

# Fingerprint Recognition II

CSE 40537/60537 Biometrics

**Daniel Moreira**  
Spring 2020

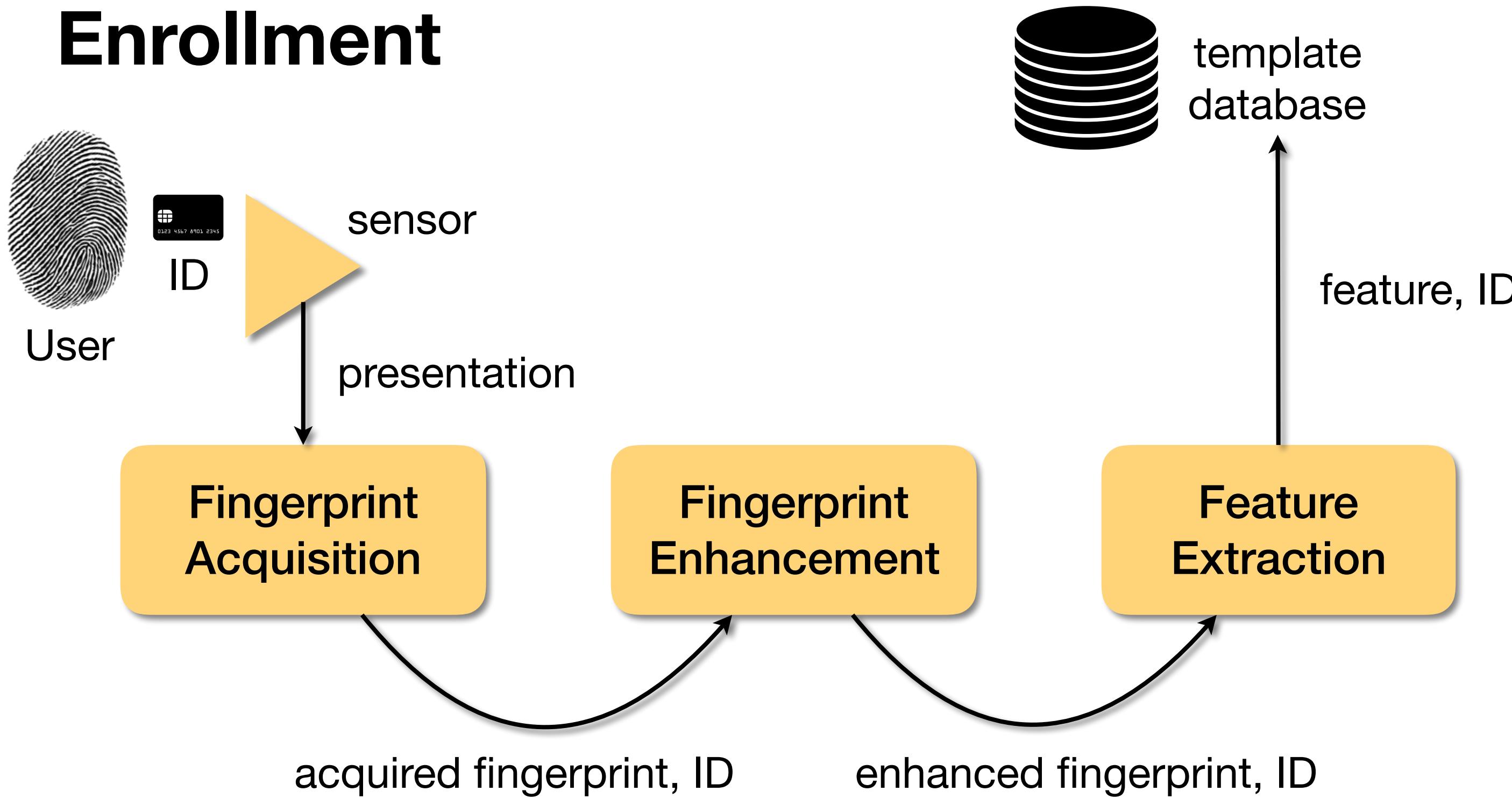


# Today you will...

*Get to know*  
Fingerprint acquisition and enhancement.

