Fingerprint Recognition II

CSE 40537/60537 Biometrics

Daniel Moreira

Spring 2022

UNIVERSITY OF NOTRE DAME
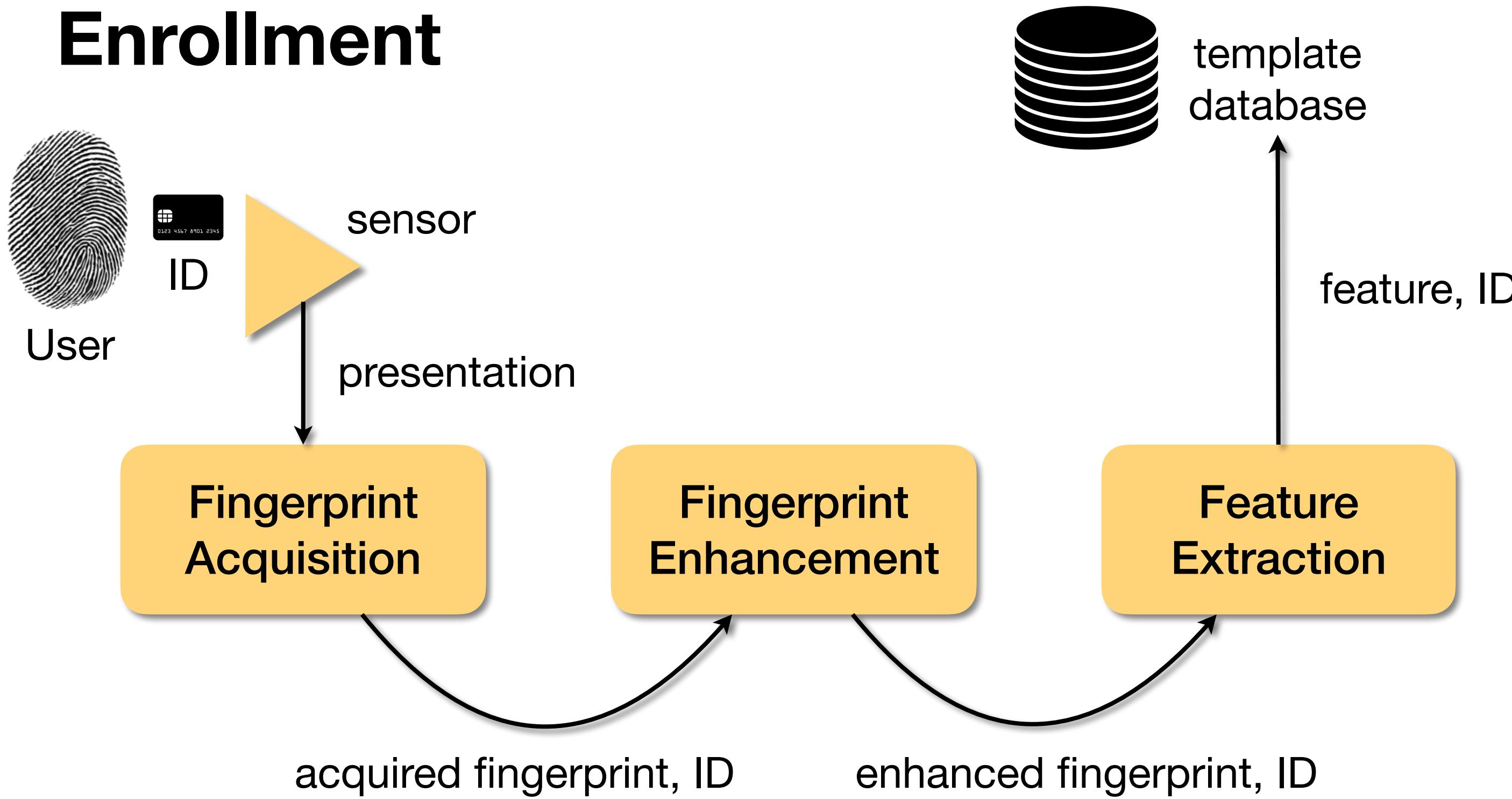
Today you will...

Get to know
Fingerprint acquisition and enhancement.

UNIVERSITY OF
NOTRE DAME
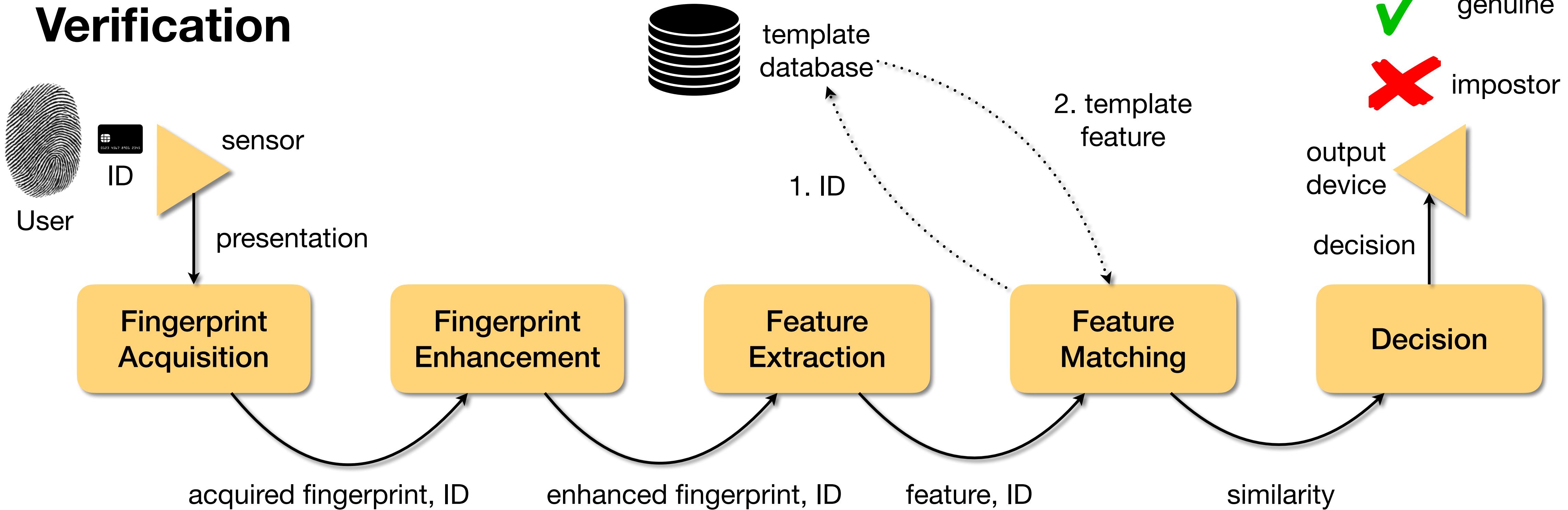
Fingerprint Recognition

Enrollment

template
database

sensor

ID

User

presentation

feature, ID

Fingerprint Acquisition

Fingerprint Enhancement

Feature Extraction

acquired fingerprint, ID

enhanced fingerprint, ID

UNIVERSITY OF
NOTRE DAME
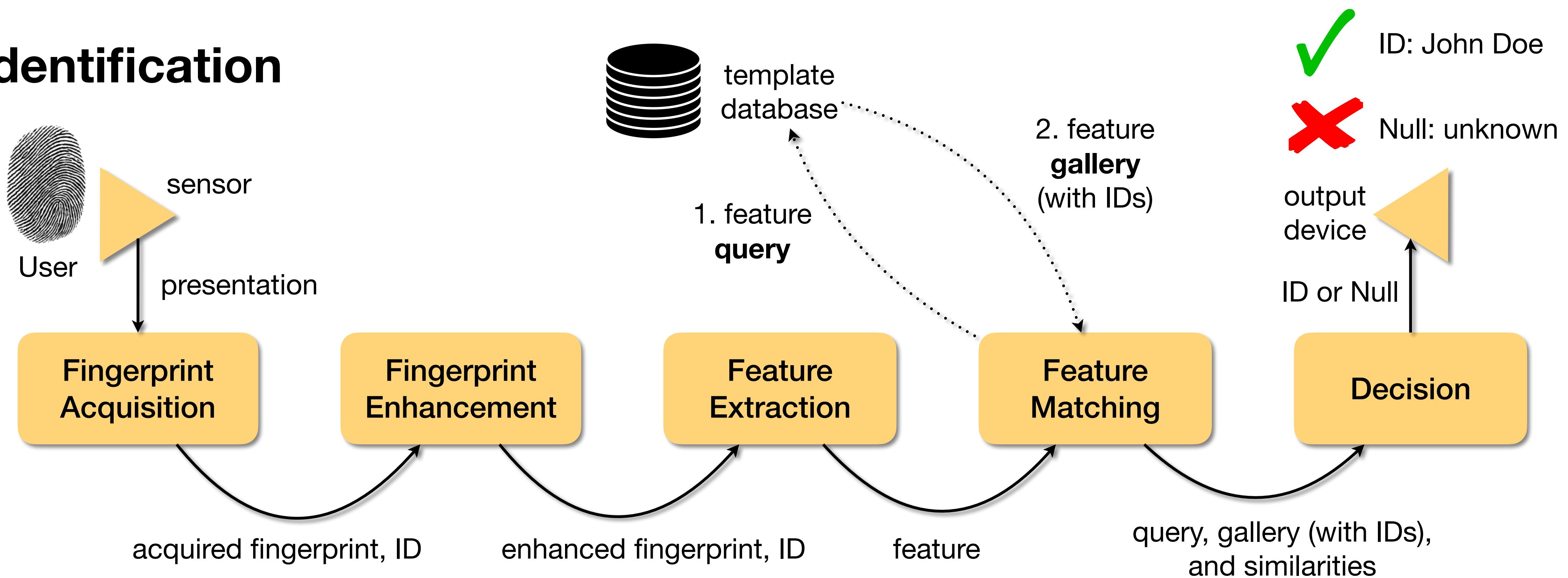
Fingerprint Recognition

Verification

User
ID
sensor
presentation

template database

1. ID
2. template feature

genuine
impostor
output device
decision

Fingerprint Acquisition → **Fingerprint Enhancement** → **Feature Extraction** → **Feature Matching** → **Decision**

acquired fingerprint, ID

enhanced fingerprint, ID

feature, ID

similarity

UNIVERSITY OF NOTRE DAME

4
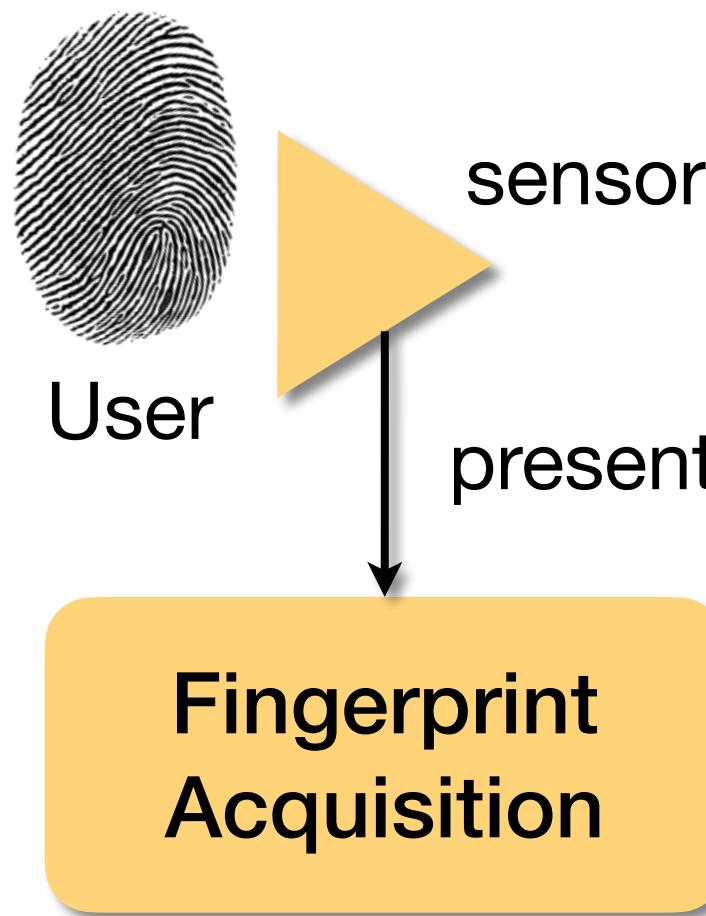
Fingerprint Recognition

Identification

template database

2. feature **gallery** (with IDs)

✓ ID: John Doe

✗ Null: unknown

sensor

1. feature **query**

output device

User

presentation

ID or Null

Fingerprint Acquisition	Fingerprint Enhancement	Feature Extraction	Feature Matching	Decision

acquired fingerprint, ID

enhanced fingerprint, ID

feature

query, gallery (with IDs), and similarities

Fingerprint Recognition

User

sensor

presentation

Fingerprint
Acquisition

UNIVERSITY OF
NOTRE DAME

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

UNIVERSITY OF
NOTRE DAME

Acquisition

Off-line Acquisition

Scanning of dactyloscopy cards.

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

UNIVERSITY OF
NOTRE DAME

Acquisition

Off-line Acquisition

Photographing of
latent fingerprints.

Source: Dr. Adam Czajka

UNIVERSITY OF
NOTRE DAME
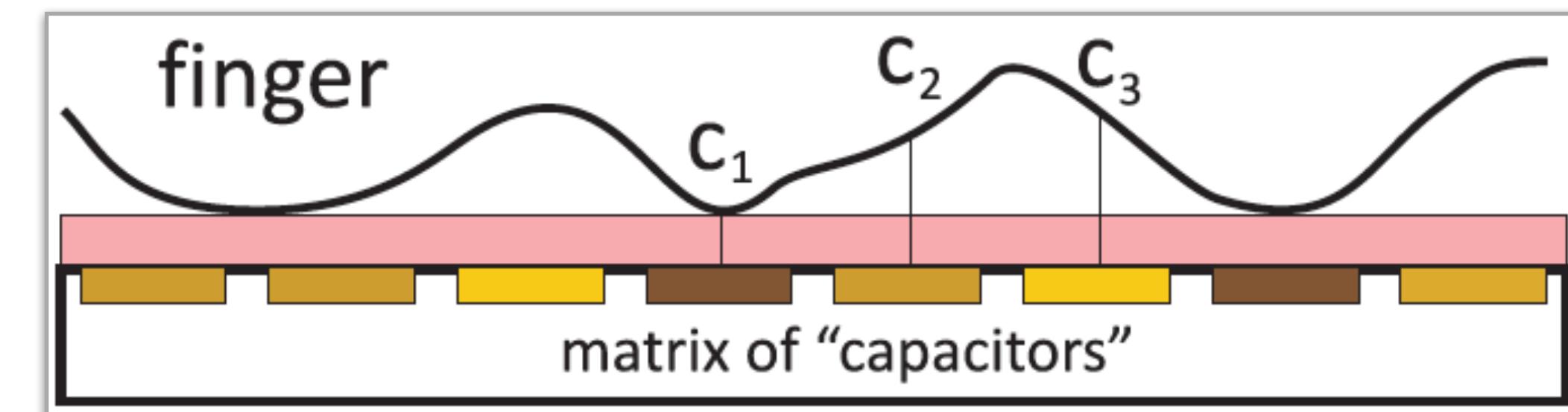
Acquisition

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).

UNIVERSITY OF
NOTRE DAME

Acquisition

On-line Acquisition

Capacitive sensors (1/6)
Device and sample.


