancement

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.



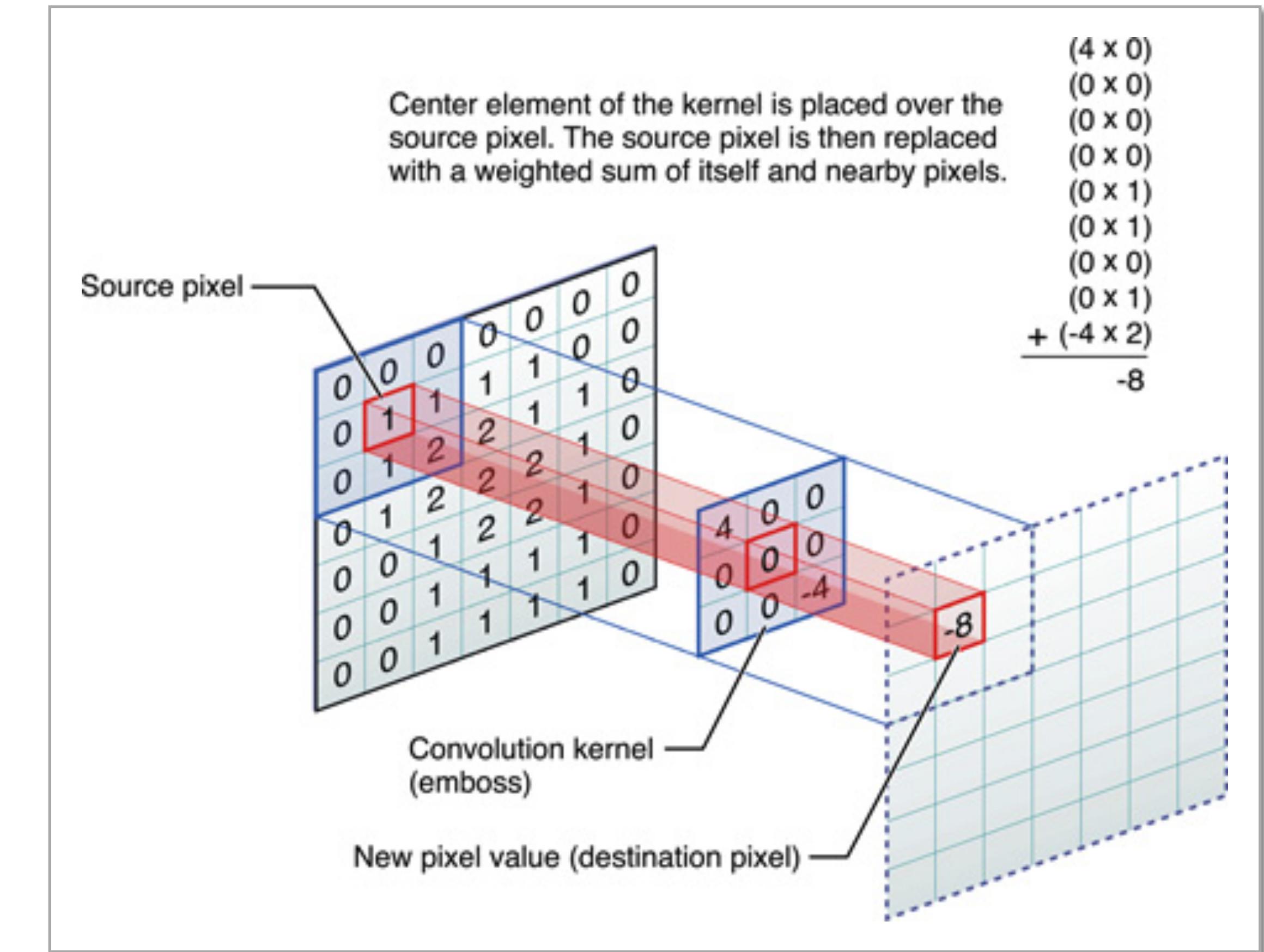
Enhancement

Ridges and Valleys

Example:

Image filtering with Gabor filters.

Gabor filters may be applied to an image through convolutions.