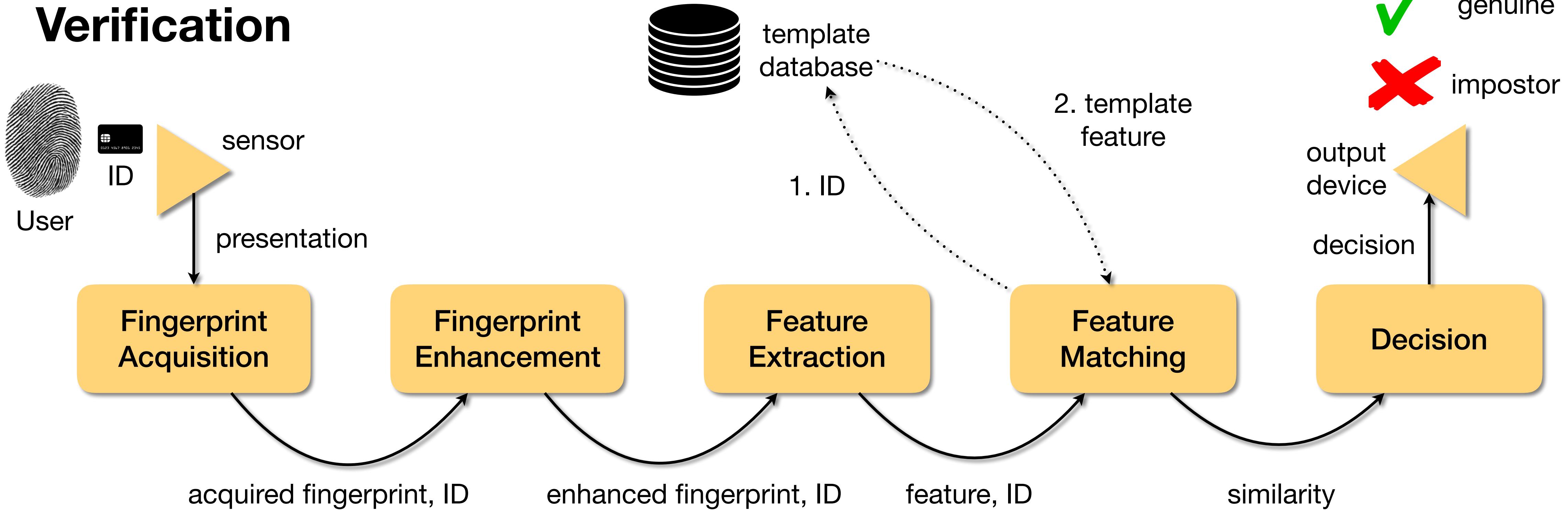
# Fingerprint Recognition

## Enrollment



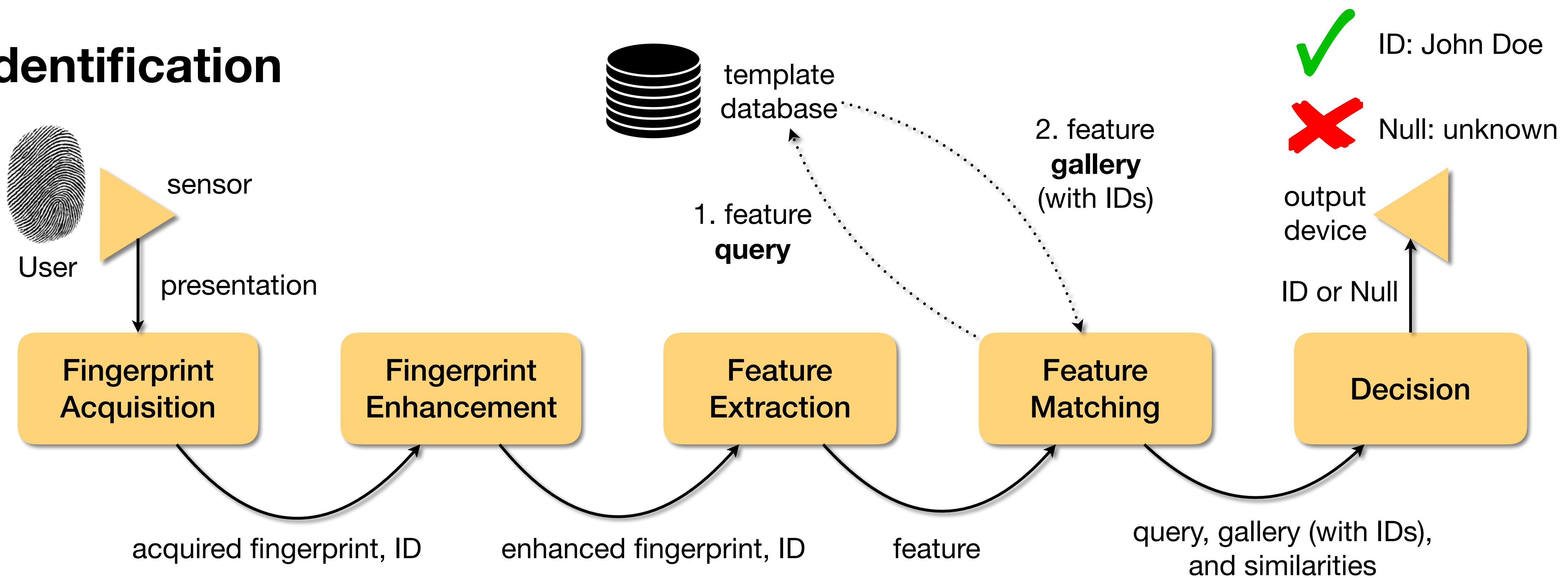
# Fingerprint Recognition

## Verification

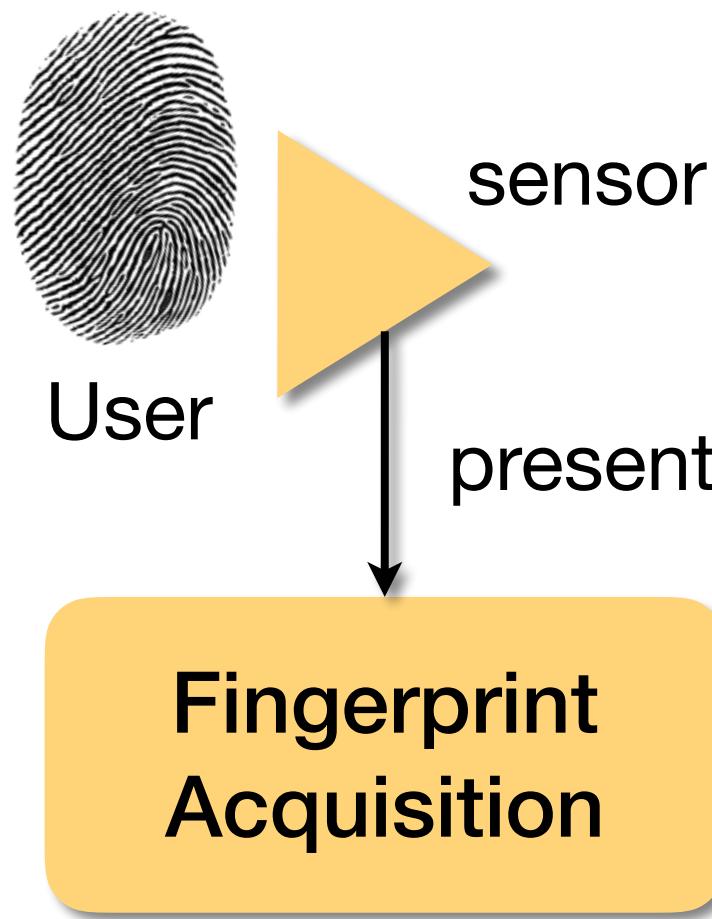


# Fingerprint Recognition

## Identification

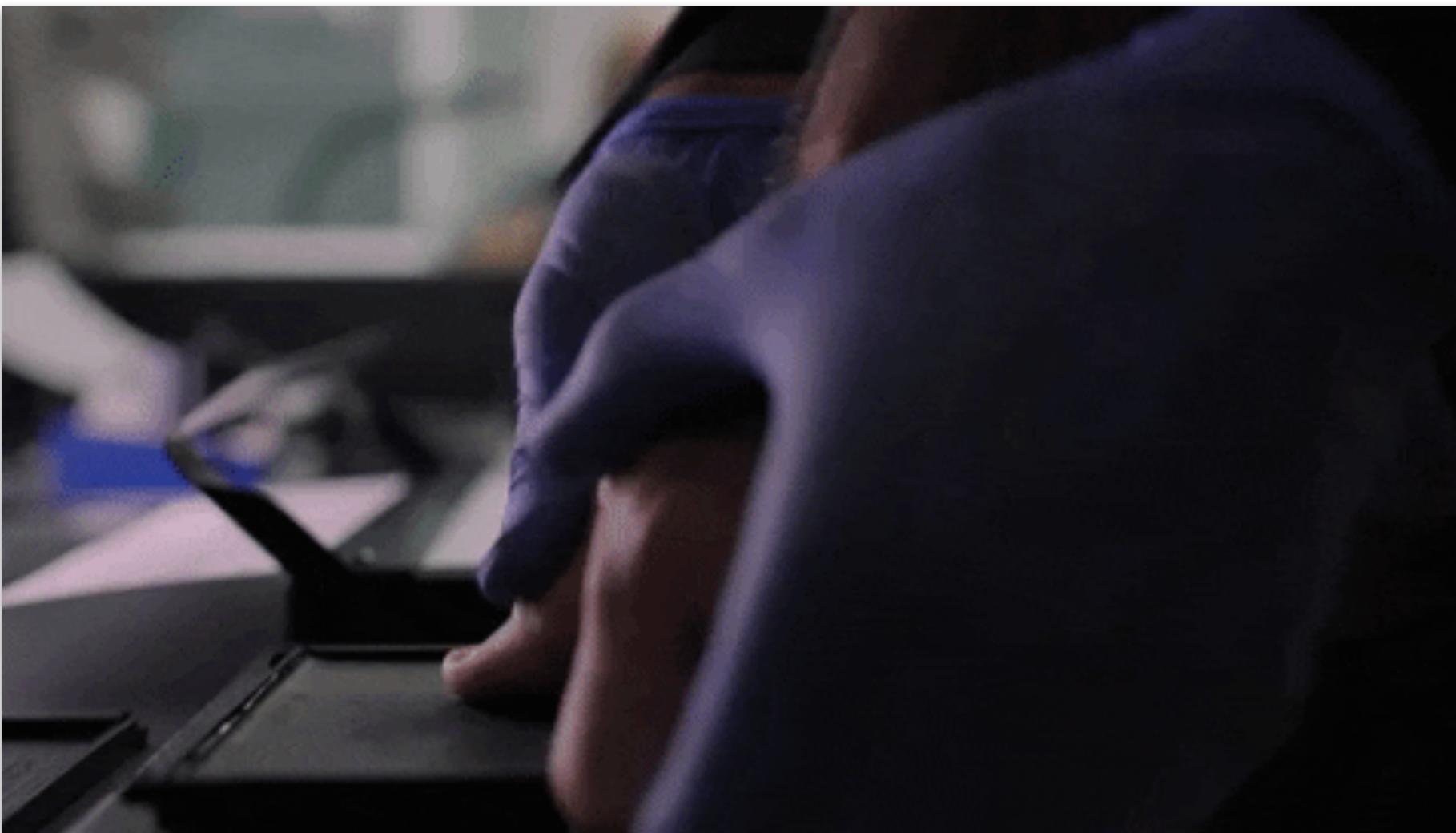


# Fingerprint Recognition



# Acquisition

Off-line versus On-line



# Acquisition

## Off-line Acquisition

Same fingerprint.