Precise Biometrics
Source: Dr. Adam Czajka

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

UNIVERSITY OF
NOTRE DAME
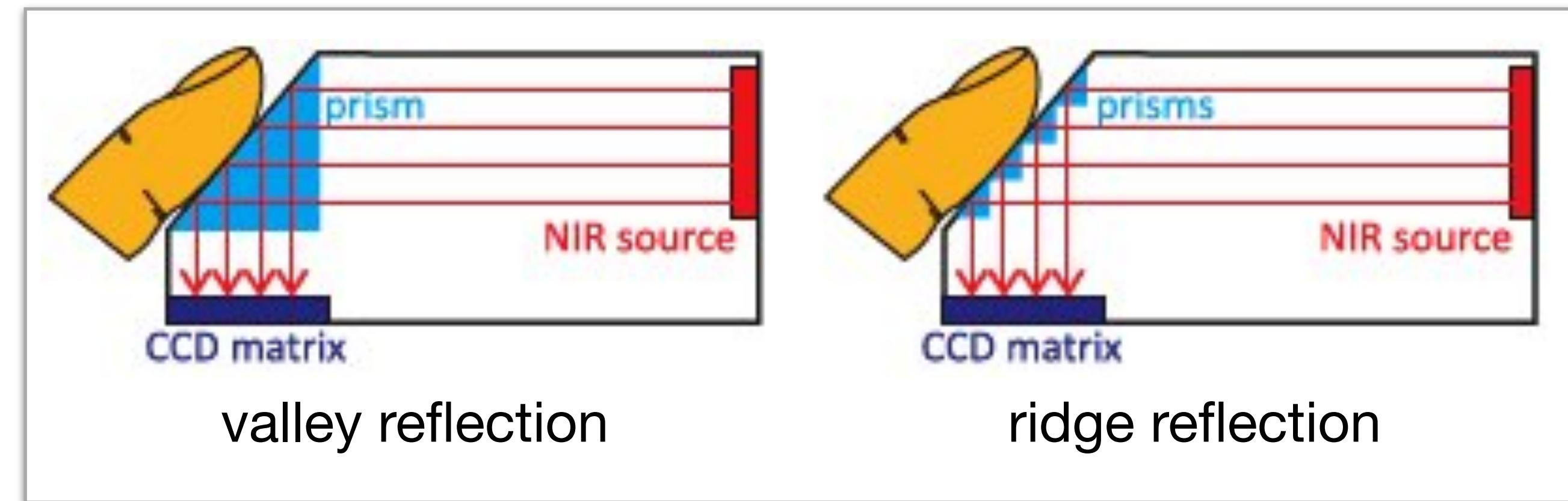
Acquisition

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

valley reflection   ridge reflection

Acquisition

On-line Acquisition

Optical sensors (2/6)
Devices.

Identix
Source: Dr. Adam Czajka

Guardian

UNIVERSITY OF NOTRE DAME

Acquisition

On-line Acquisition

Optical sensors (2/6) - Samples.

slap
Biometrika FX2000

rolled
CrossMatch LS320

thumbs
L1 TP4100

little, ring, middle, and index
L1 TP4100

UNIVERSITY OF
NOTRE DAME
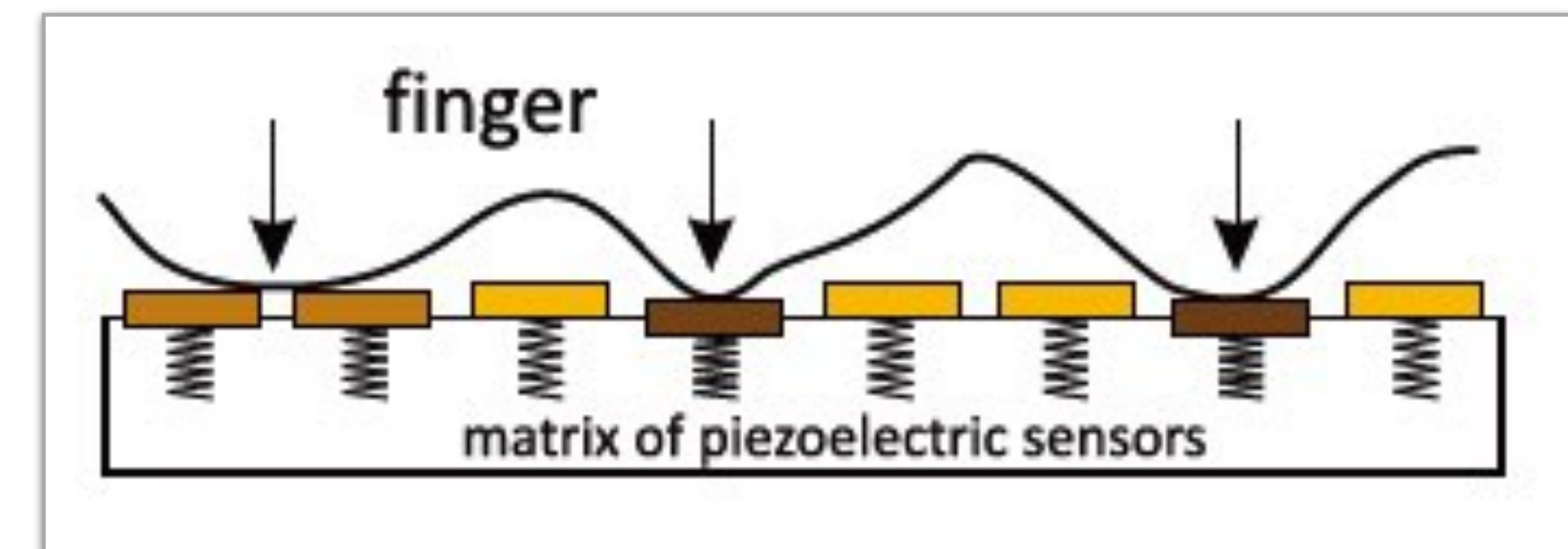
Acquisition

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.

BMF/Hitachi
Source: Dr. Adam Czajka

sensor:
BMF/Hitachi

UNIVERSITY OF
NOTRE DAME

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.

UNIVERSITY OF
NOTRE DAME

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.
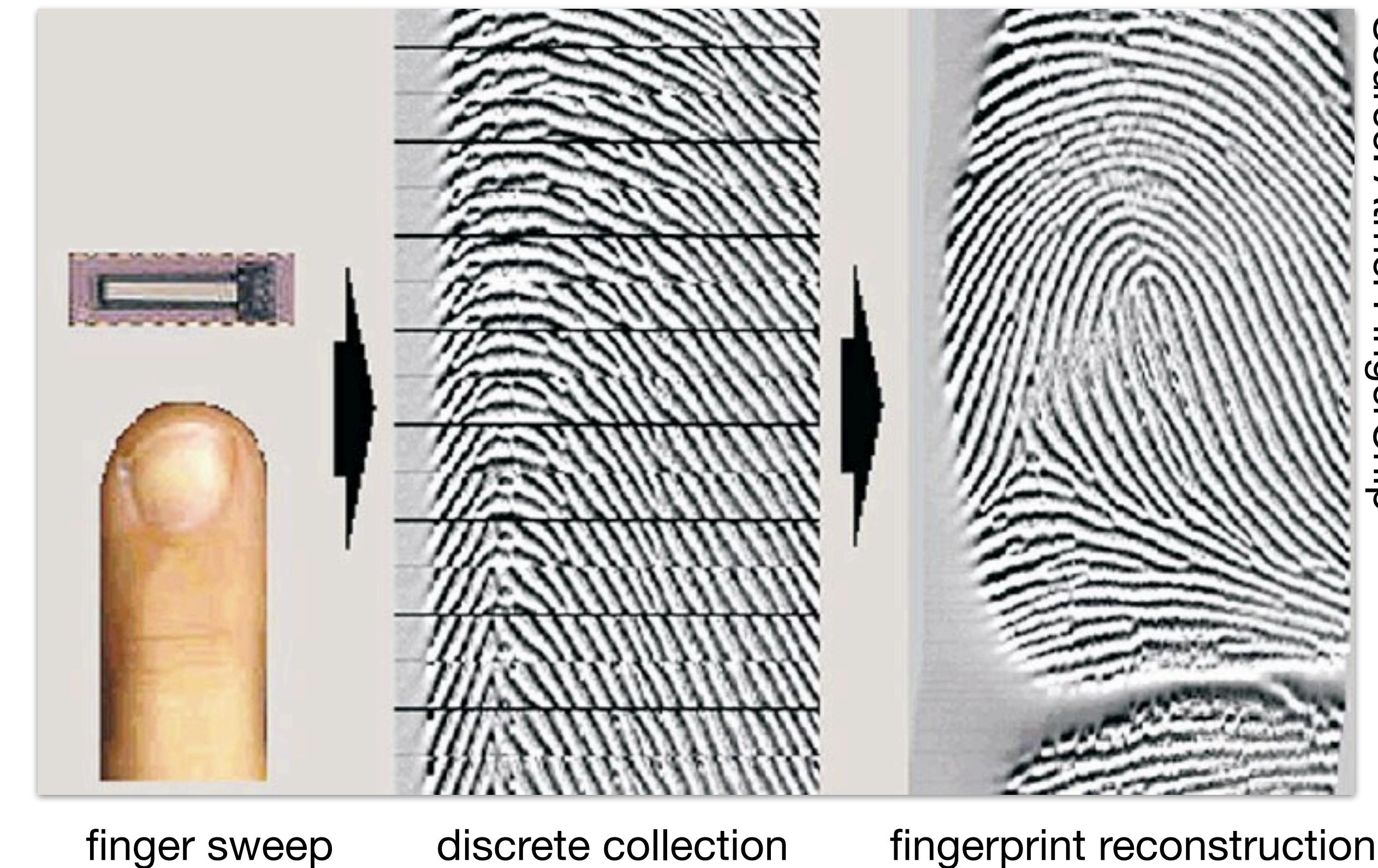
Source: Dr. Adam Czajka

Acquisition

On-line Acquisition

Thermal sensors (4/6)
Example: Atmel FingerChip
Sample generation.

finger sweep   discrete collection   fingerprint reconstruction

UNIVERSITY OF
NOTRE DAME
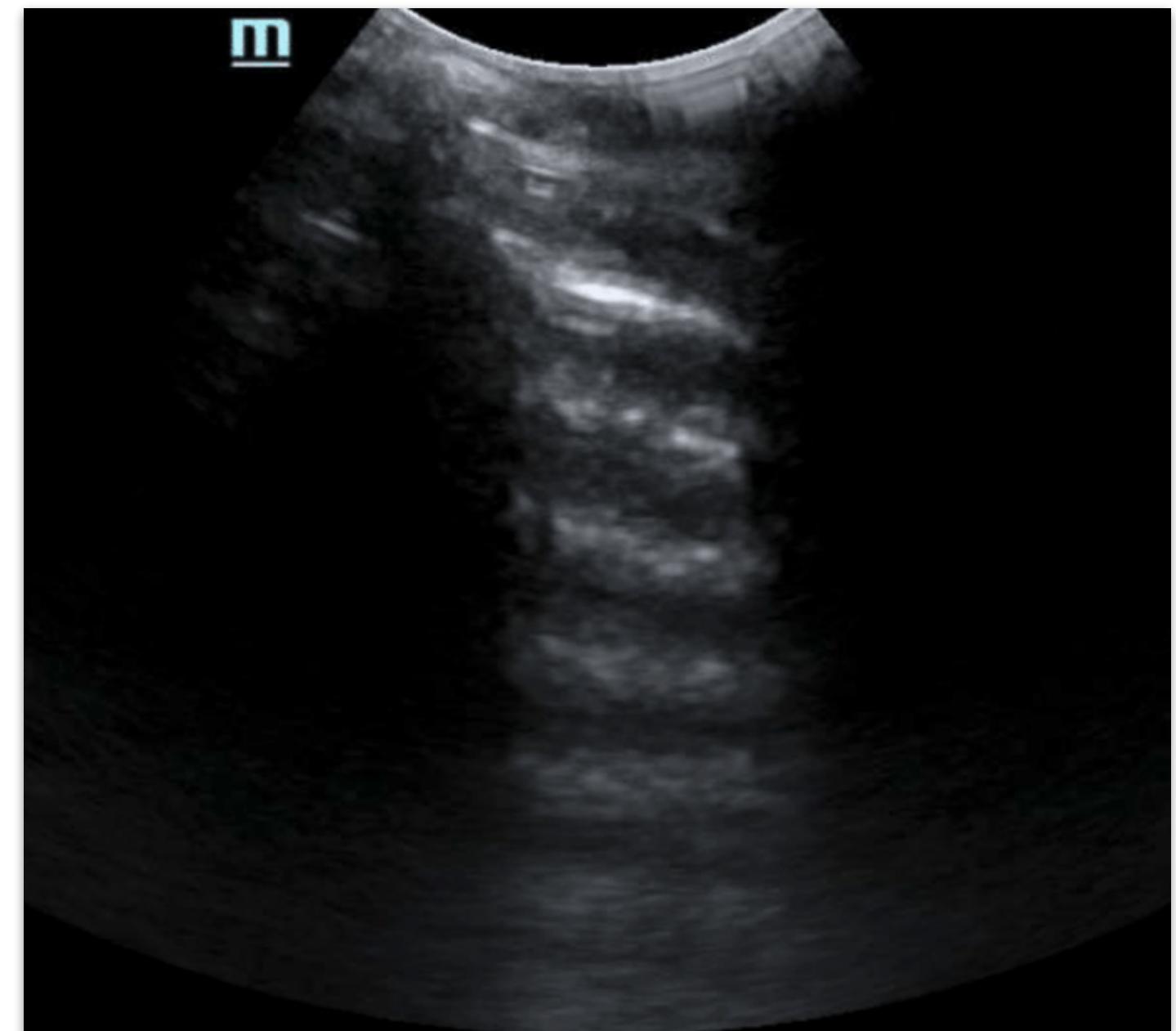
Acquisition

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.
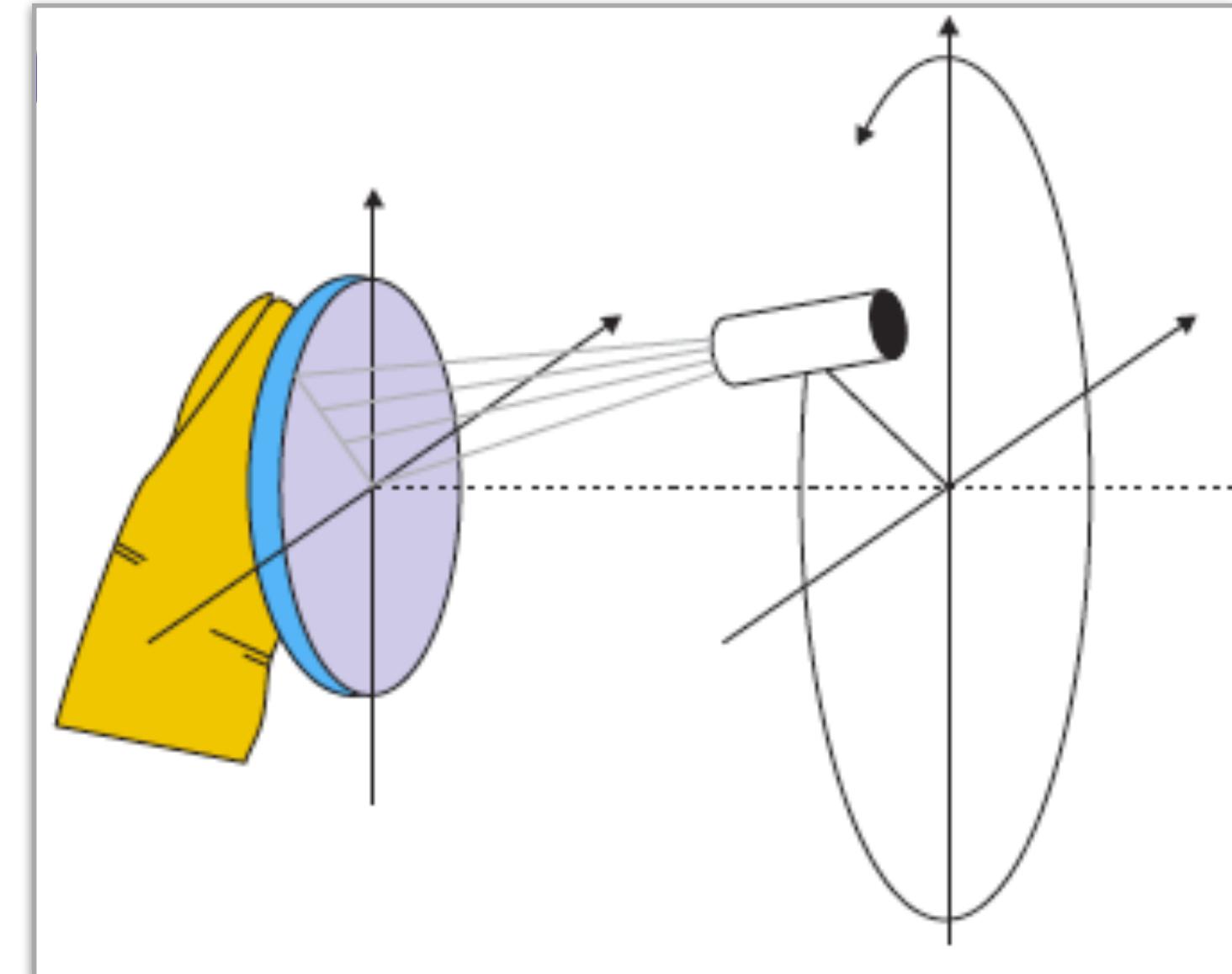
Acquisition

On-line Acquisition

Ultrasound sensors (5/6)
Example: Optel

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

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

Source: Dr. Adam Czajka

UNIVERSITY OF
NOTRE DAME

Acquisition

On-line Acquisition

Ultrasound sensors (5/6)
Example: Optel
Device and sample.