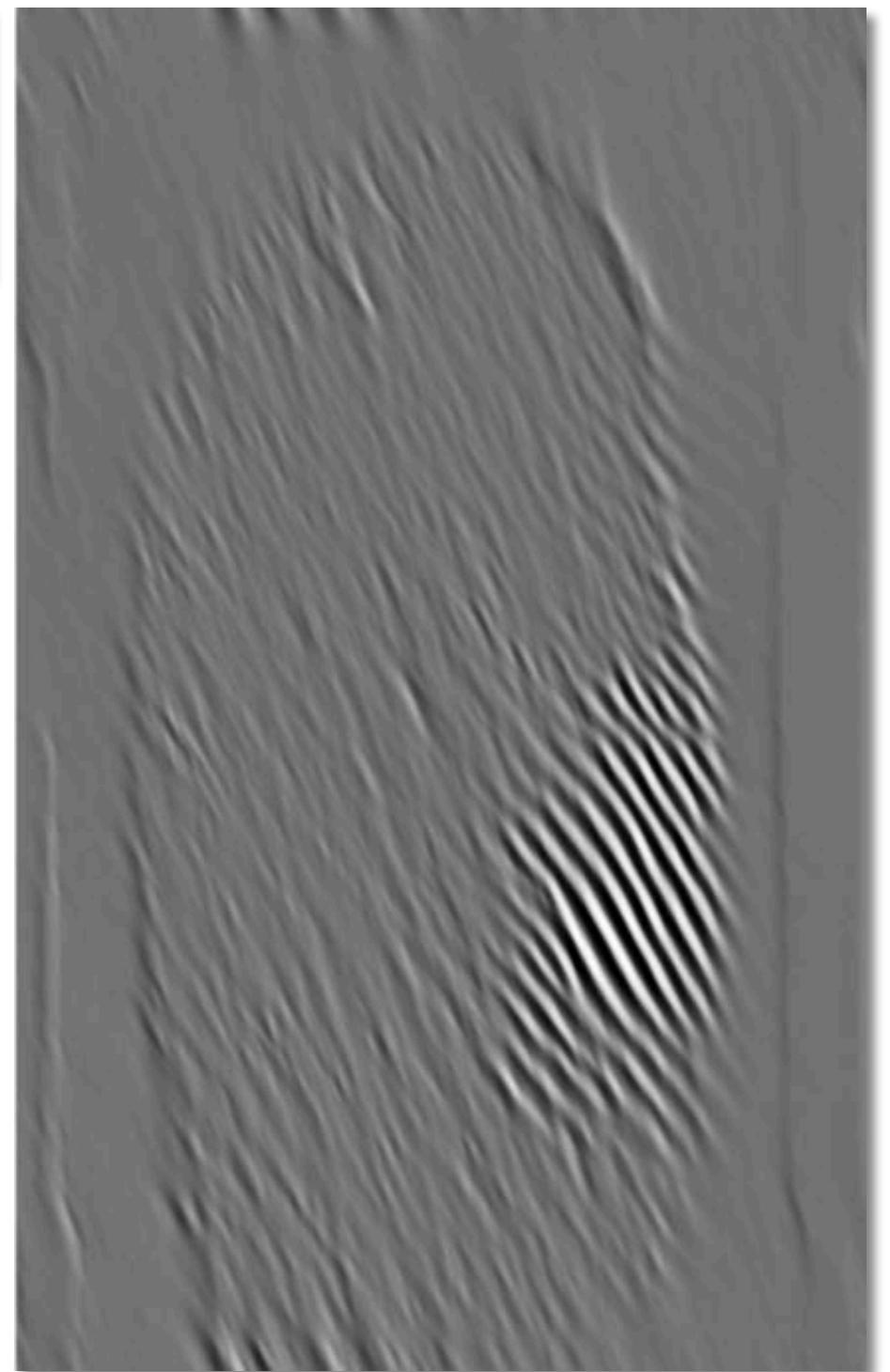
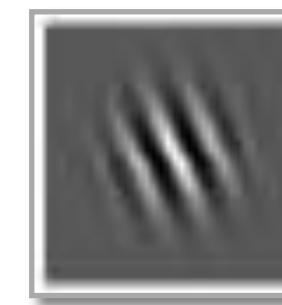
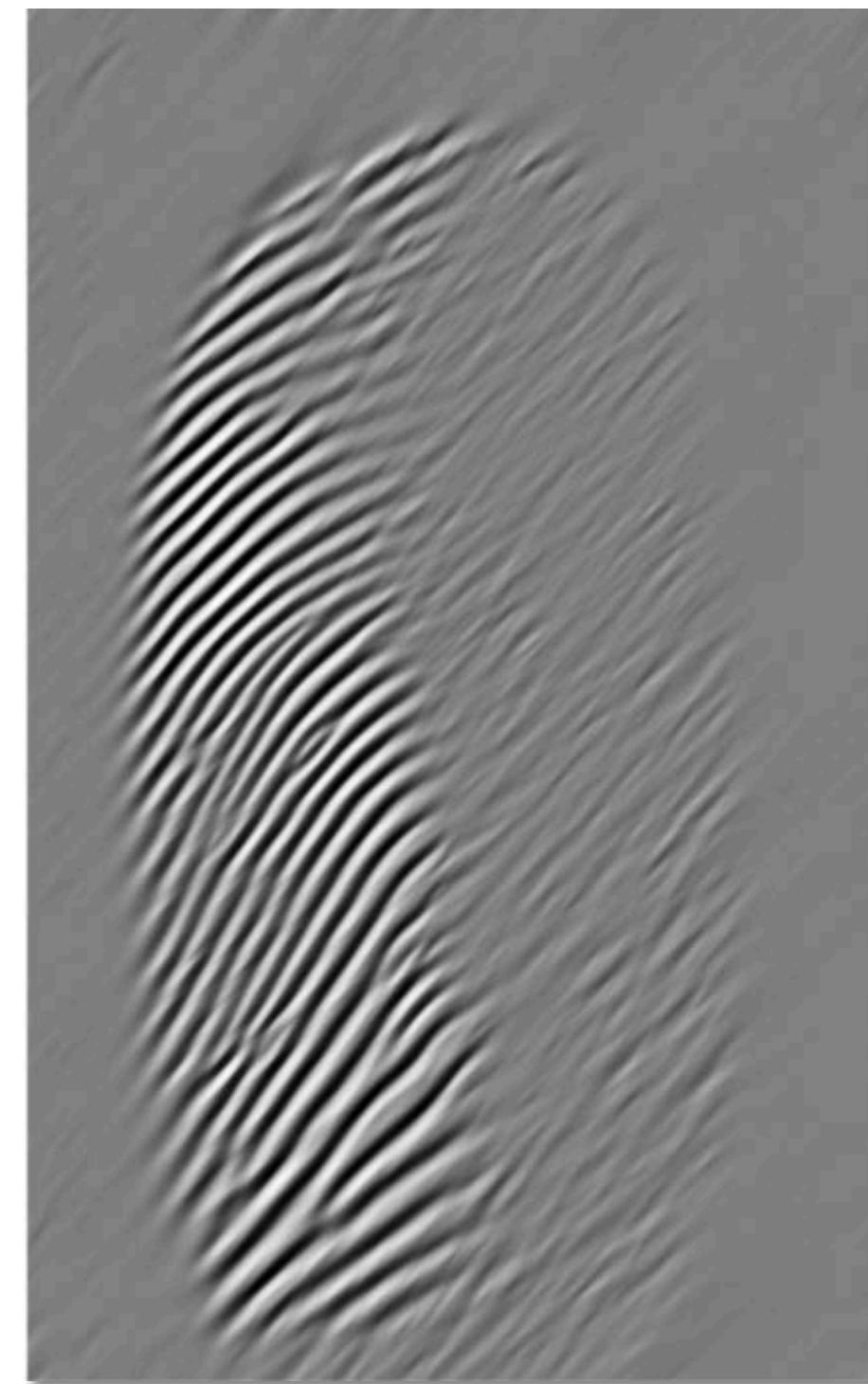
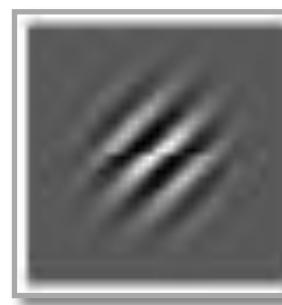