rolled inked fingerprint



slap inked fingerprint



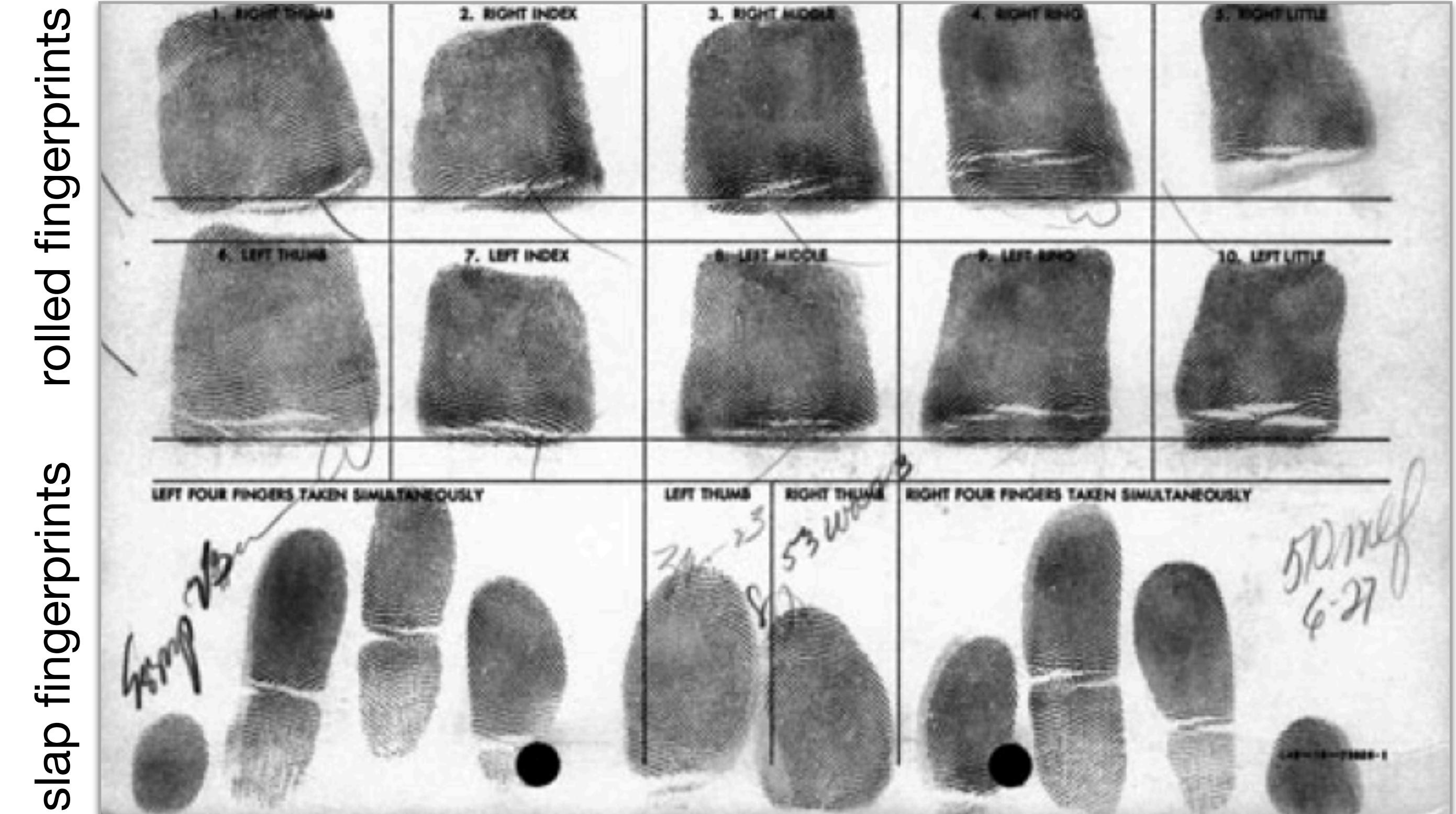
latent fingerprint

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

# Acquisition

## Off-line Acquisition

Scanning of dactyloscopy cards.



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

# Acquisition

## Off-line Acquisition

Photographing of latent fingerprints.