Source: www.optel.com.pl

UNIVERSITY OF
NOTRE DAME

Acquisition

On-line Acquisition

Ultrasound sensor (5/6)
Example: Qualcomm Fingerprint

Sensor embedded into the
device display.

Source: mashable.com

UNIVERSITY OF
NOTRE DAME

Acquisition

On-line Acquisition

Touchless sensor (6/6)
3D imaging with CCD sensor.
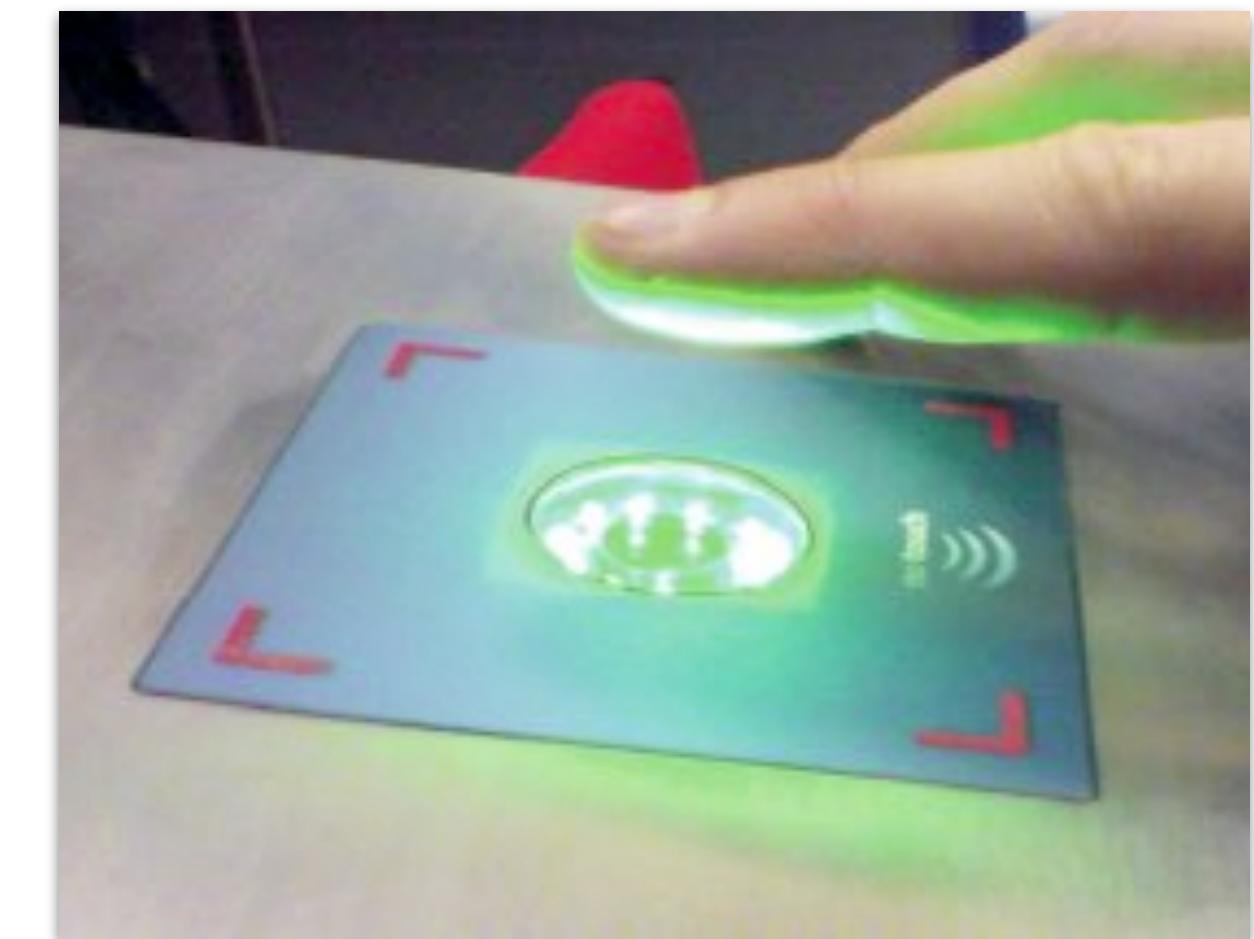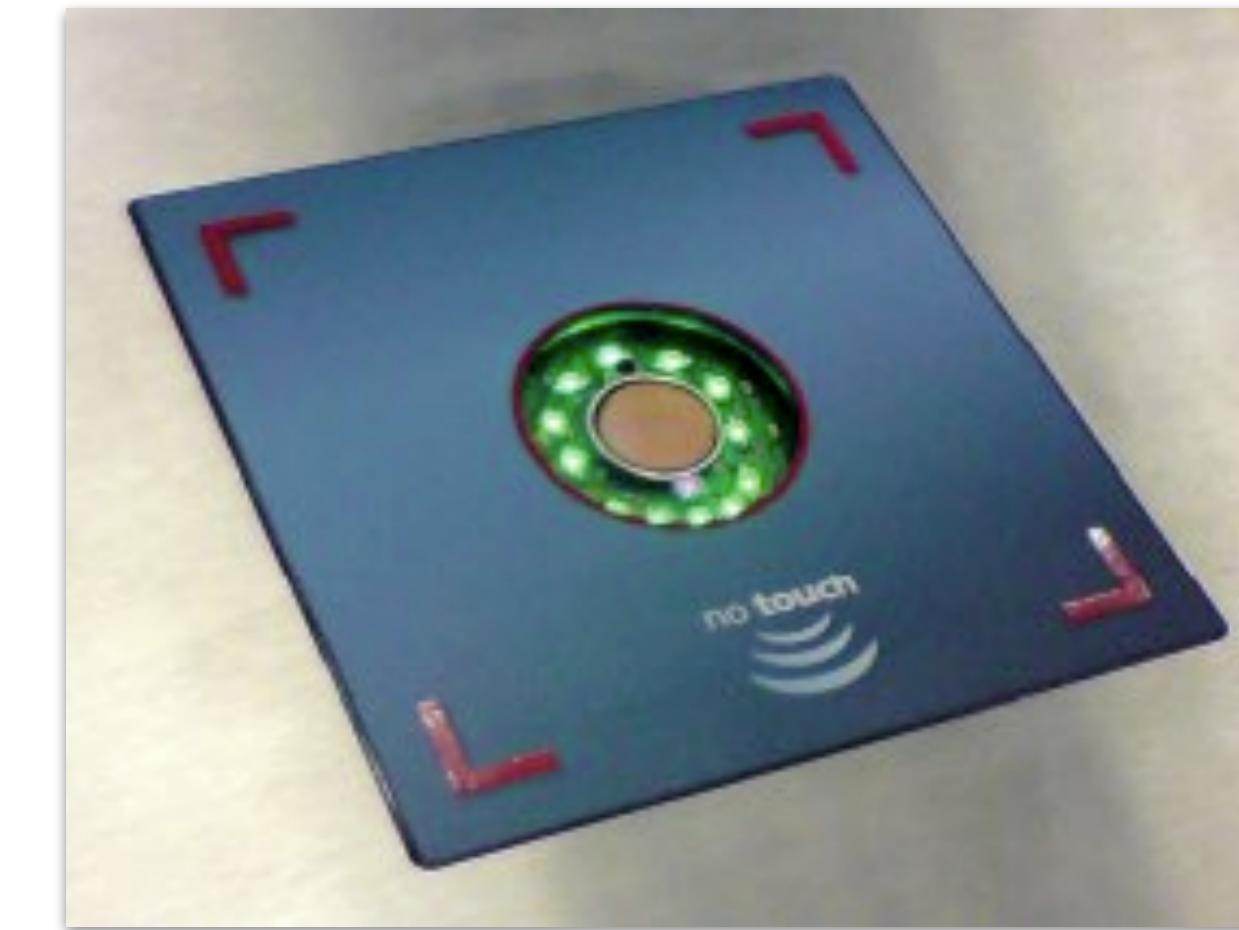
Acquisition

On-line Acquisition

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

Source: Dr. Adam Czajka

UNIVERSITY OF
NOTRE DAME
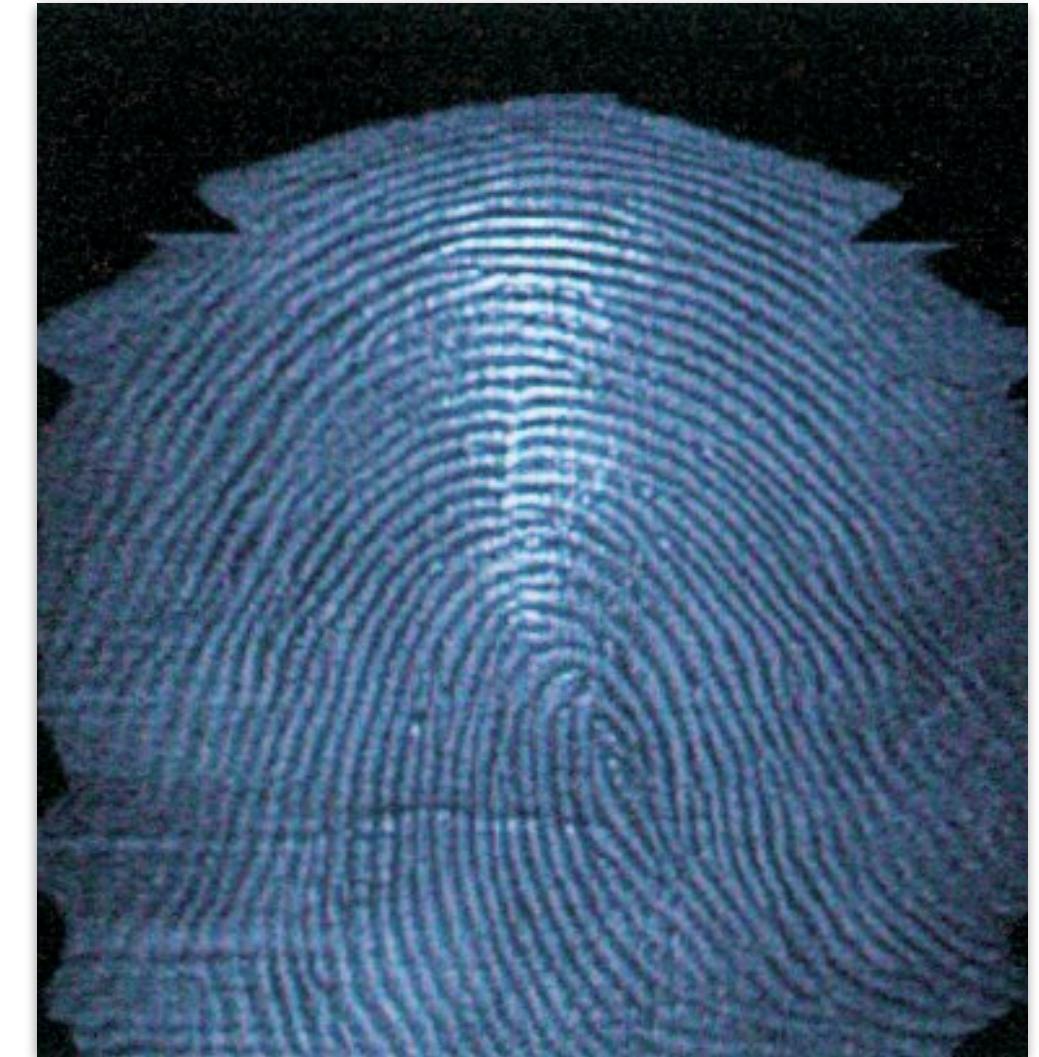
Acquisition

On-line Acquisition

Touchless sensor (6/6)
Example: MorphoWave
Device and sample.

Source: Dr. Adam Czajka

UNIVERSITY OF
NOTRE DAME

Acquisition

Problems

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

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

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

UNIVERSITY OF NOTRE DAME

Acquisition

Problems

Presentation Attack
Techniques to generate
fake fingerprints:
Paper printouts.
Clay or latex molds, plus
wood-glue, gelatin,
or silicone mold filling.

Objectives: spoofing and obfuscation.

Source: Dr. Adam Czajka

UNIVERSITY OF
NOTRE DAME

Faking Fingerprints

FAKE FINGER GETS PAST FINGERPRINT SCANNER

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.

UNIVERSITY OF
NOTRE DAME

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.

UNIVERSITY OF
NOTRE DAME

Acquisition

Problems

Presentation Attack
How about humans?

UNIVERSITY OF
NOTRE DAME

Fake or authentic?