Enhancement

Ridges and Valleys

Example:

Image filtering with
Gabor filters.



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

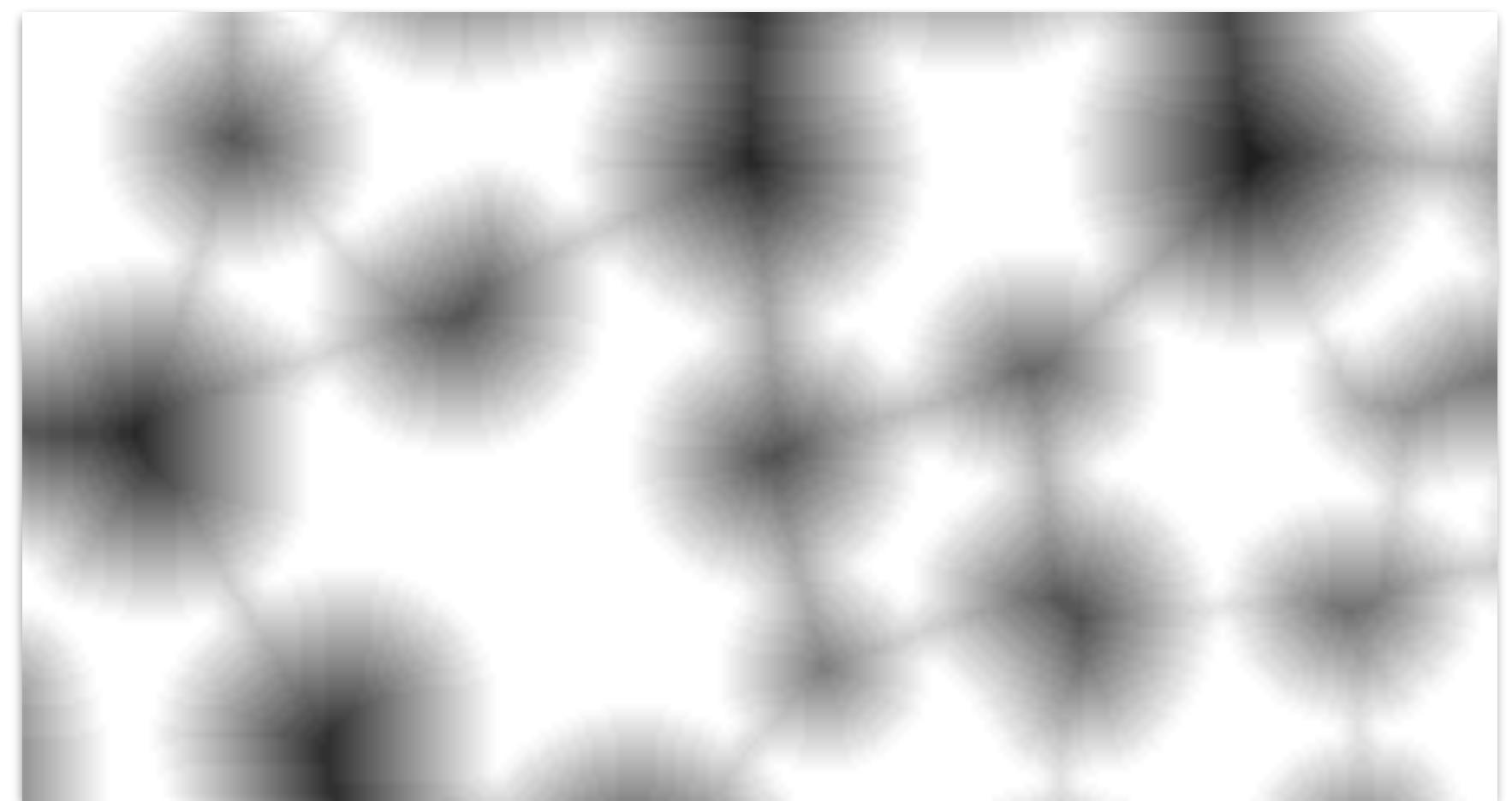
Tasks

Enhancement of image contrast.

Enhancement of ridges and valleys.

Content segmentation.

Others.