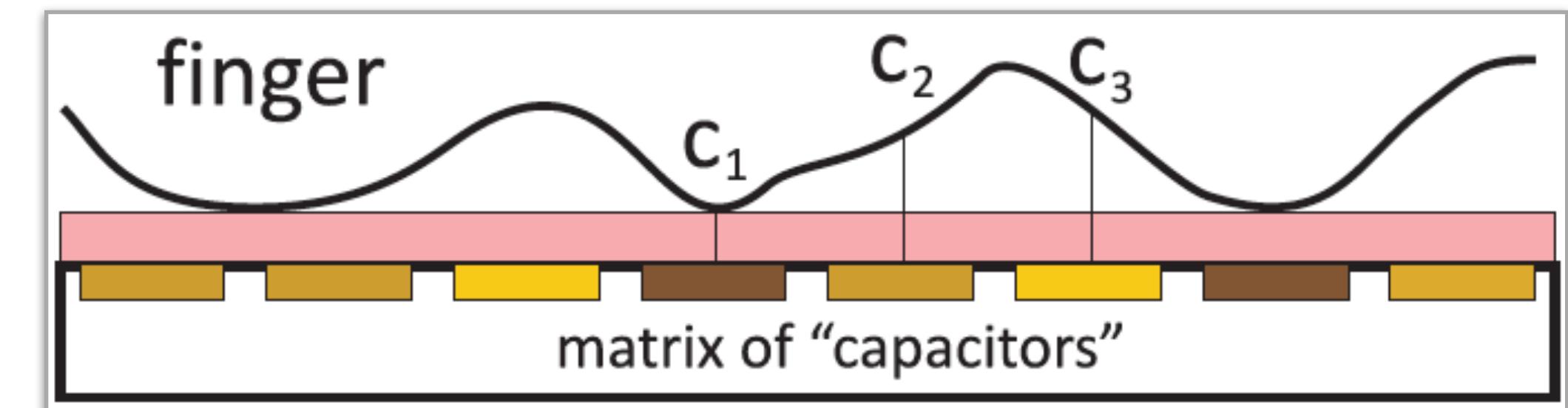
Source: Dr. Adam Czajka

# 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/>

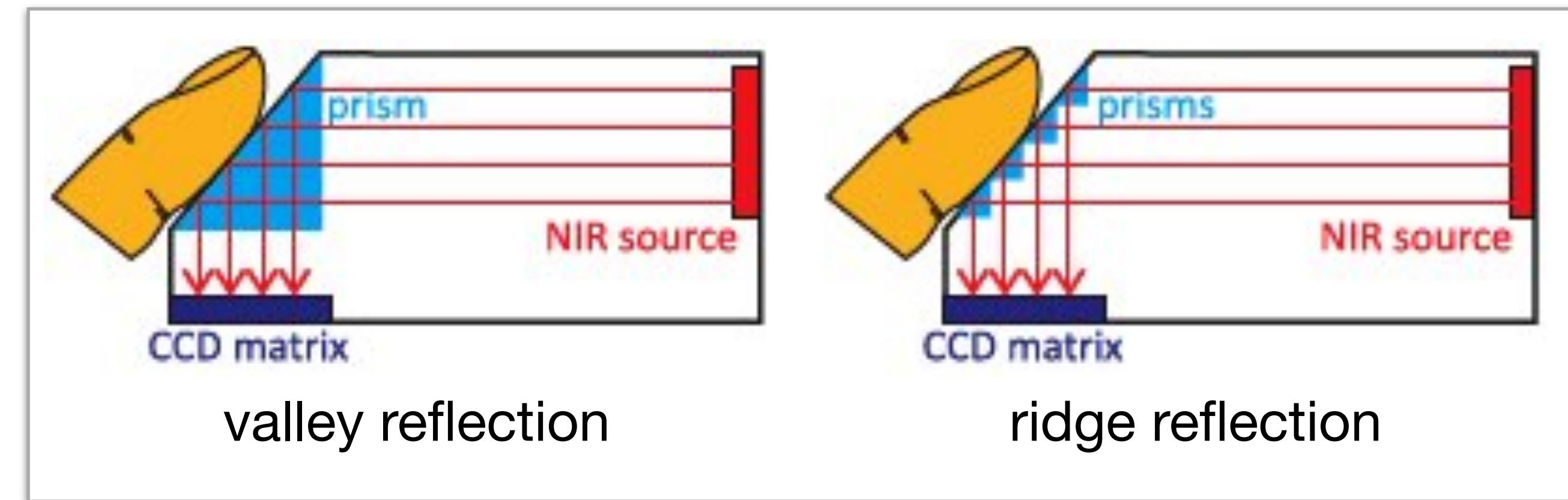
# Acquisition

## 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*

# Acquisition

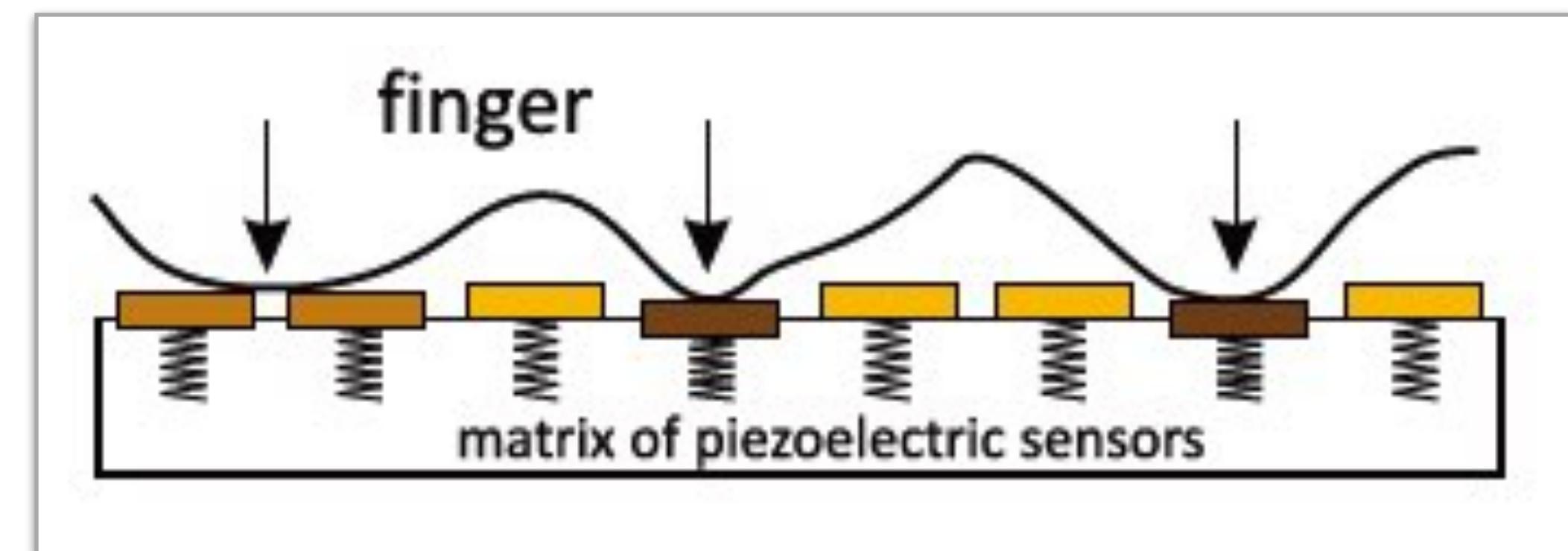
## On-line Acquisition

### 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

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

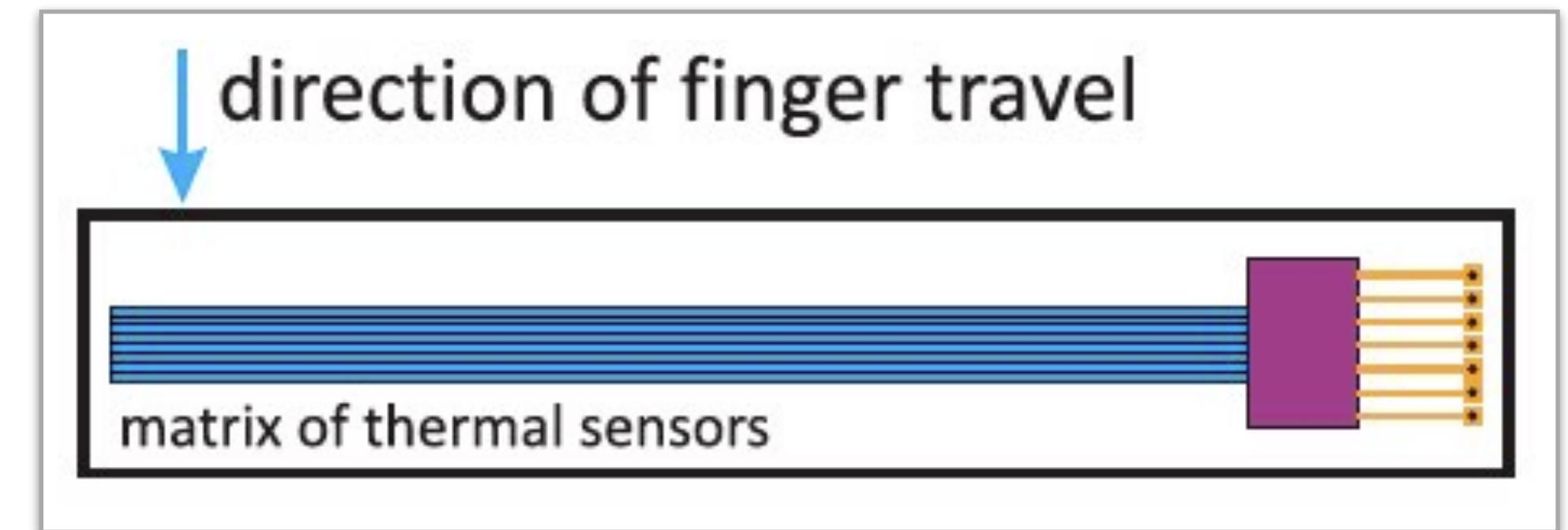
### Thermal sensors (4/6)

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.