From capacitive sensor
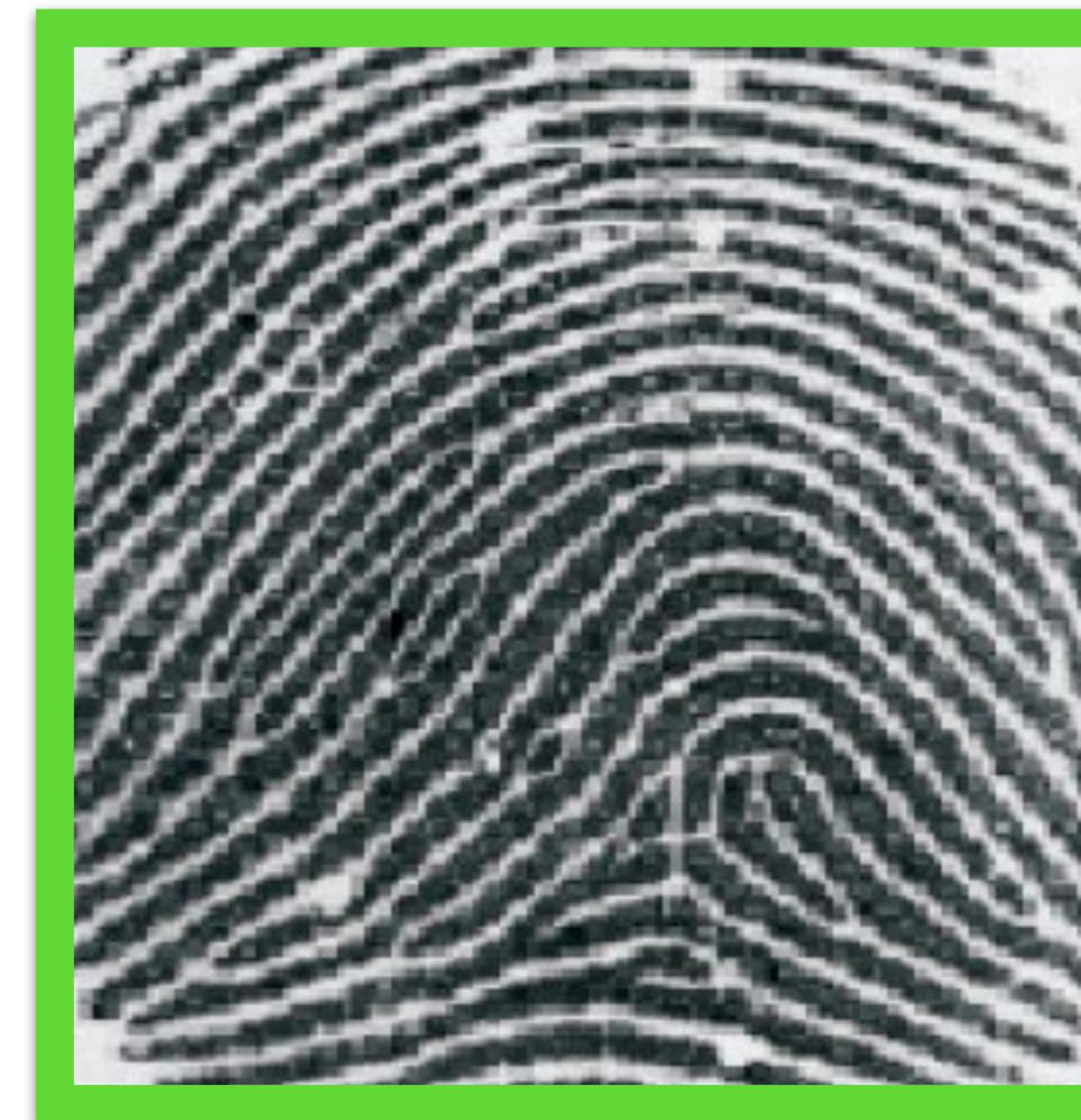
Fake or authentic?
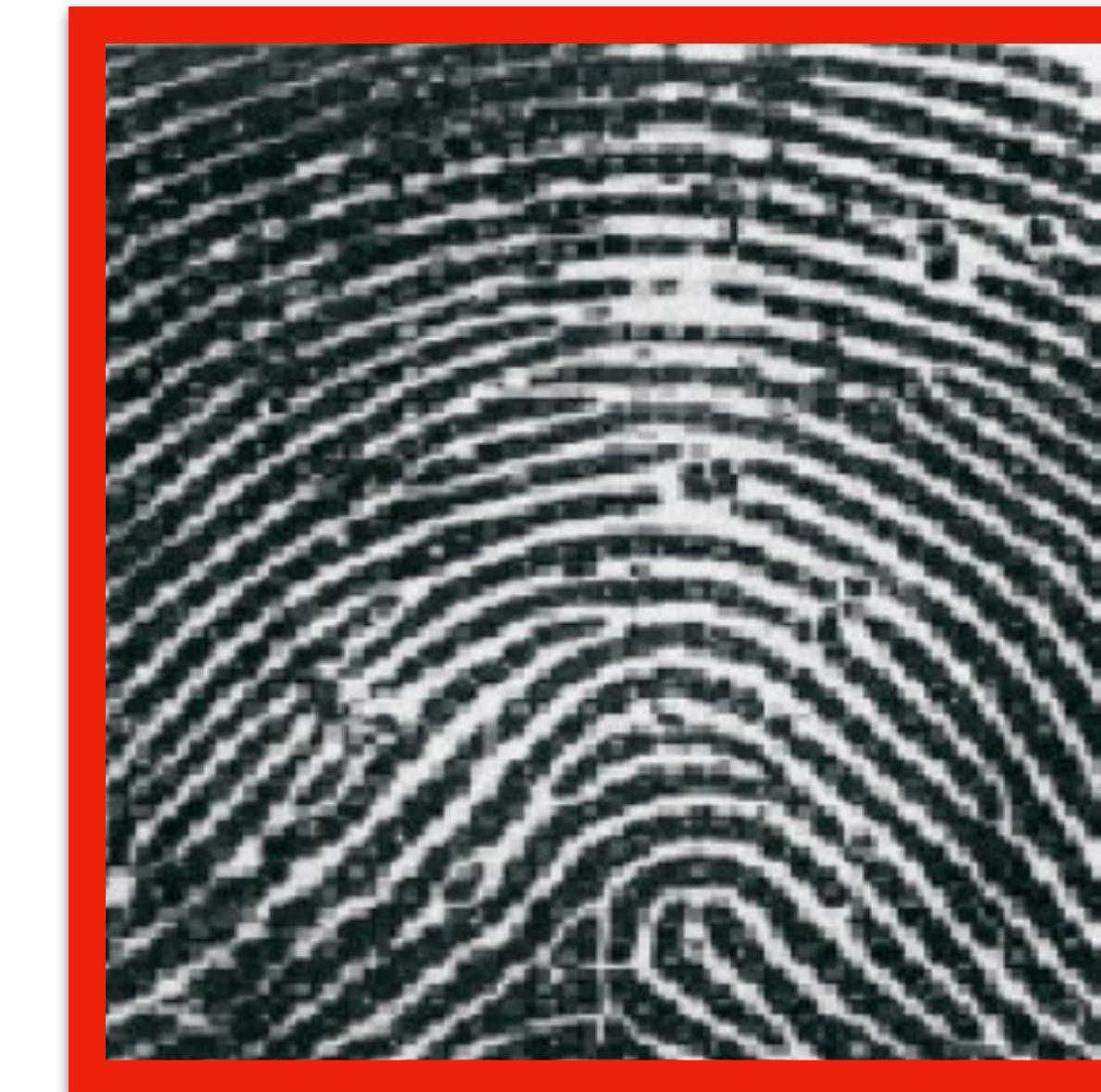
From capacitive sensor

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

UNIVERSITY OF
NOTRE DAME
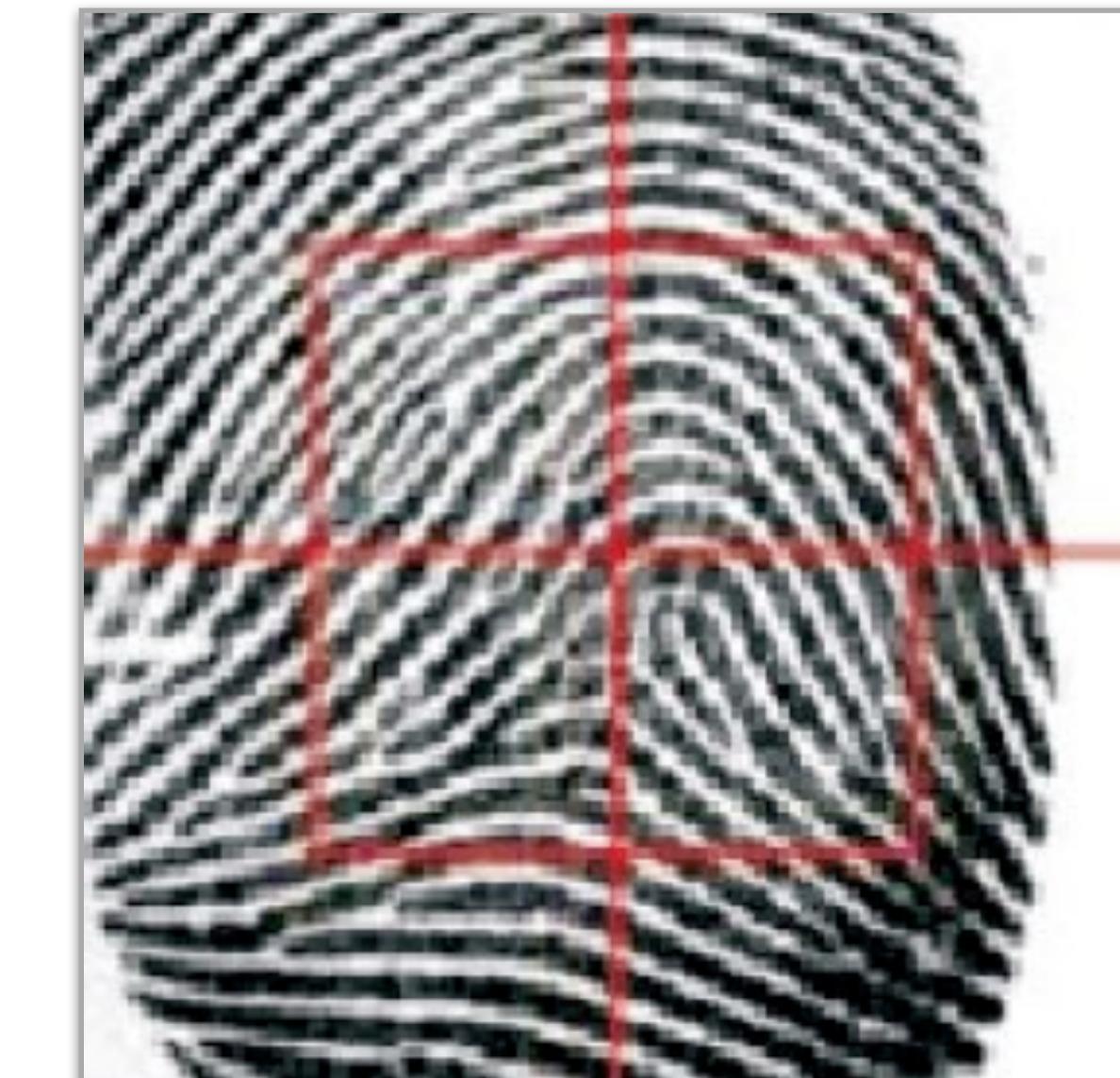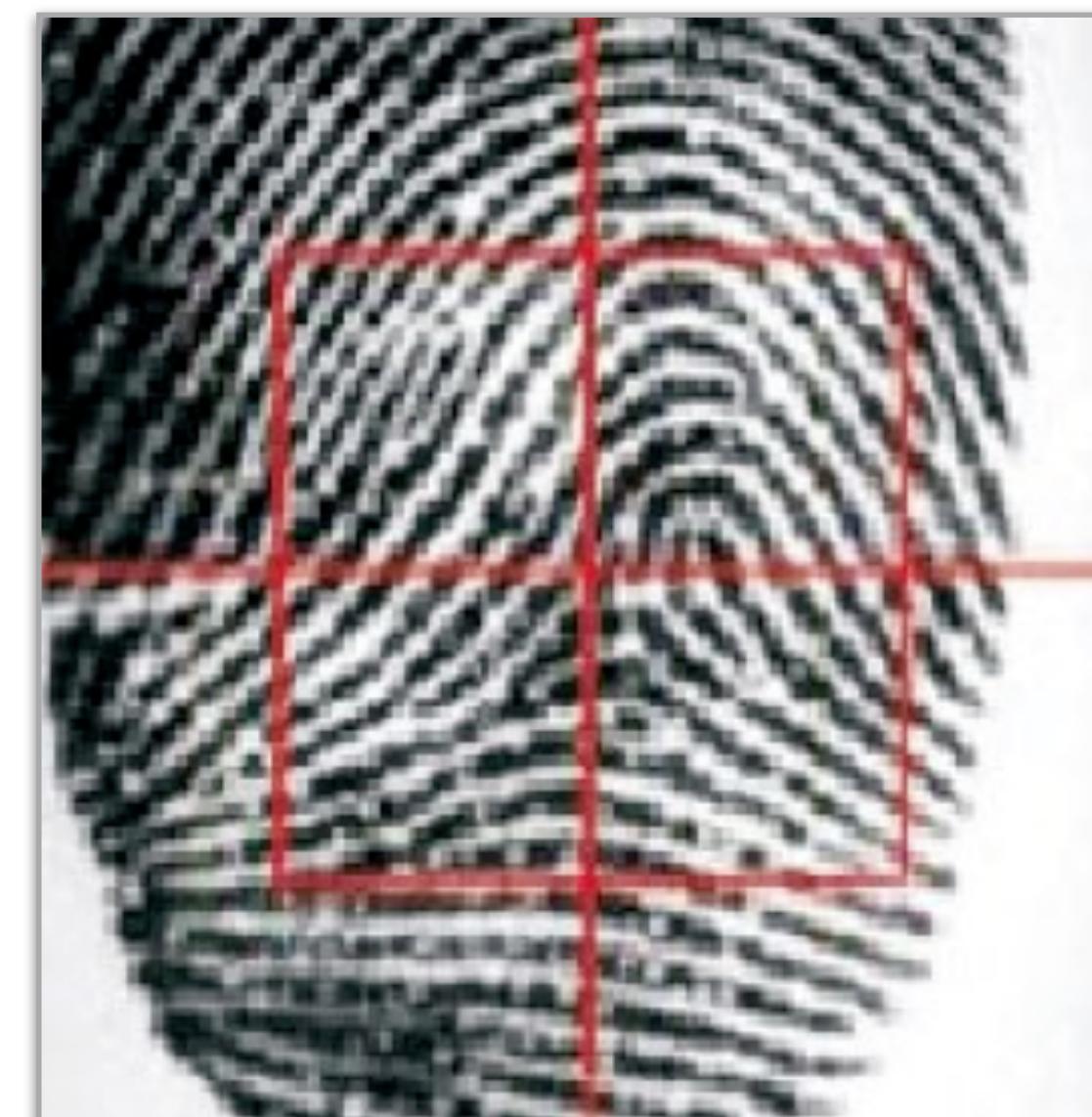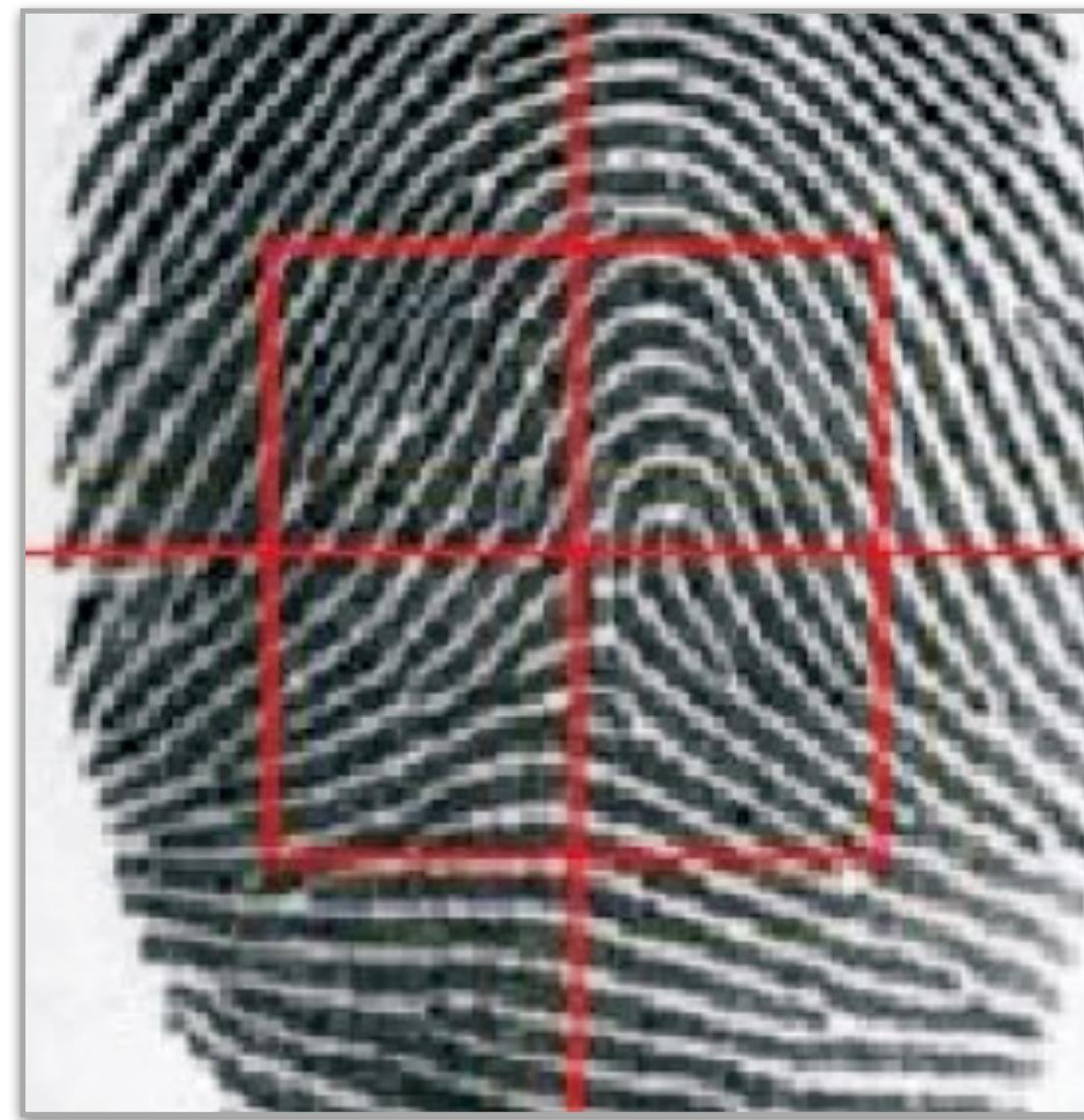
Fake or authentic?