Enhancement

Segmentation

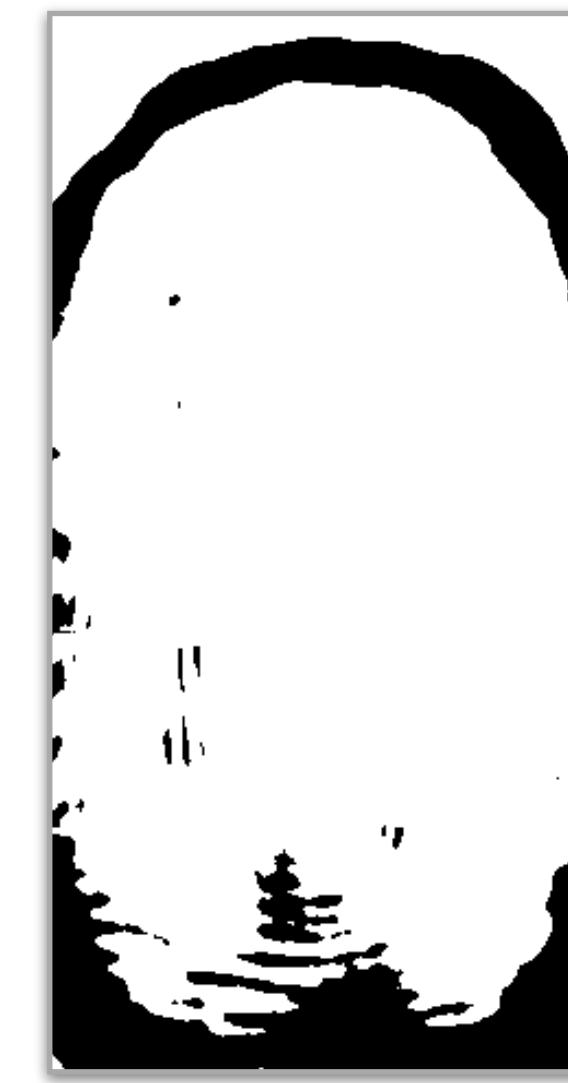
Example: blurring, thresholding, and morphological operations.