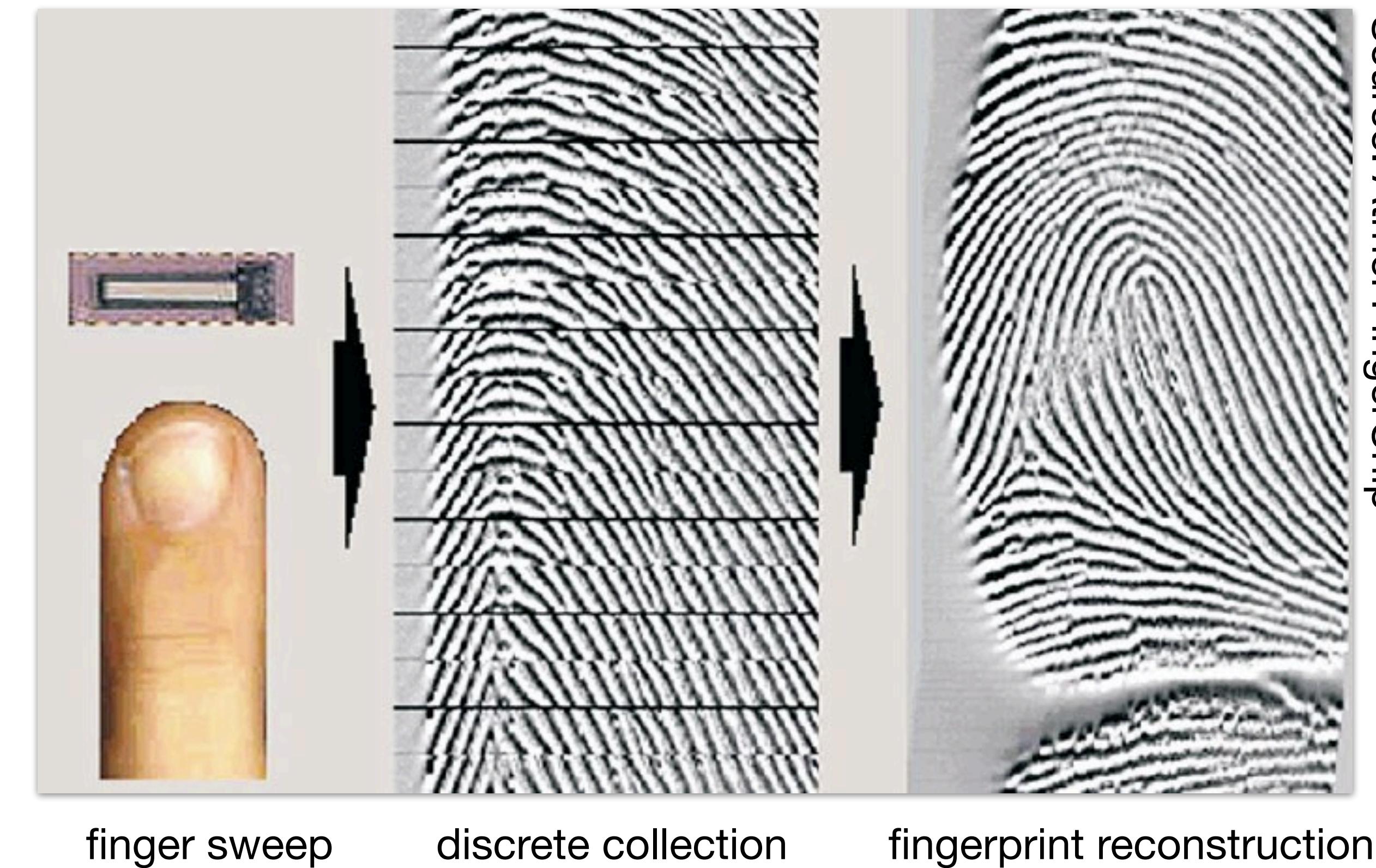
Source: Dr. Adam Czajka

# Acquisition

## On-line Acquisition

### Thermal sensors (4/6)

Example: Atmel FingerChip  
Sample generation.