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

37
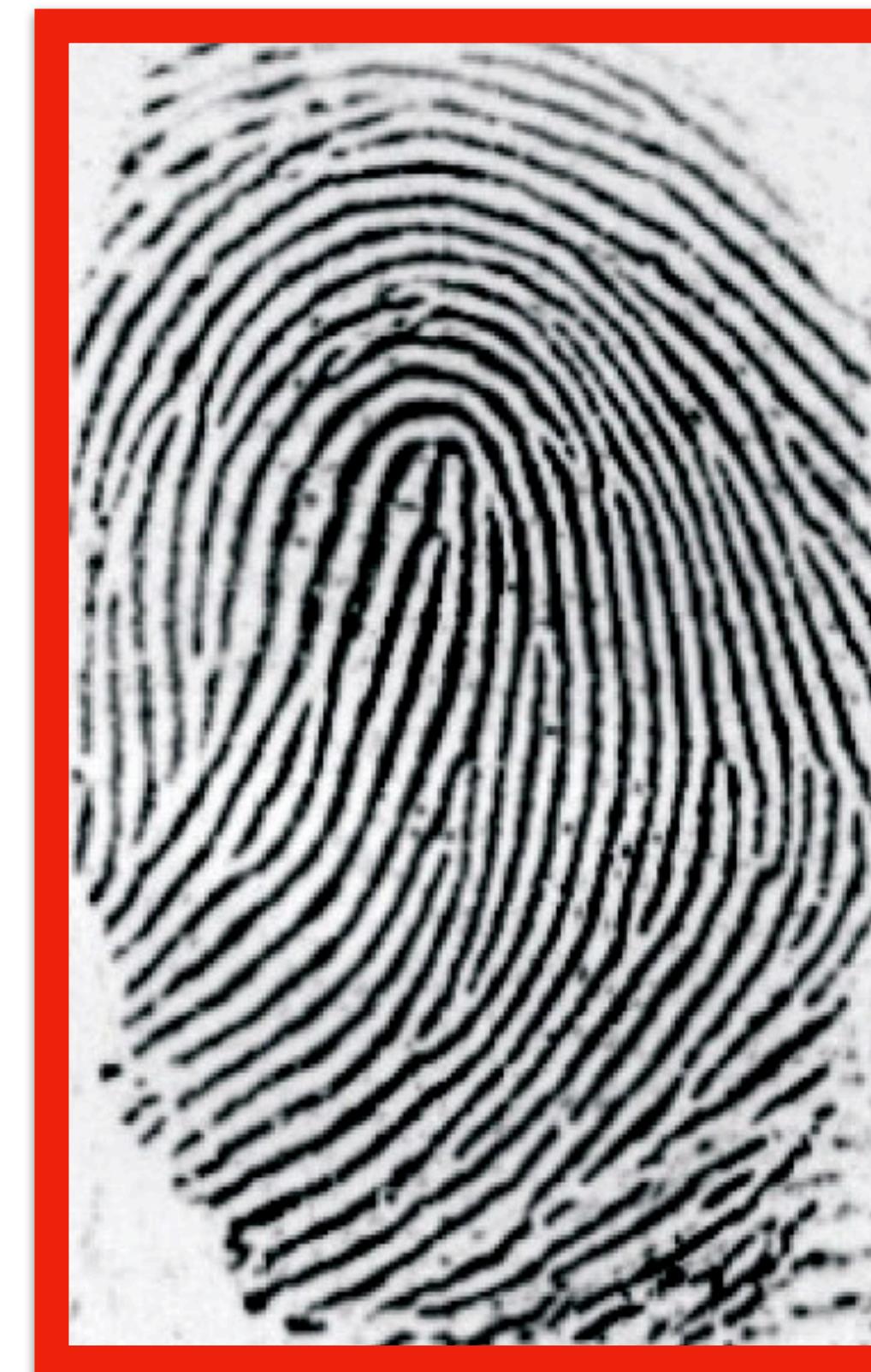
Fake or authentic?

From optical sensor

Fake or authentic?

From optical sensor

Source: Dr. Adam Czajka

wood glue
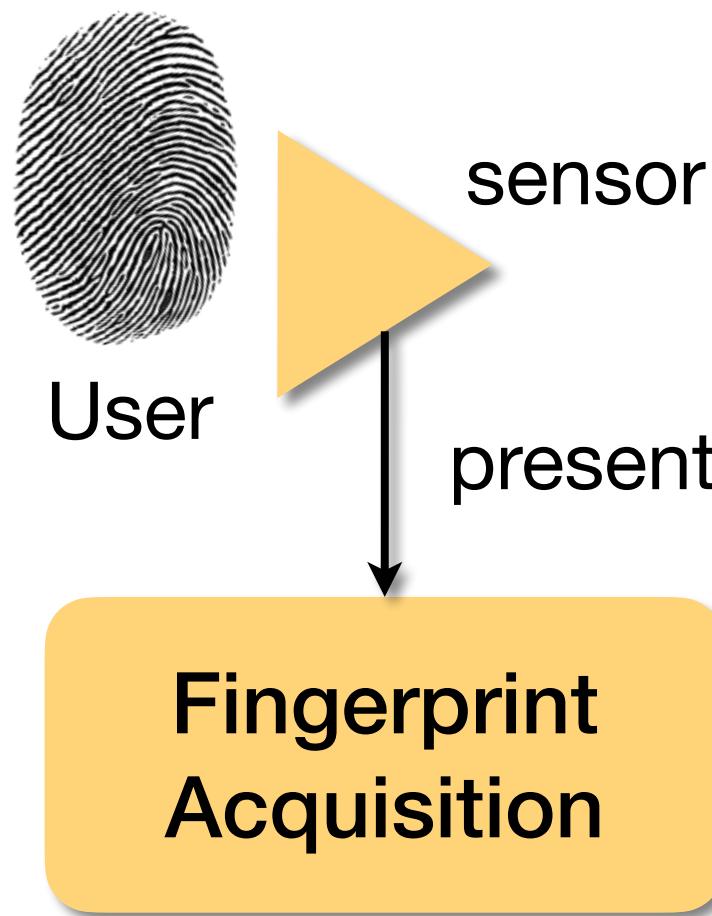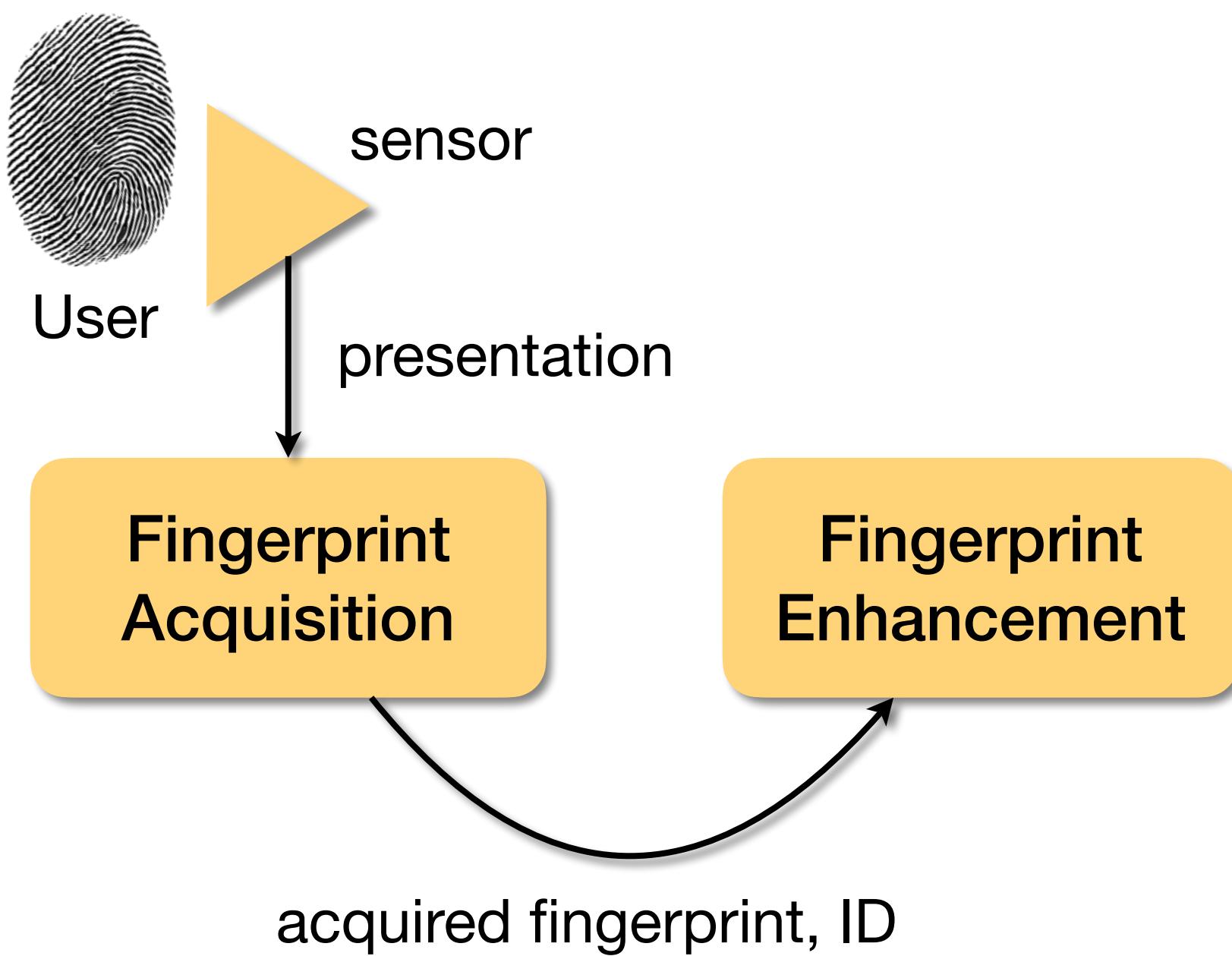
authentic

Fingerprint Recognition

sensor

User

presentation

Fingerprint Acquisition

UNIVERSITY OF
NOTRE DAME

Fingerprint Recognition

sensor

User

presentation

Fingerprint Acquisition

Fingerprint Enhancement

acquired fingerprint, ID

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.

UNIVERSITY OF
NOTRE DAME

Enhancement

Capture Condition

too bright

too dark

Enhancement

Skin Condition

normal

dry

wet

U N I V E R S I T Y O F
NOTRE DAME

Enhancement

Image Processing Solutions

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

Enhancement

Image Processing Solutions
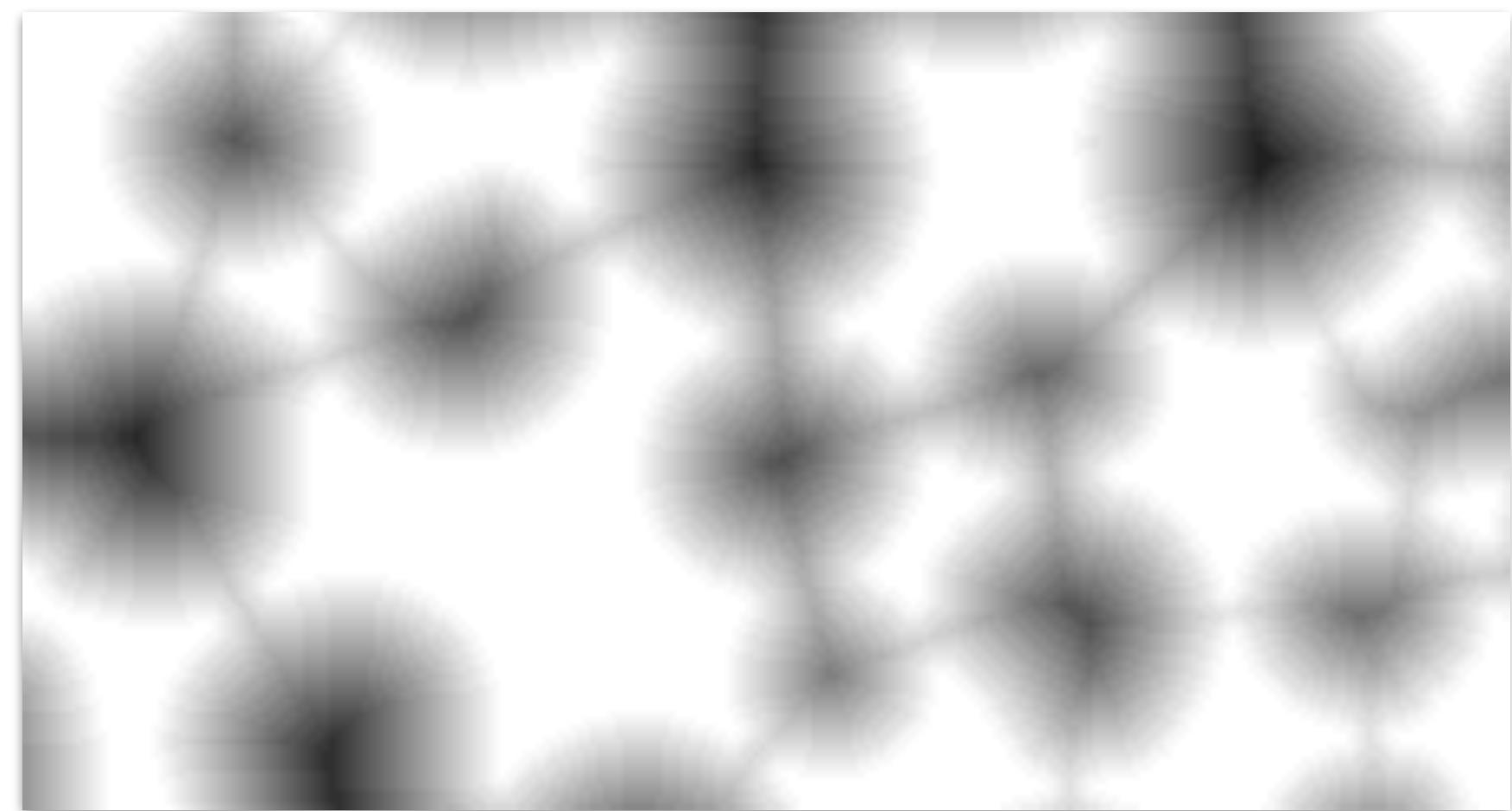
Tasks
Enhancement of image contrast.
Enhancement of ridges and valleys.
Content segmentation.
Others.