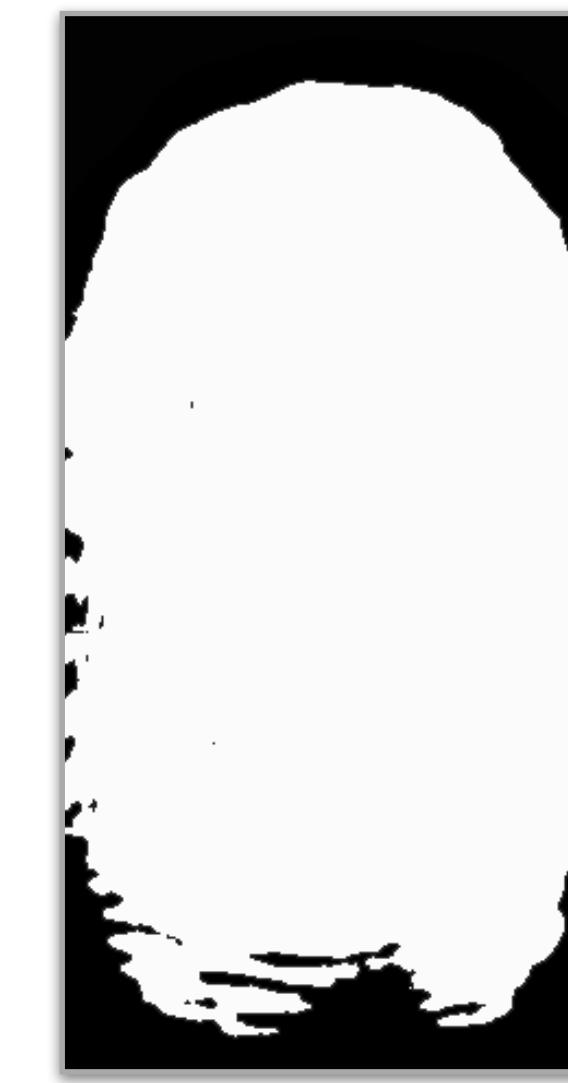
before



blur



threshold



open



after

Enhancement

Image Processing Solutions

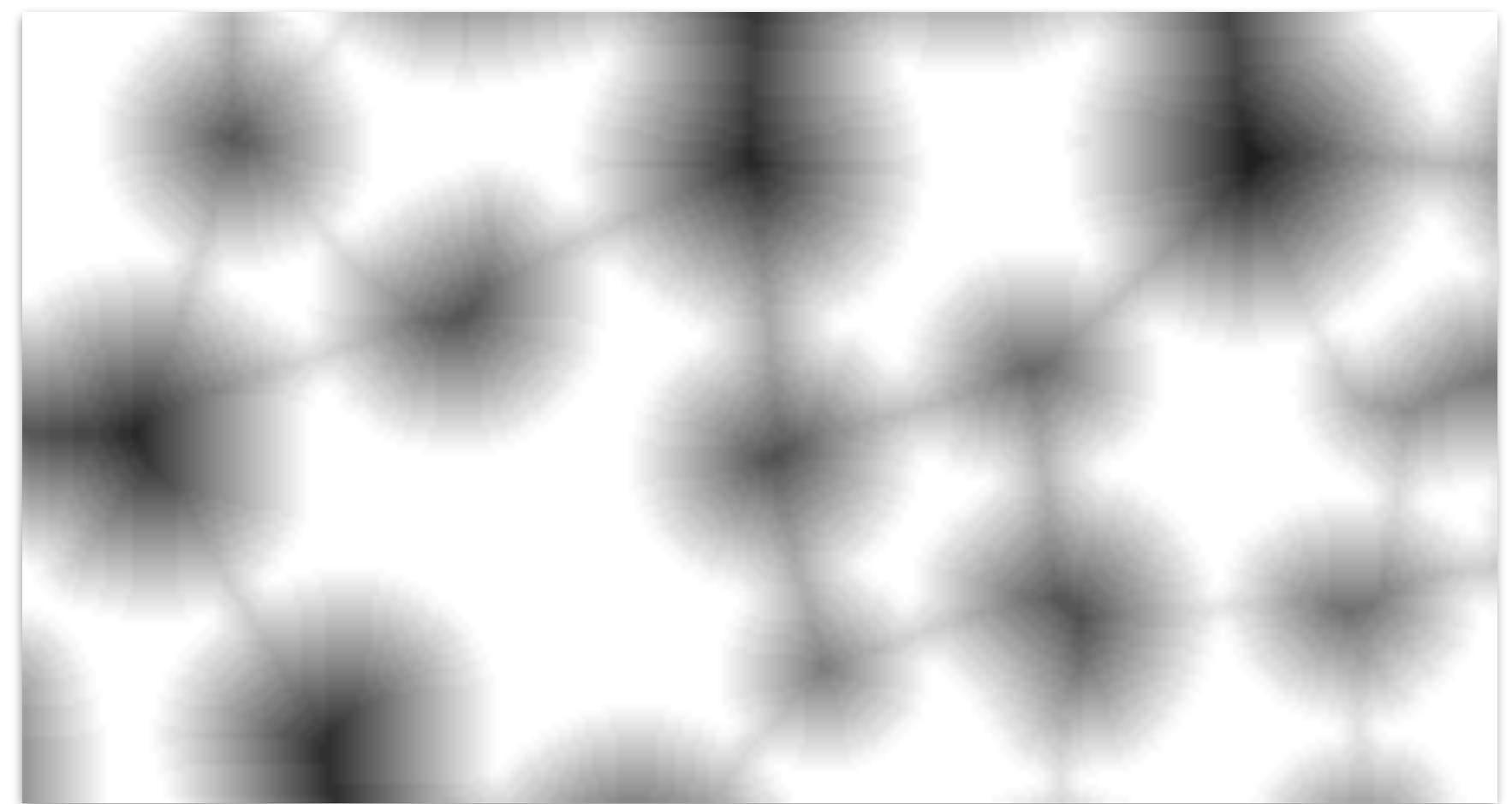
Tasks

Enhancement of image contrast.

Enhancement of ridges and valleys.

Content segmentation.

Others.