Source: Atmel FingerChip

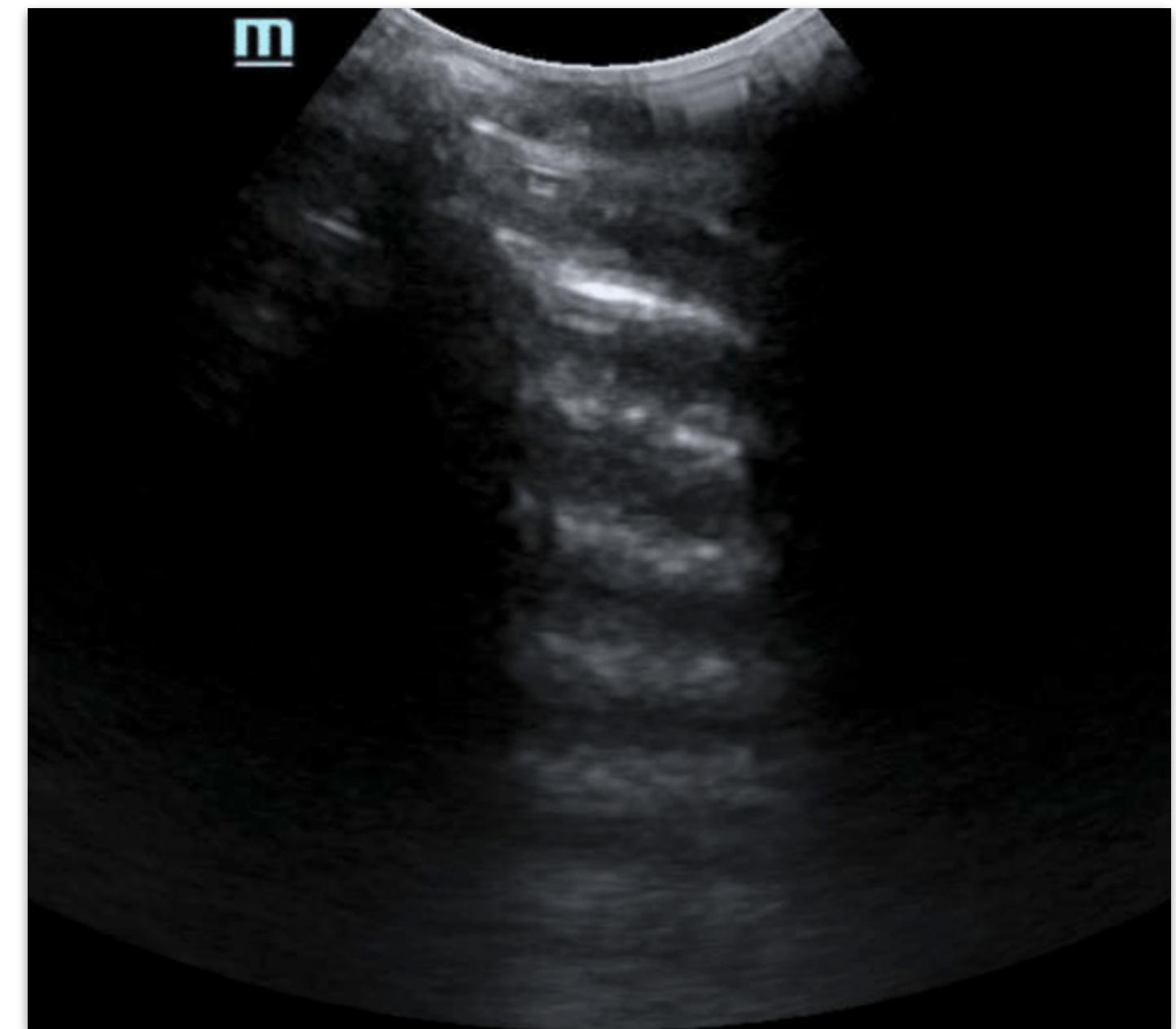
# Acquisition

## 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.



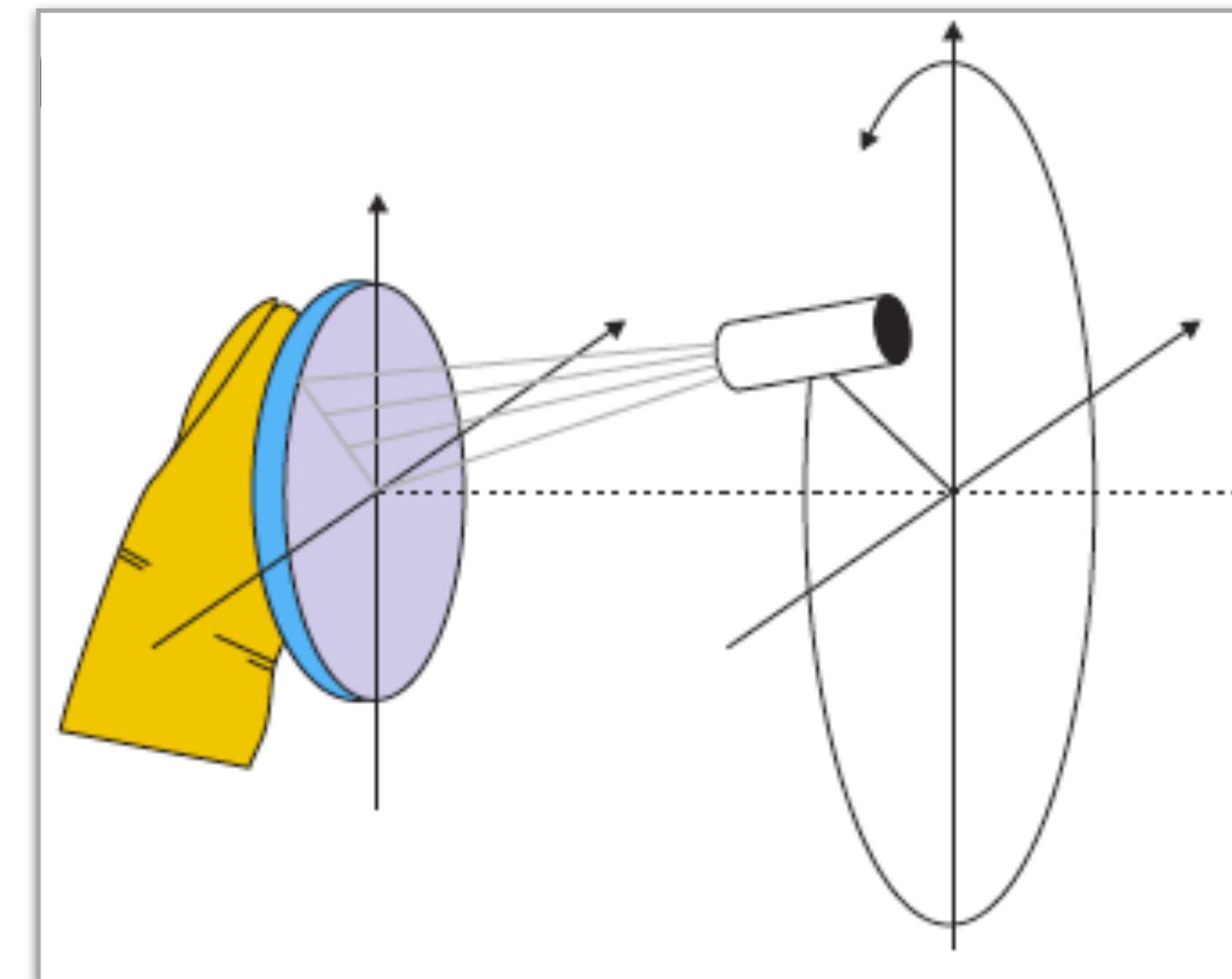
# Acquisition

## 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

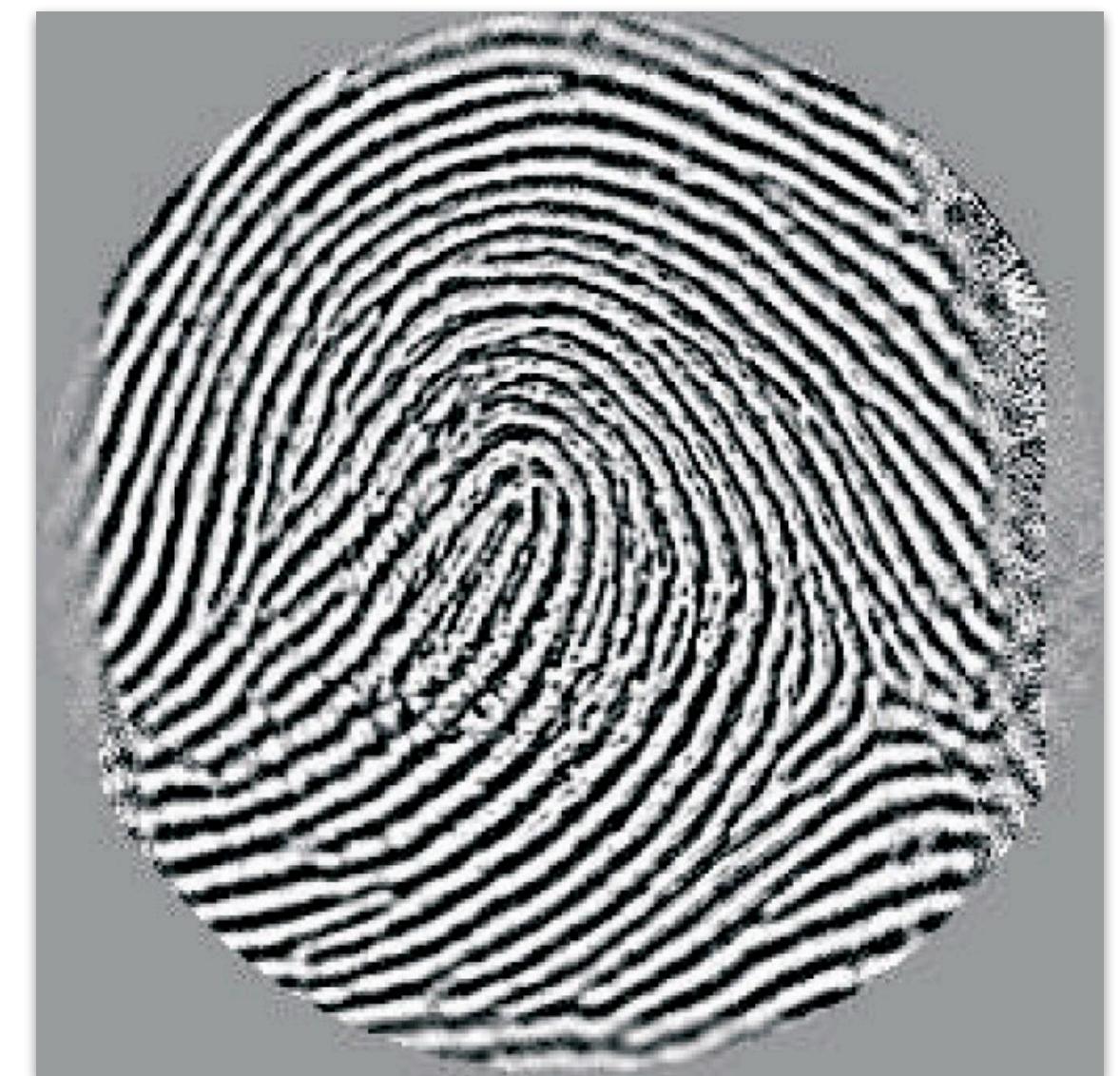
More expensive. Typical resolution: 250 dpi.  
Harder to be spoofed (due to ultrasounds penetration).

# Acquisition

## On-line Acquisition

### Ultrasound sensors (5/6)

Example: Optel  
Device and sample.



Source: [www.optel.com.pl](http://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.