UNIVERSITY OF
NOTRE DAME
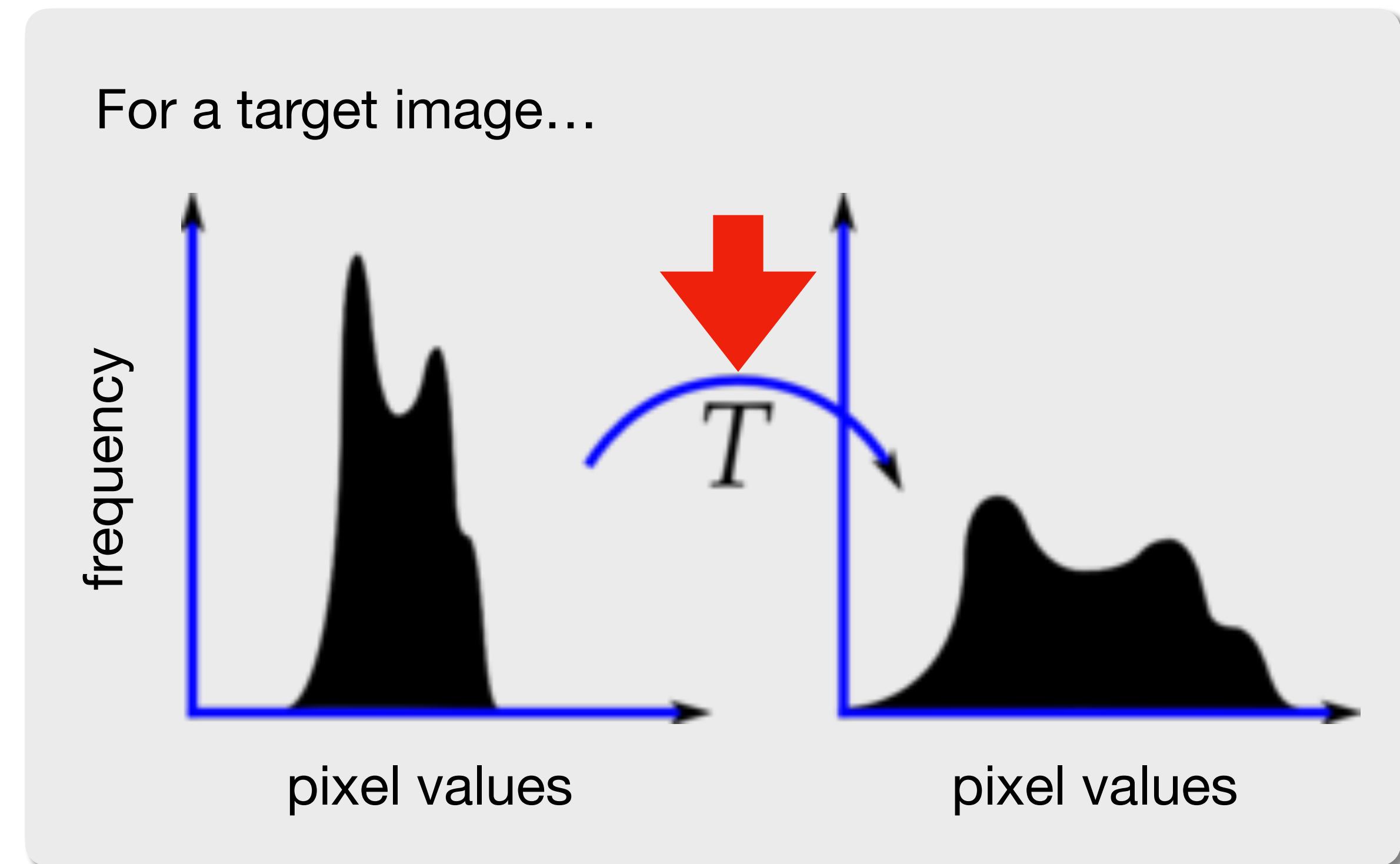
Enhancement

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…

frequency

pixel values

T

pixel values

UNIVERSITY OF
NOTRE DAME

Enhancement

Color Histogram Equalization
Simple implementation

Toy Case

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

UNIVERSITY OF
NOTRE DAME

Enhancement

Color Histogram Equalization
Simple implementation

Toy Case

1. Compute cumulative distribution function (CDF)

color histogram

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

Value	Count	Value	Count	Value	Count	Value	Count	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

UNIVERSITY OF
NOTRE DAME

Enhancement

Color Histogram Equalization
Simple implementation

Toy Case

1. Compute cumulative
distribution function
(CDF)

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

UNIVERSITY OF
NOTRE DAME

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

· · ·

126	62	247
144	63	251
154	64	255

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

UNIVERSITY OF
NOTRE DAME

51

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

UNIVERSITY OF
NOTRE DAME

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

UNIVERSITY OF
NOTRE DAME

Enhancement

Image Contrast
Example:
Color histogram equalization.

Example: too bright capture.

before

after

UNIVERSITY OF
NOTRE DAME

Enhancement

Image Contrast
Example:
Color histogram equalization.

Example: too dark capture.

before

after

Enhancement
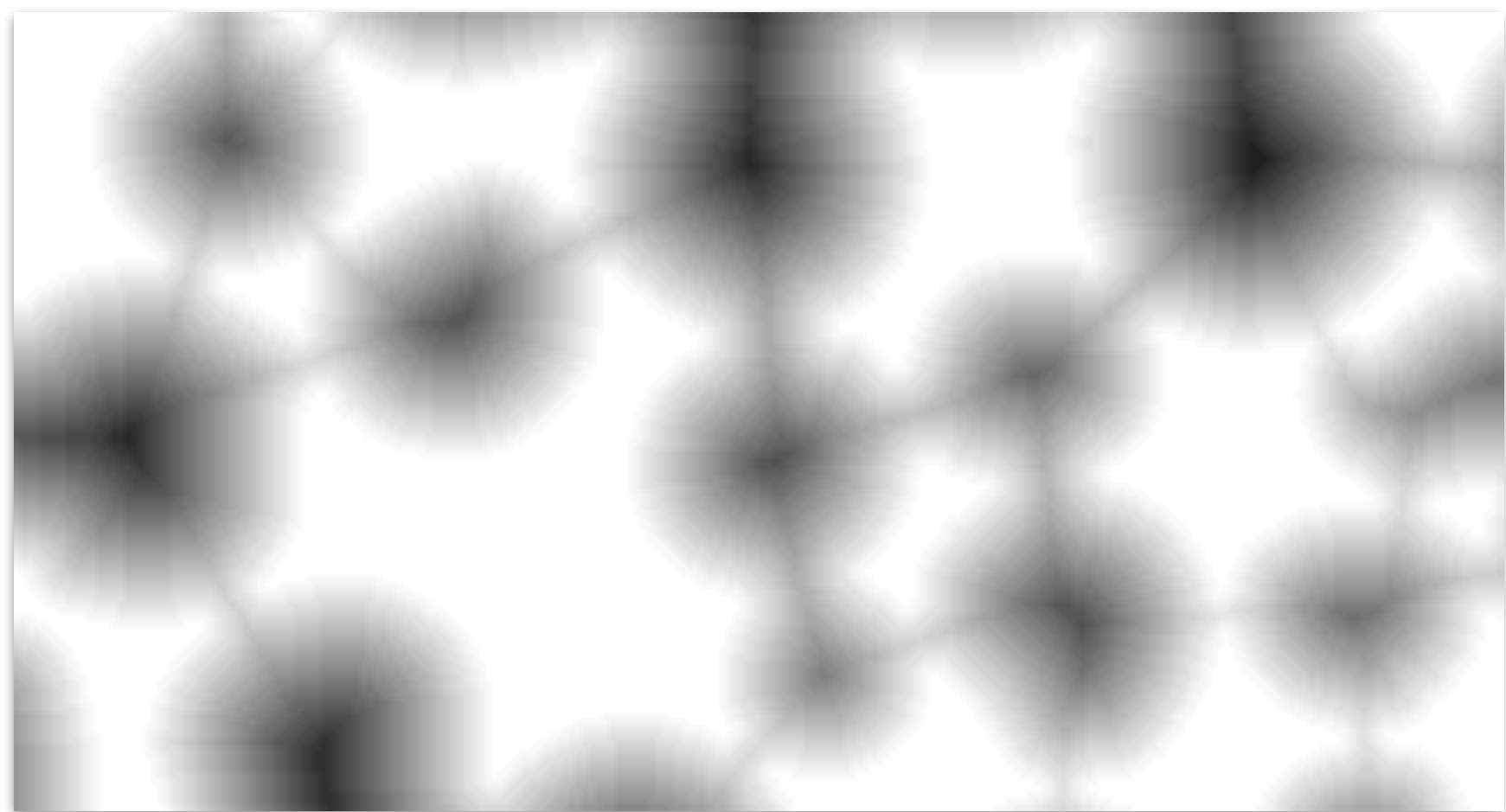
Image Processing Solutions

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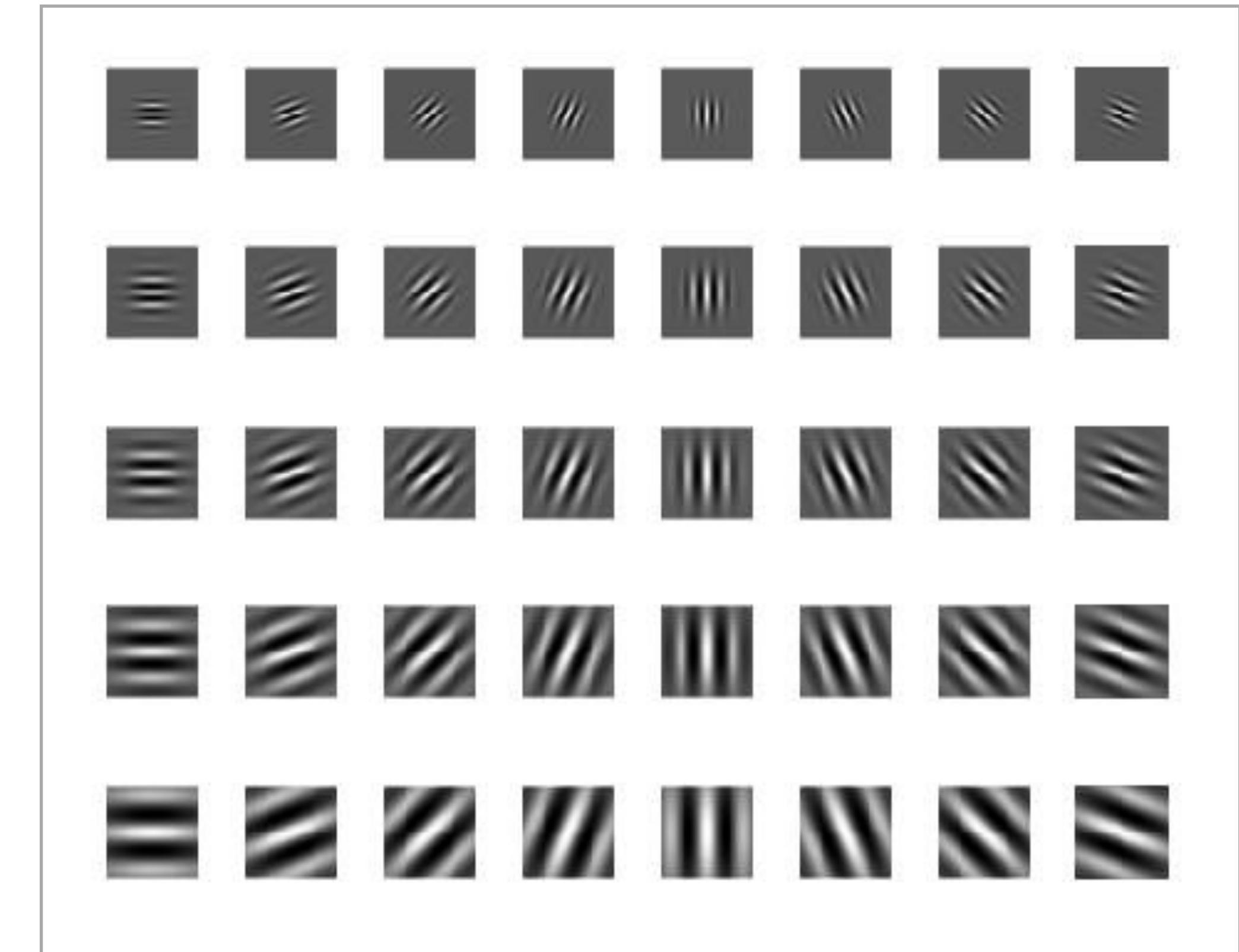
Enhancement

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.
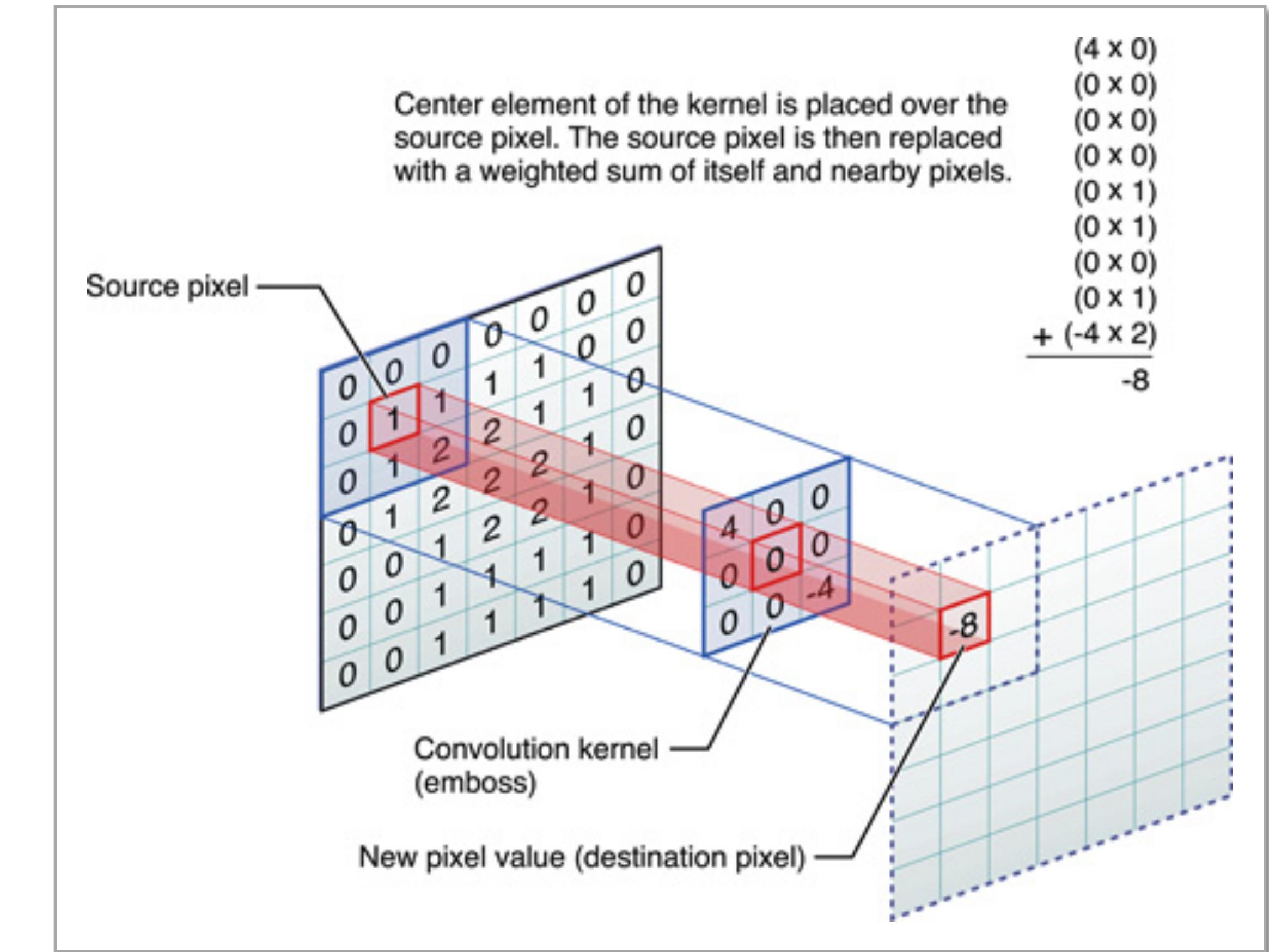
Enhancement

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.

UNIVERSITY OF
NOTRE DAME

Enhancement

Ridges and Valleys
Example:
Image filtering with
Gabor filters.

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

before

after

UNIVERSITY OF
NOTRE DAME

Enhancement

Image Processing Solutions

Tasks
Enhancement of image contrast.
Enhancement of ridges and valleys.
**Content segmentation.**
Others.