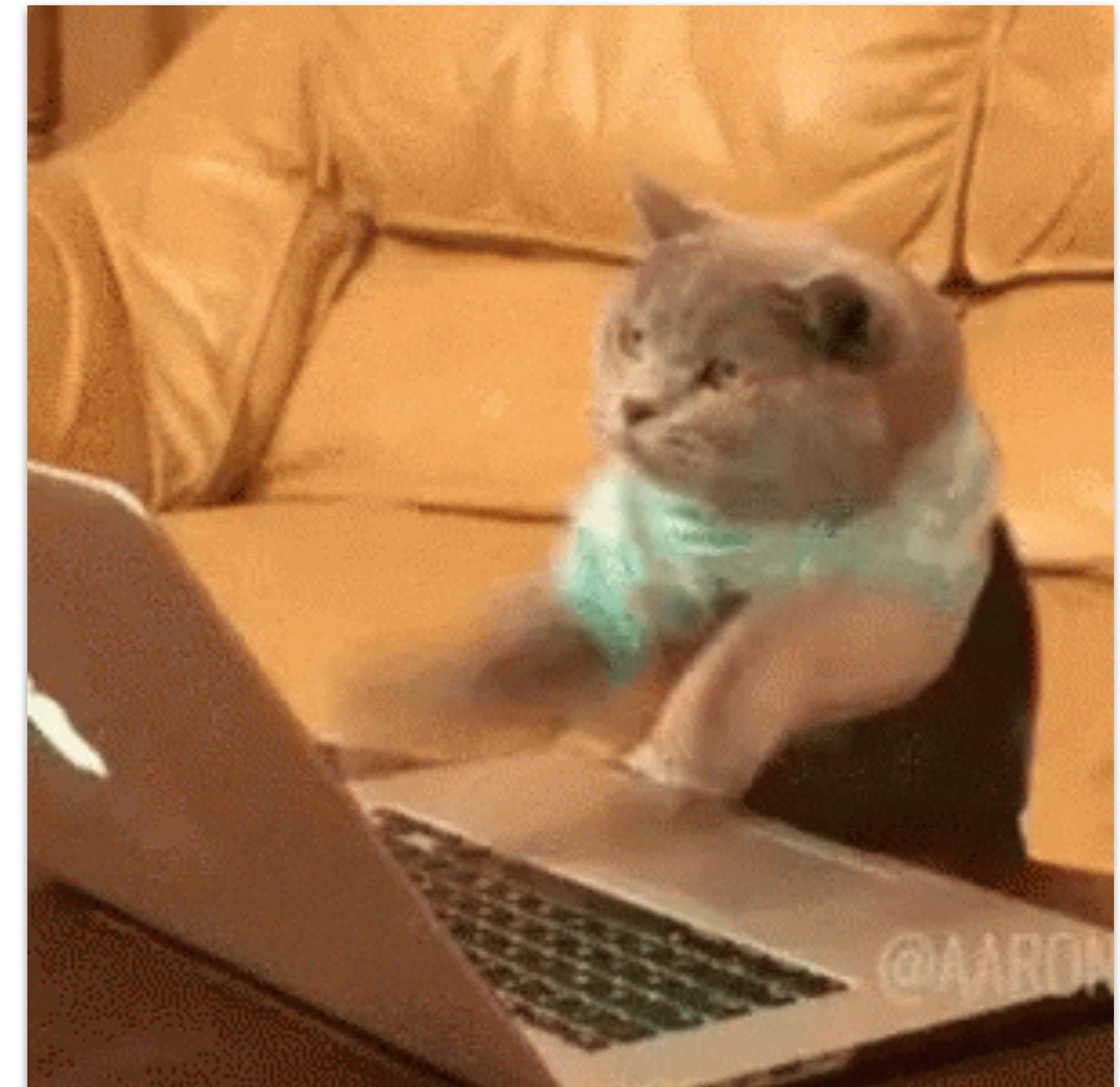
Enhancement

Image Processing Solutions

Be Aware

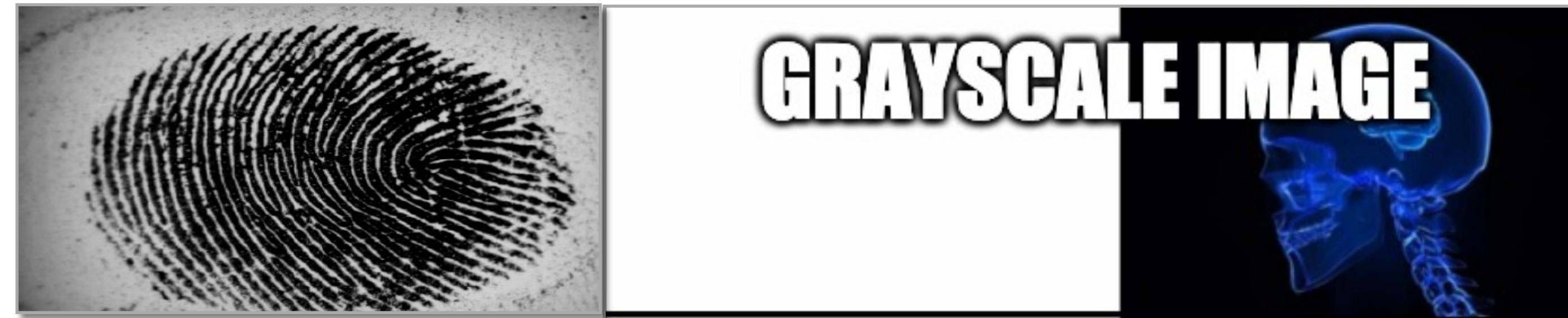
Besides the aforementioned techniques, there are much more sophisticated and effective ones.

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



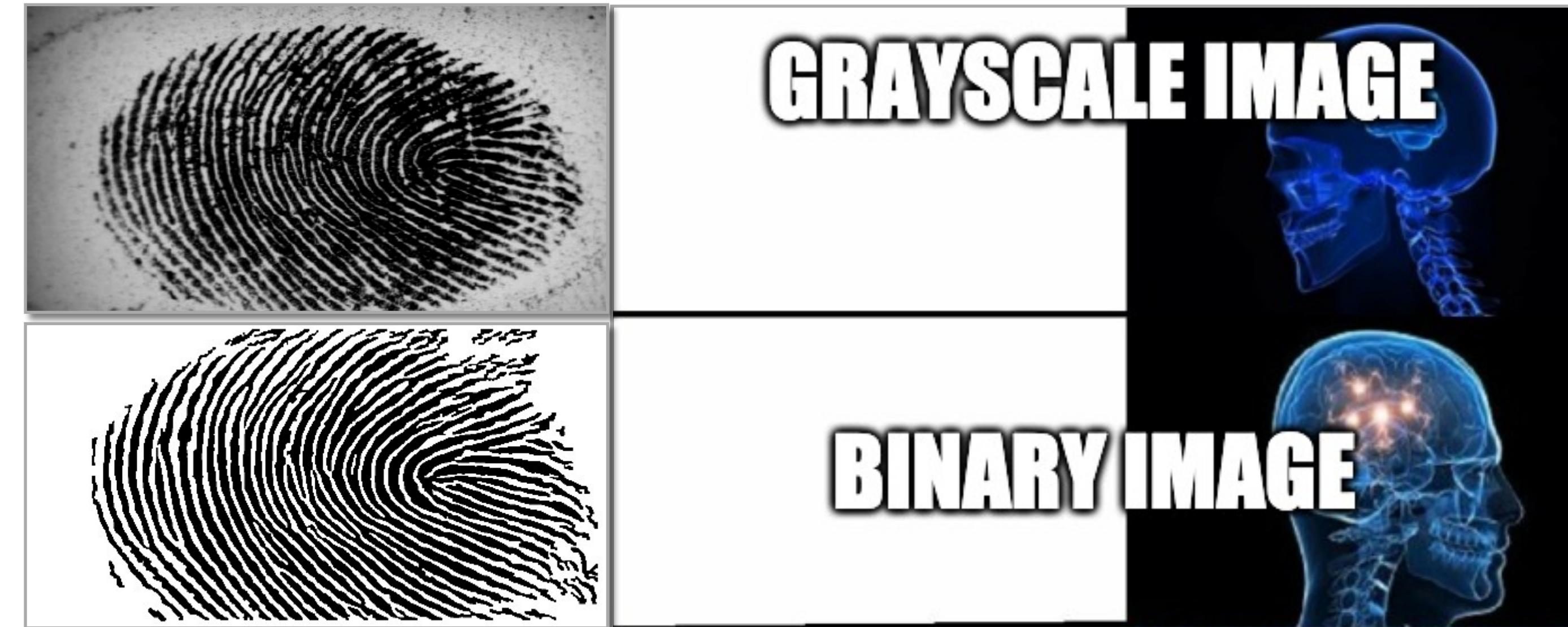
Enhancement

Other Strategies
Start from...