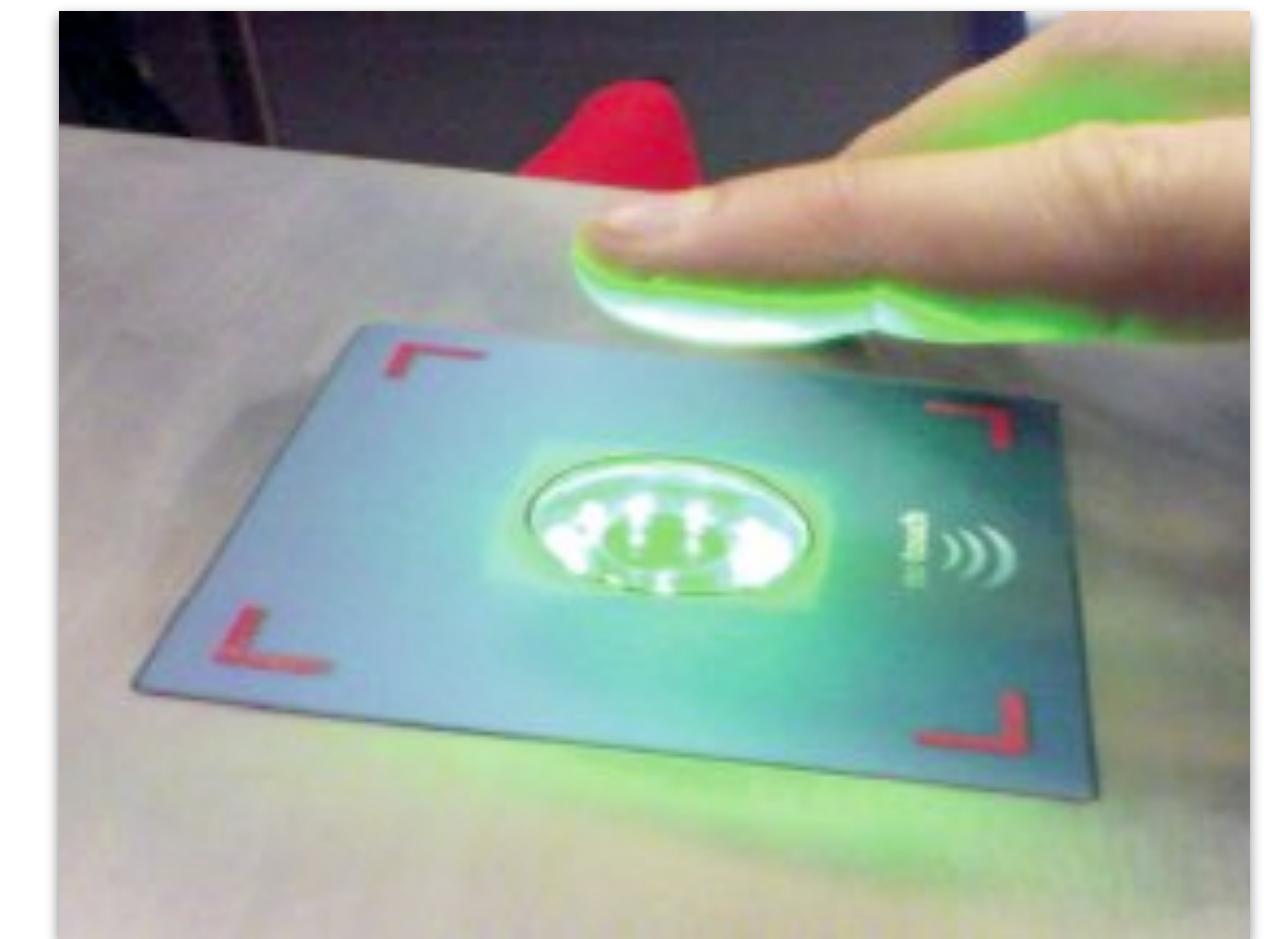
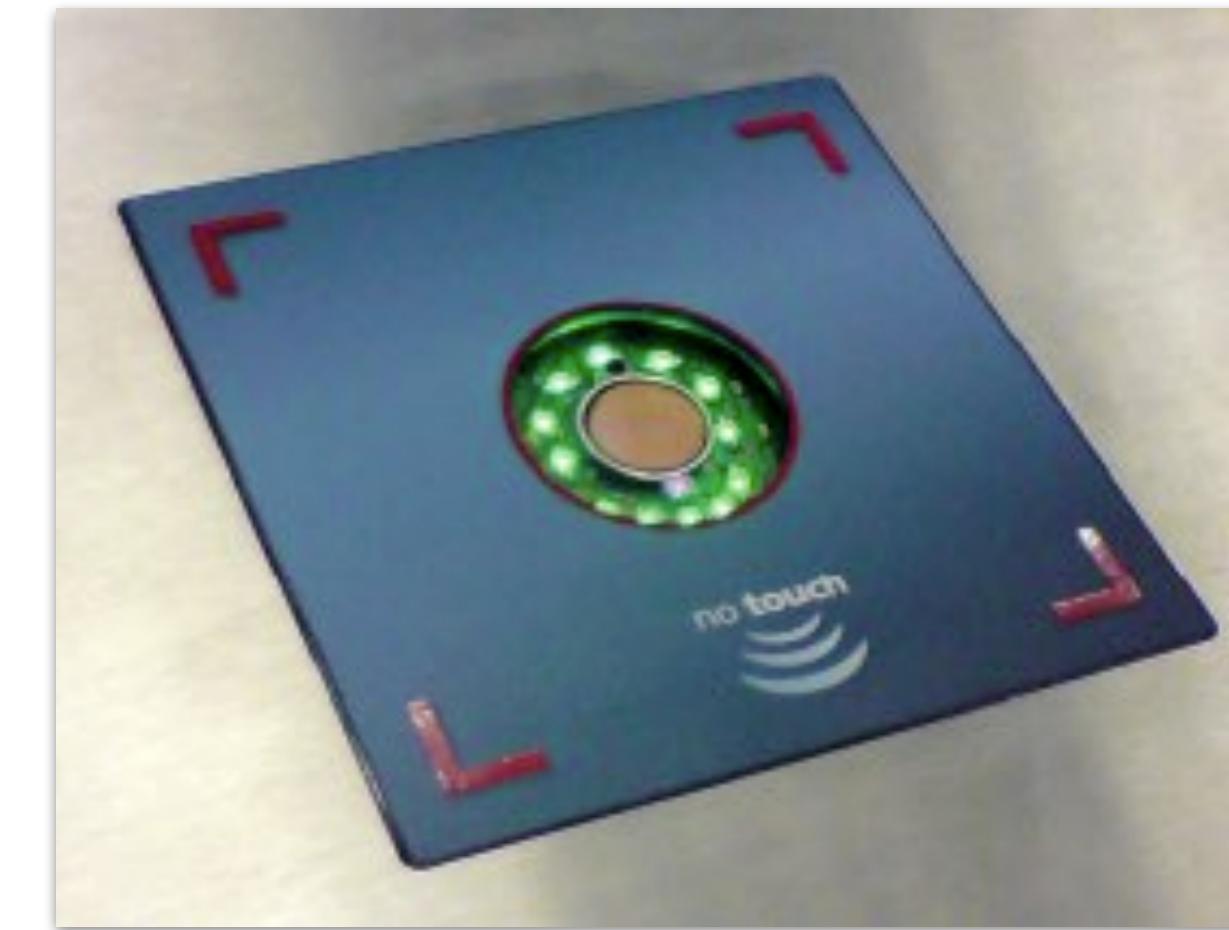


# Acquisition

## On-line Acquisition

### Touchless sensor (6/6)

Example: TST Biometrics Device.



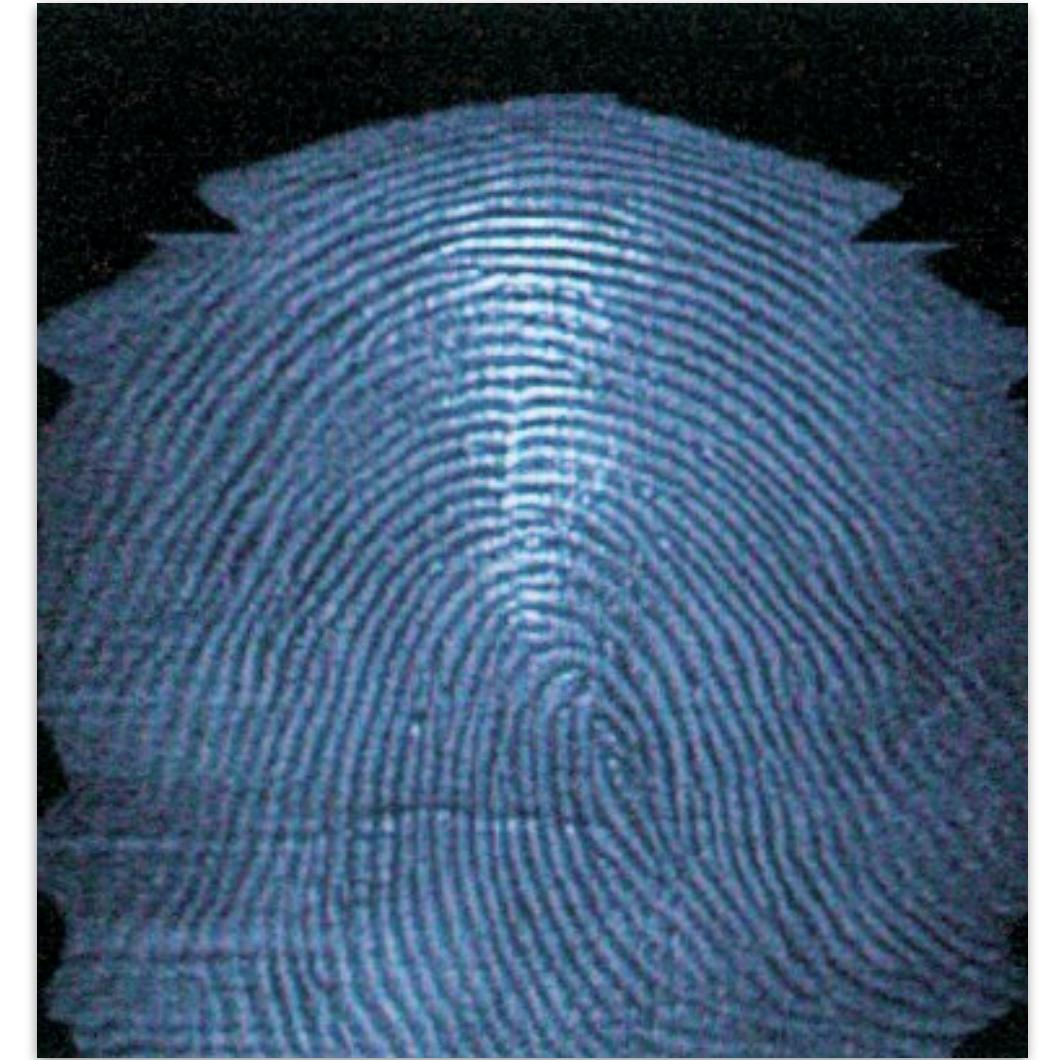
Source: Dr. Adam Czajka

# 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/>

Smithsonian  
MAGAZINE

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### 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.