UNIVERSITY OF
NOTRE DAME

Enhancement

Segmentation
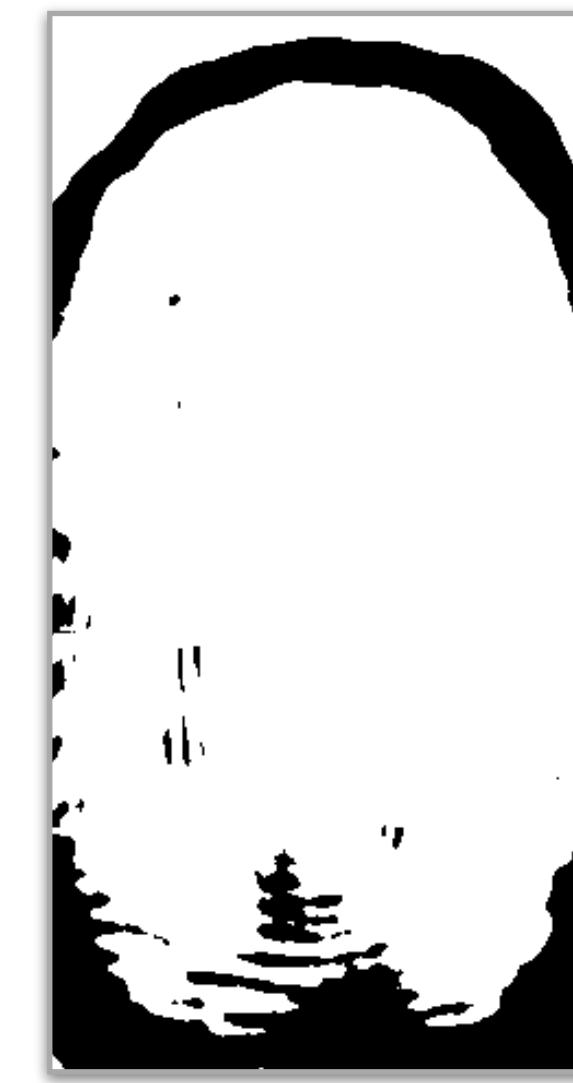
Example: blurring, thresholding, and morphological operations.
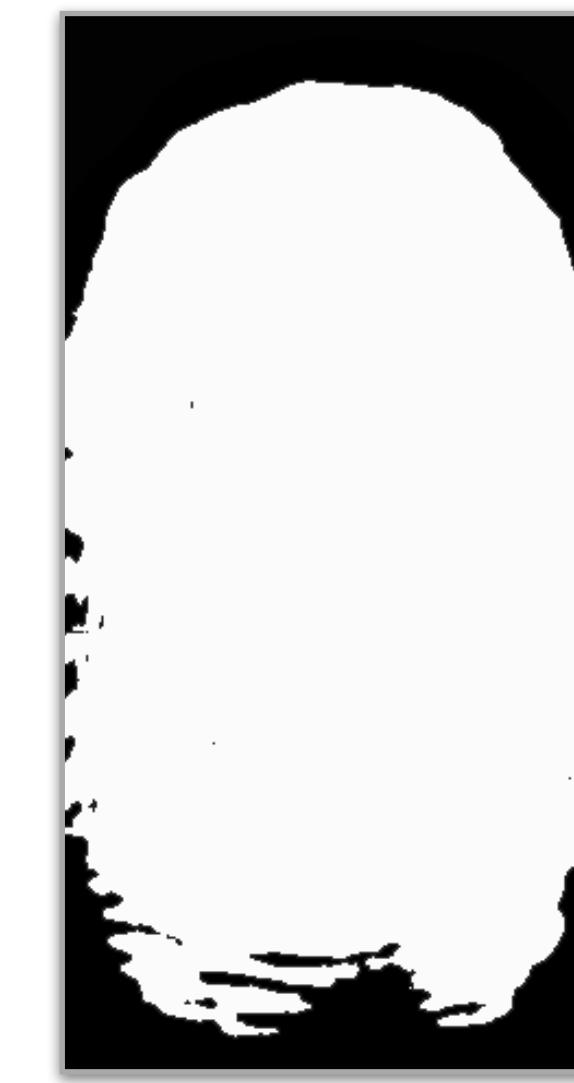
| before | blur | threshold | open | after |

Enhancement
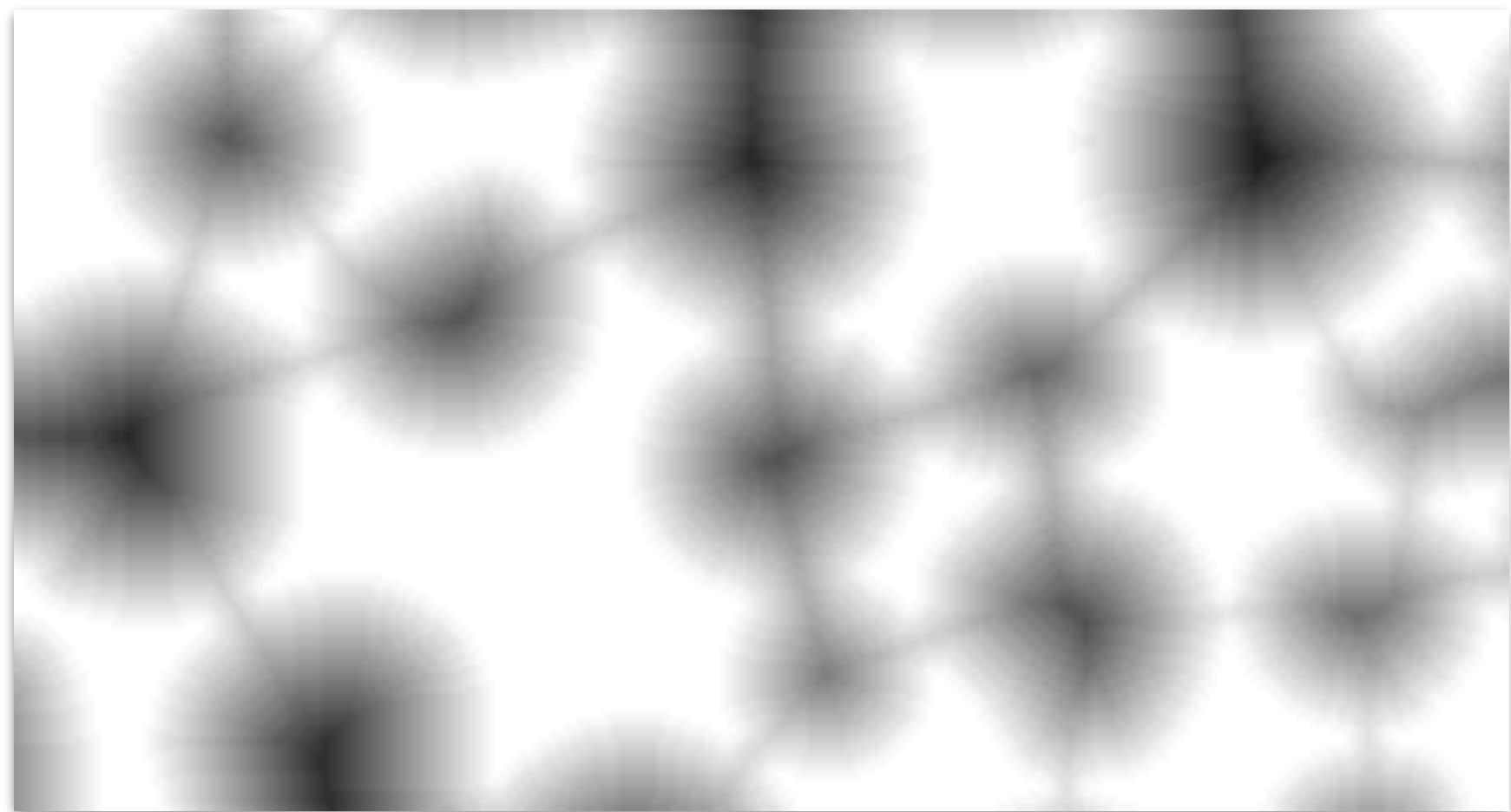
Image Processing Solutions

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

UNIVERSITY OF
NOTRE DAME
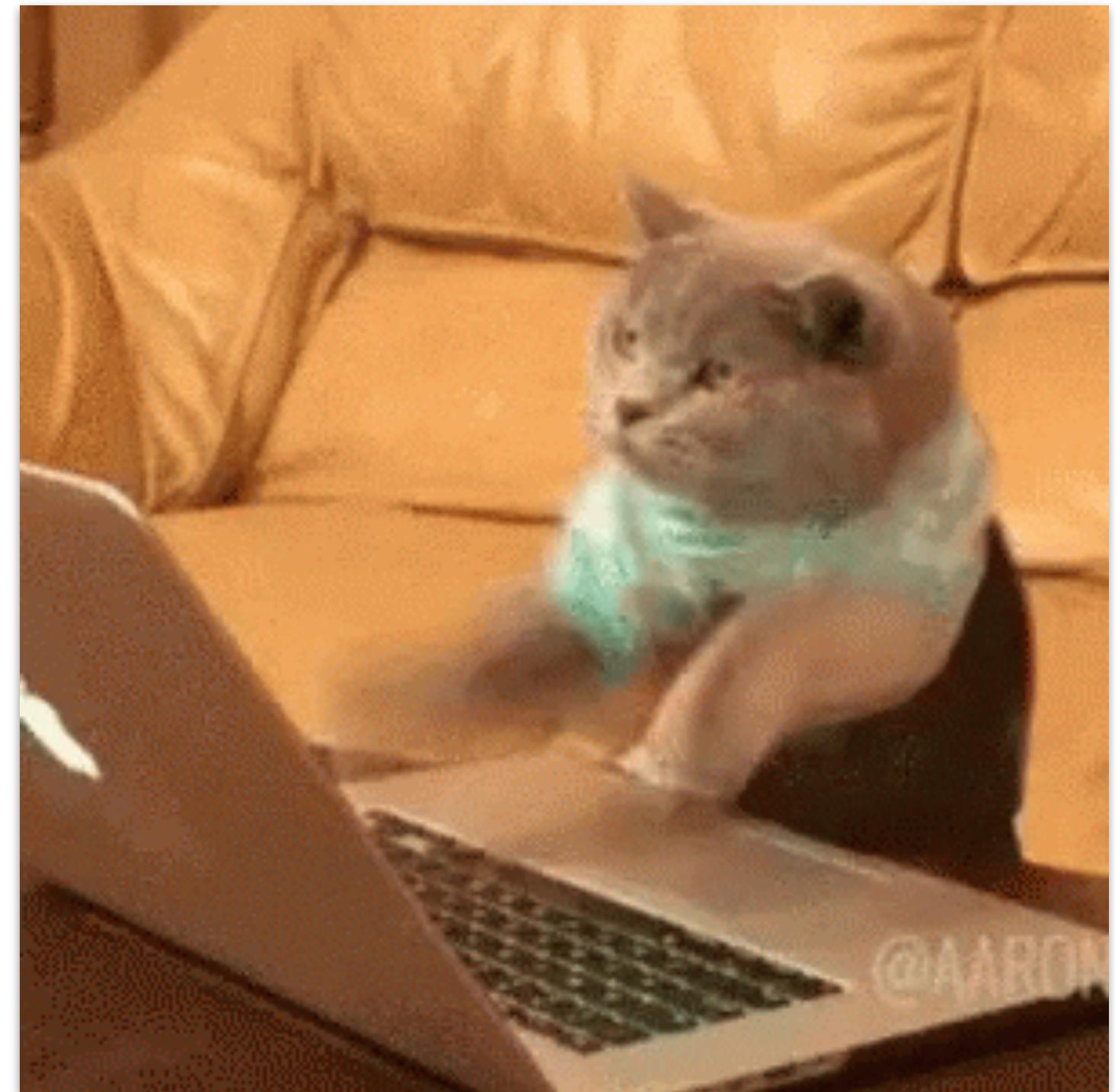
Enhancement

**Image Processing Solutions**
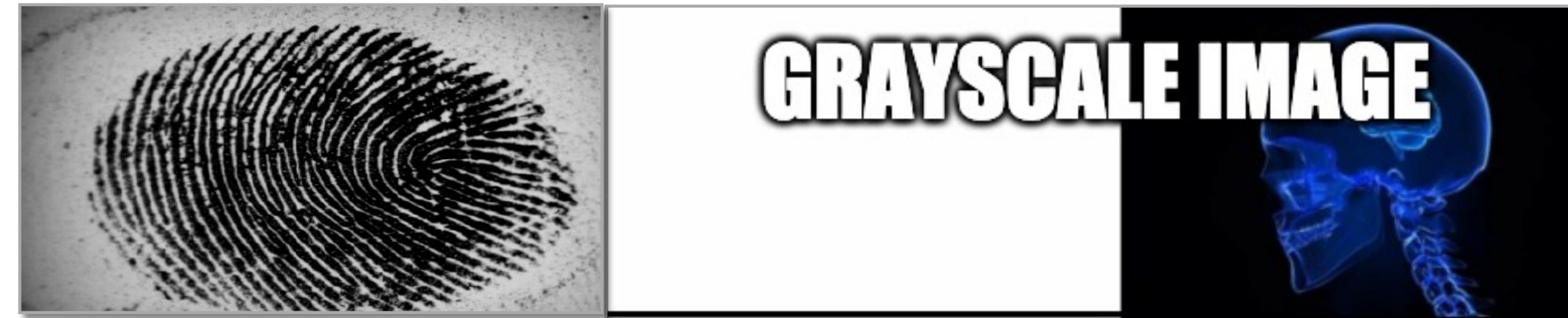
Be Aware
Besides the aforementioned techniques, there are much more sophisticated and effective ones.

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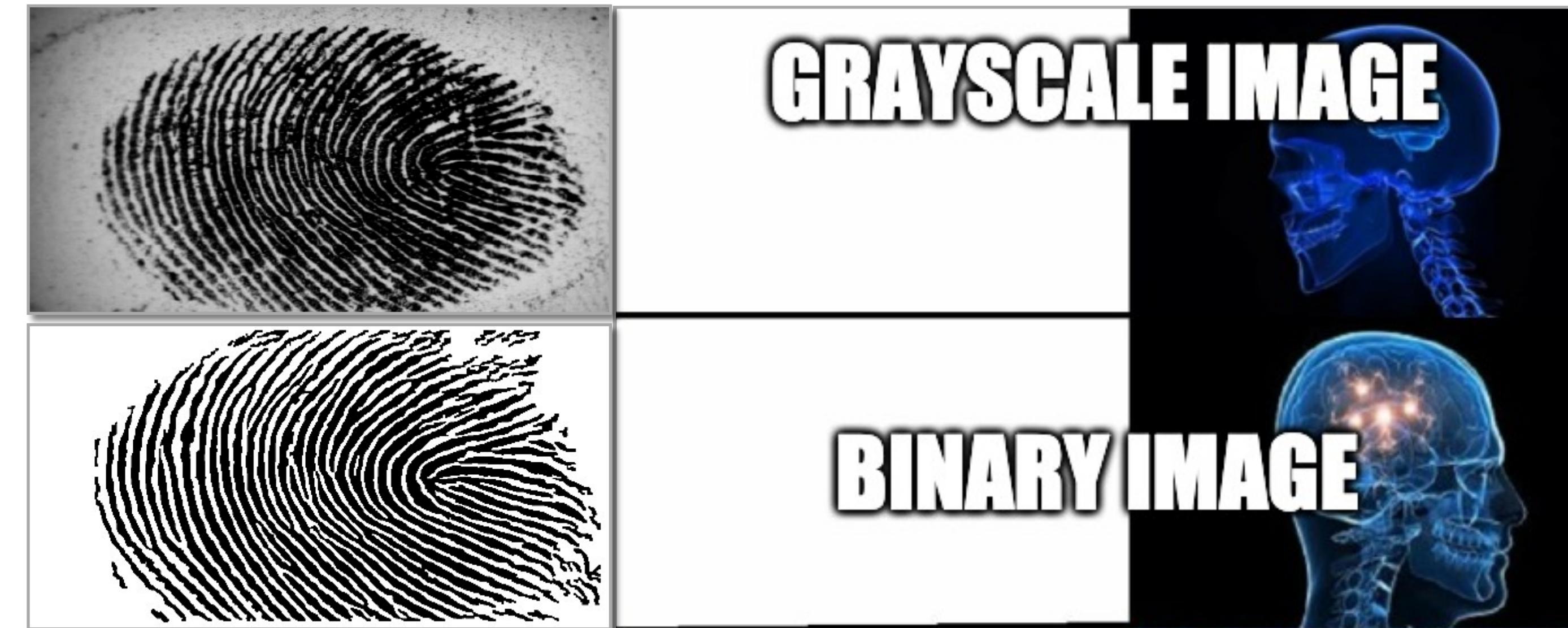
UNIVERSITY OF NOTRE DAME