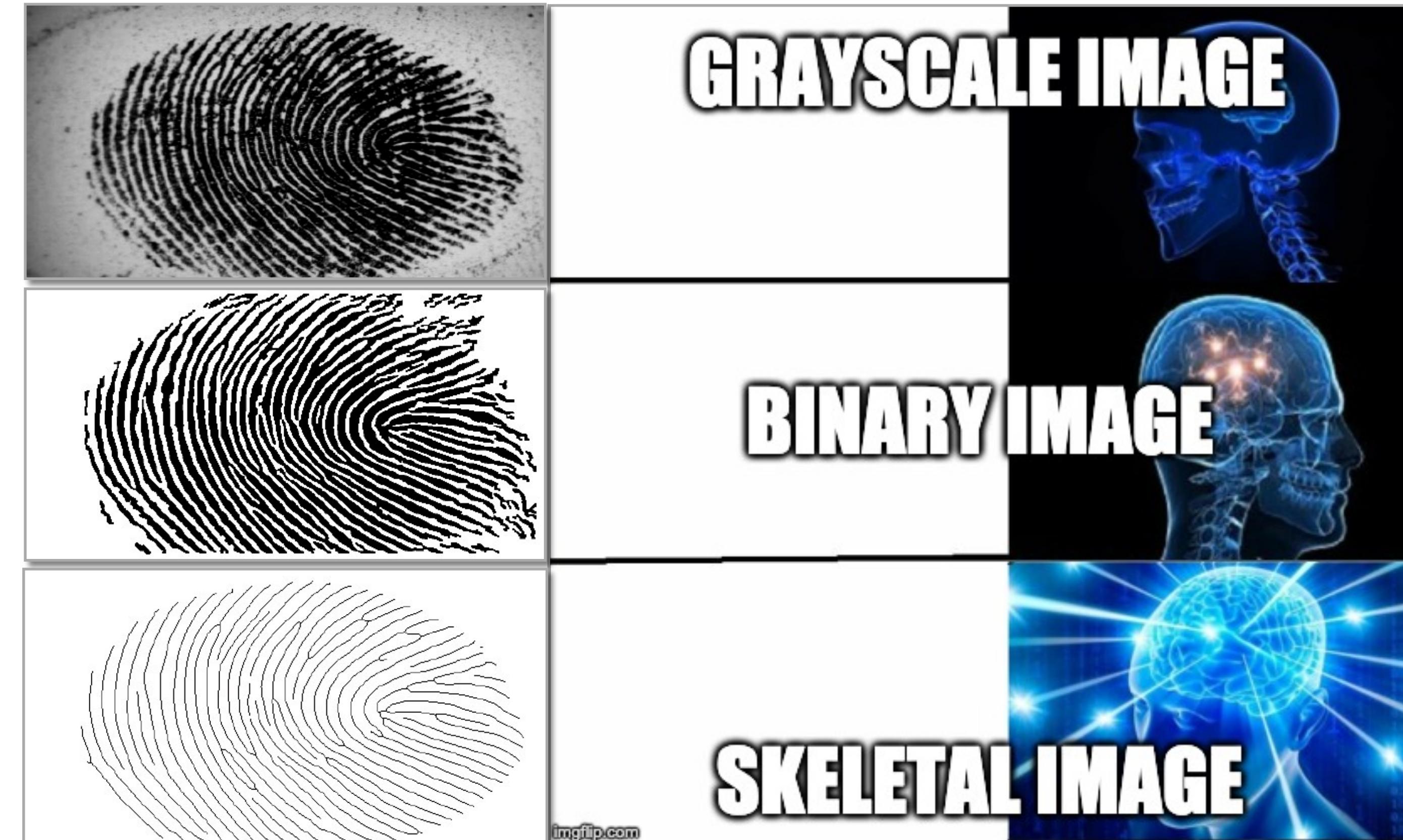
Enhancement

Other Strategies
Start from...



Enhancement

Other Strategies
Start from...



Source: Dr. Adam Czajka

imgflip.com

Enhancement

Other Strategies Start from...

Each strategy has its own set of pros and cons, and will lead to different performance.



Source: Dr. Adam Czajka



Just kidding...