Enhancement

Other Strategies
Start from…
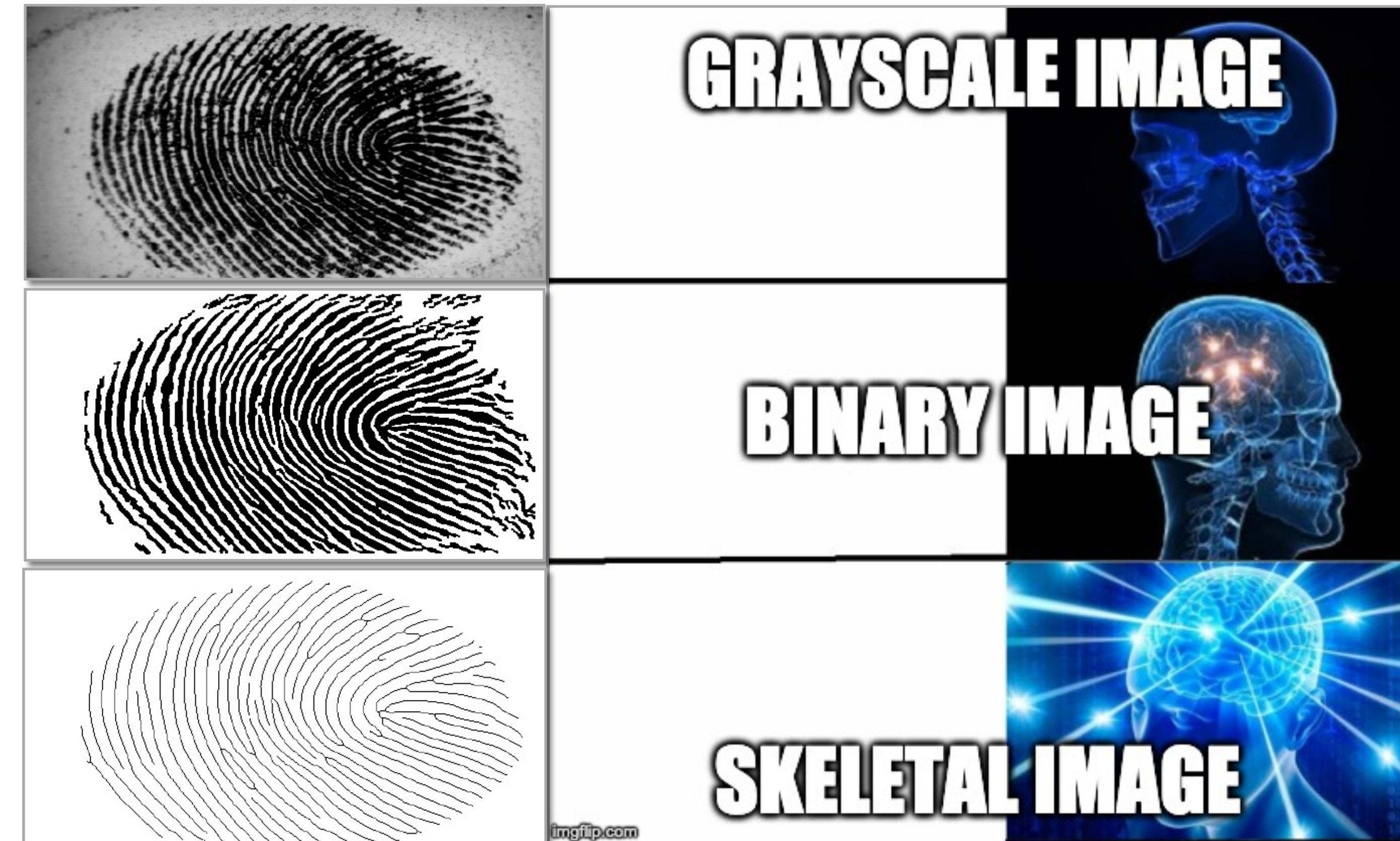
Enhancement

Other Strategies
Start from…

Enhancement

Other Strategies
Start from…

Source: Dr. Adam Czajka

67

Enhancement

Other Strategies
Start from…
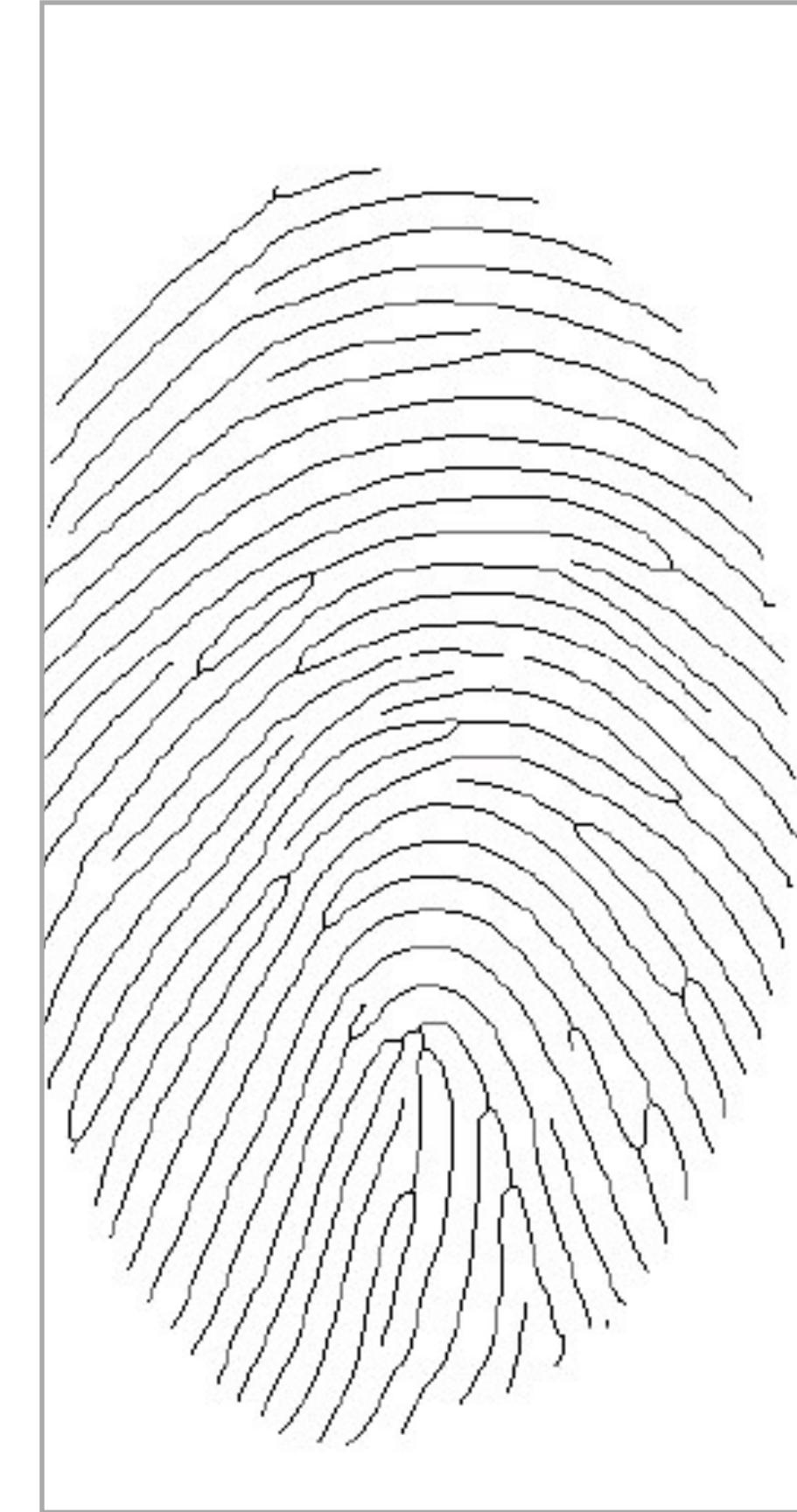
Each strategy has its own set of pros and cons, and will lead to different performance.


Source: Dr. Adam Czajka

GRAYSCALE IMAGE

Just kidding…

SKELETAL IMAGE

UNIVERSITY OF
NOTRE DAME
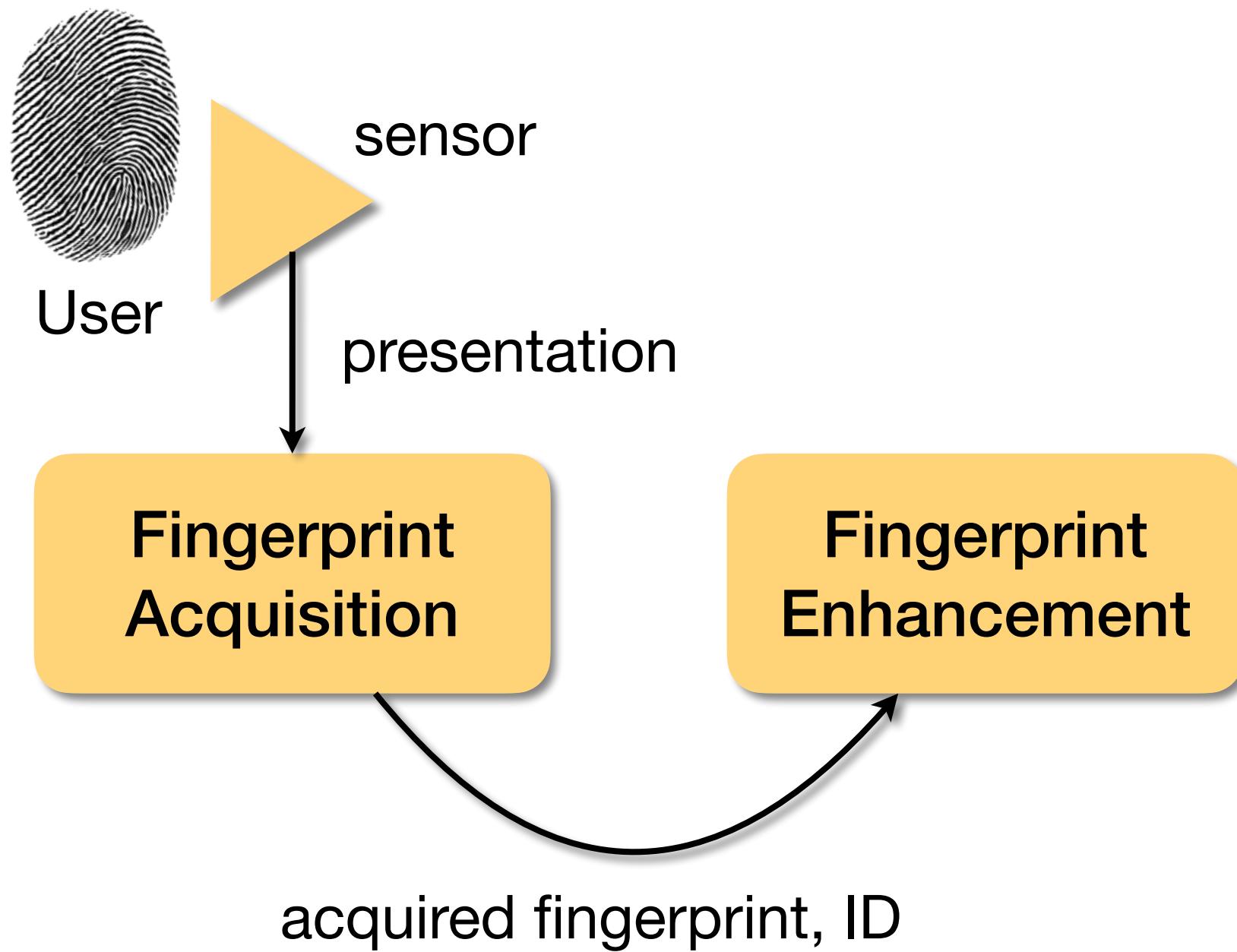
Enhancement

Source: Dr. Adam Czajka

UNIVERSITY OF
NOTRE DAME

69

Fingerprint Recognition

sensor

User

presentation

Fingerprint Acquisition

Fingerprint Enhancement

acquired fingerprint, ID
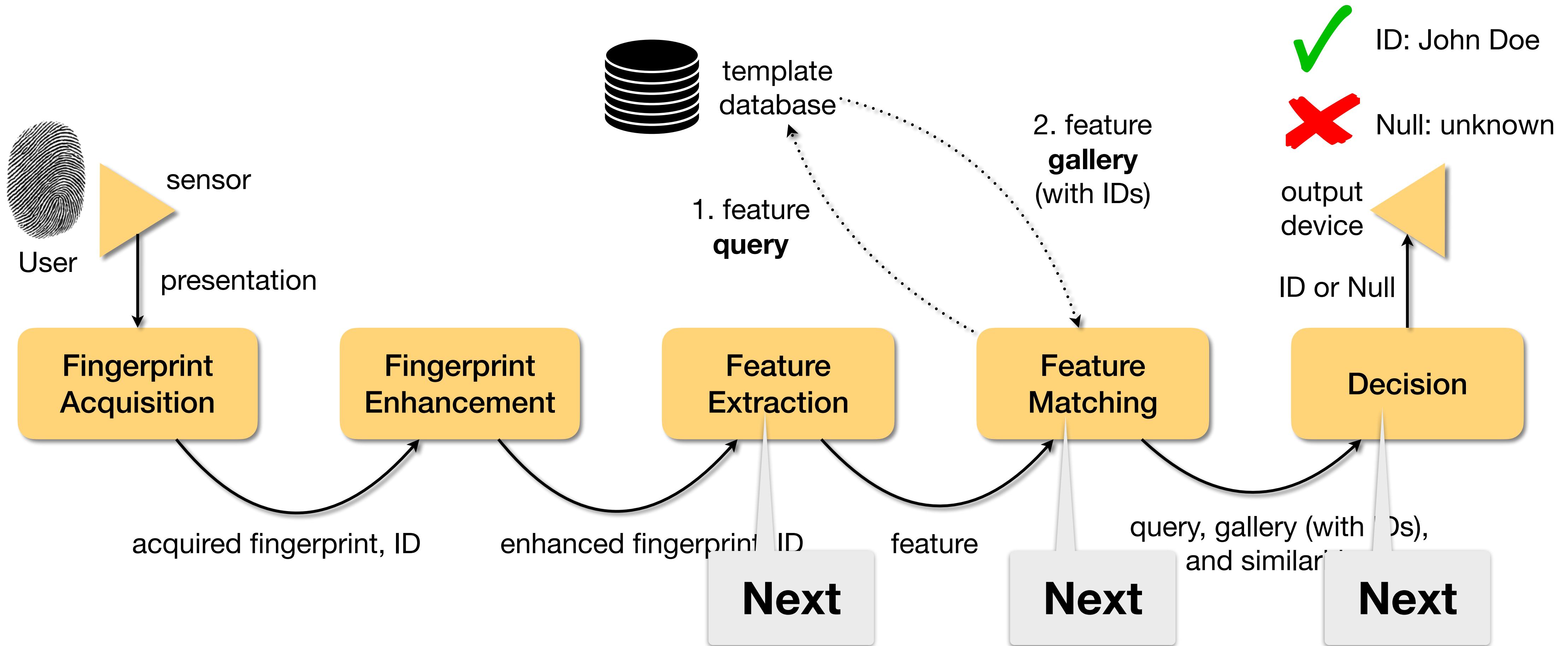
Fingerprint Recognition

S'up Next?

Even more about fingerprints
Fingerprint feature extraction methods.
Fingerprint matching methods.
Visit to see fingerprint sensors.

© TIMELAPSE VISION INC.

UNIVERSITY OF
NOTRE DAME