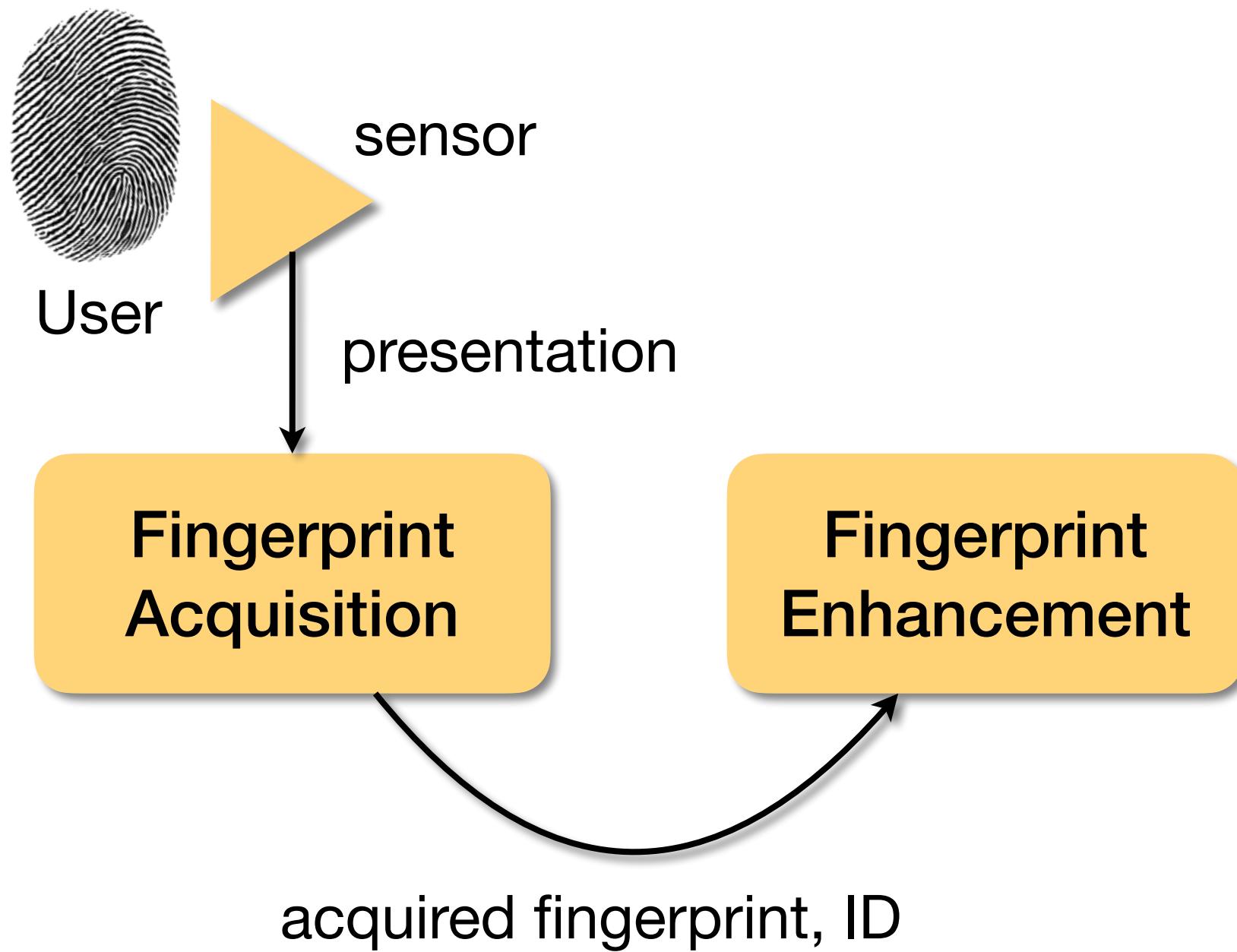
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Enhancement

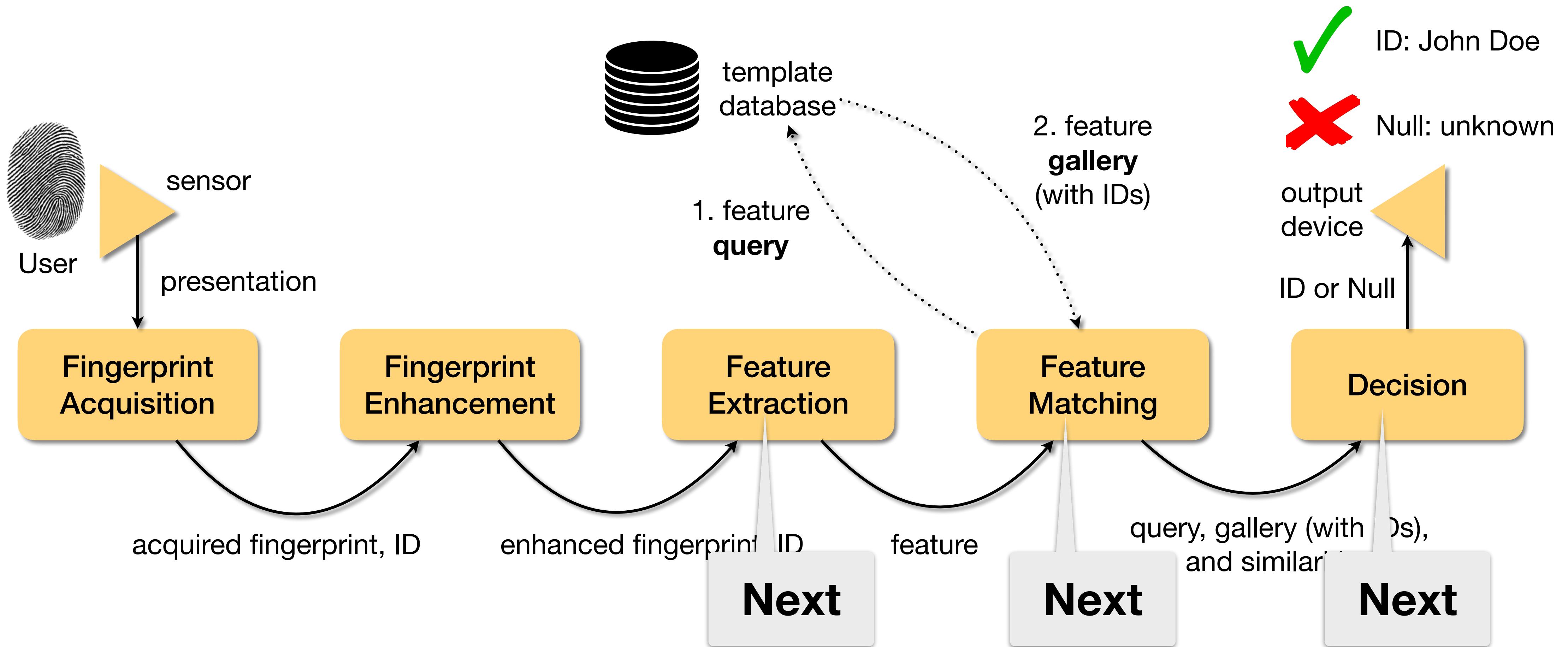


Source: Dr. Adam Czajka

Fingerprint Recognition



Fingerprint Recognition



What's Next?

Even more about fingerprints

Fingerprint feature extraction methods.
Fingerprint matching methods.



Fill out your *Today-I-missed* Statement

Please visit <https://sakai.luc.edu/x/PnQvIG>.