# 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

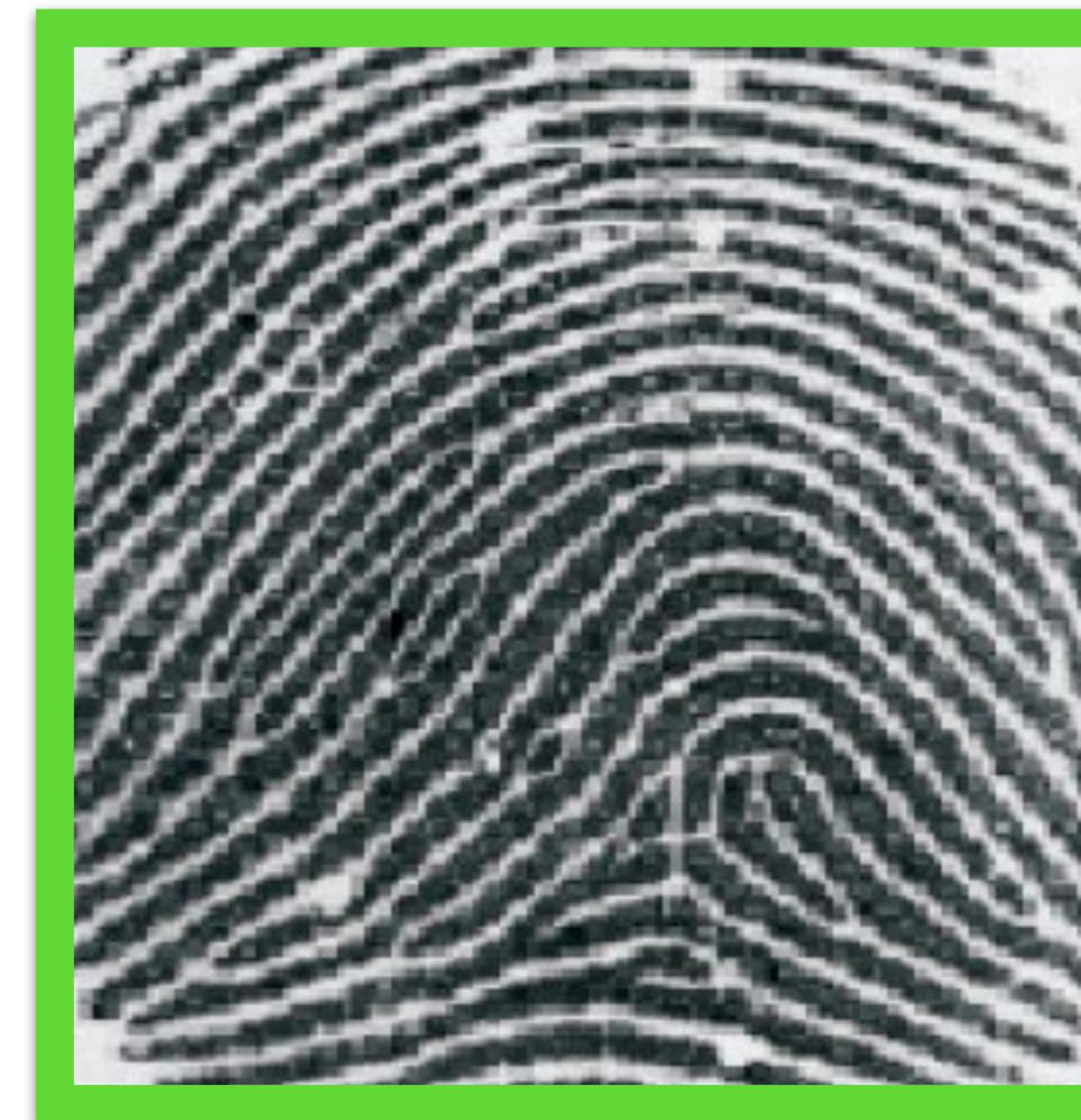


# Fake or authentic?

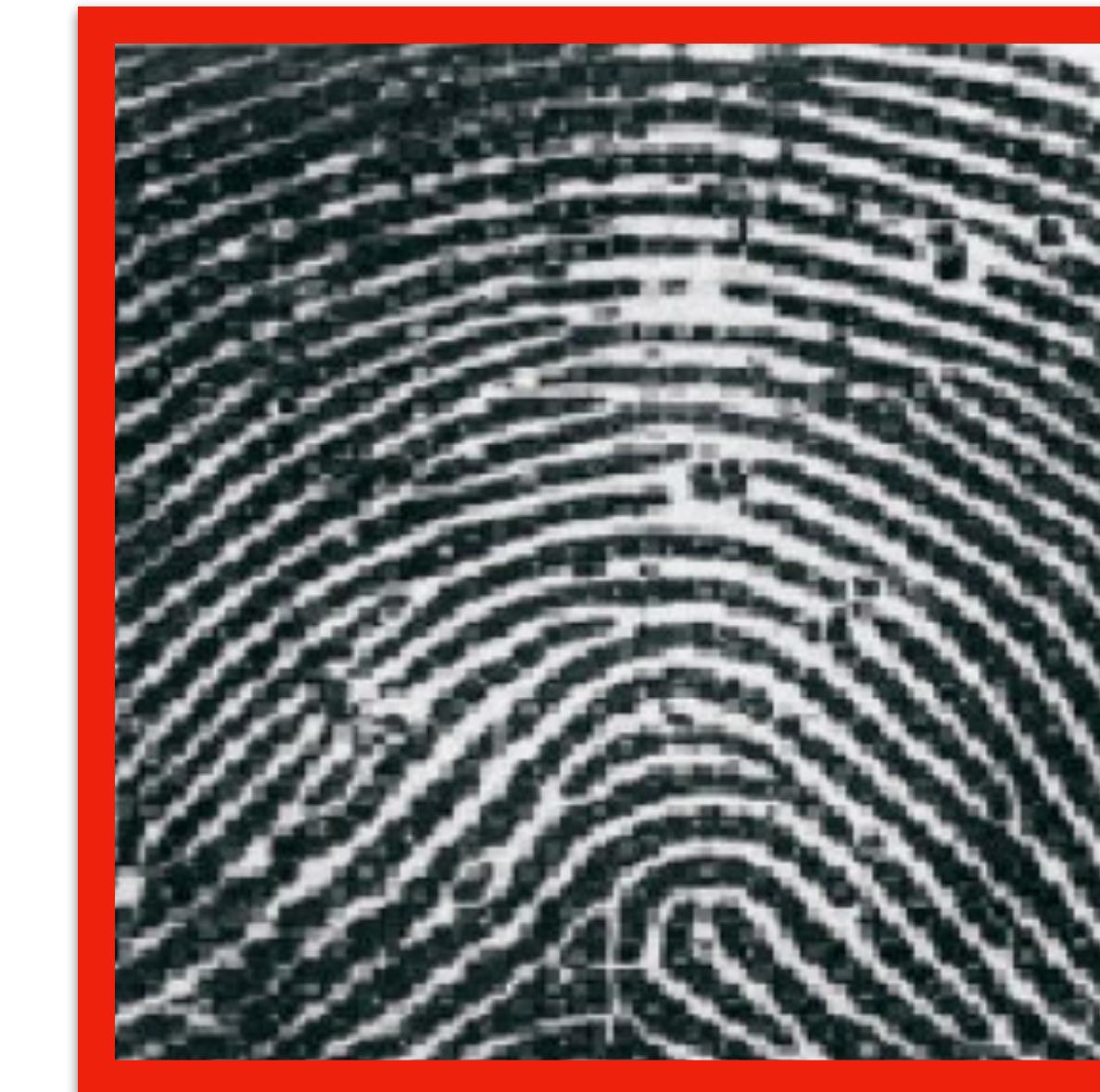
## From capacitive sensor

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



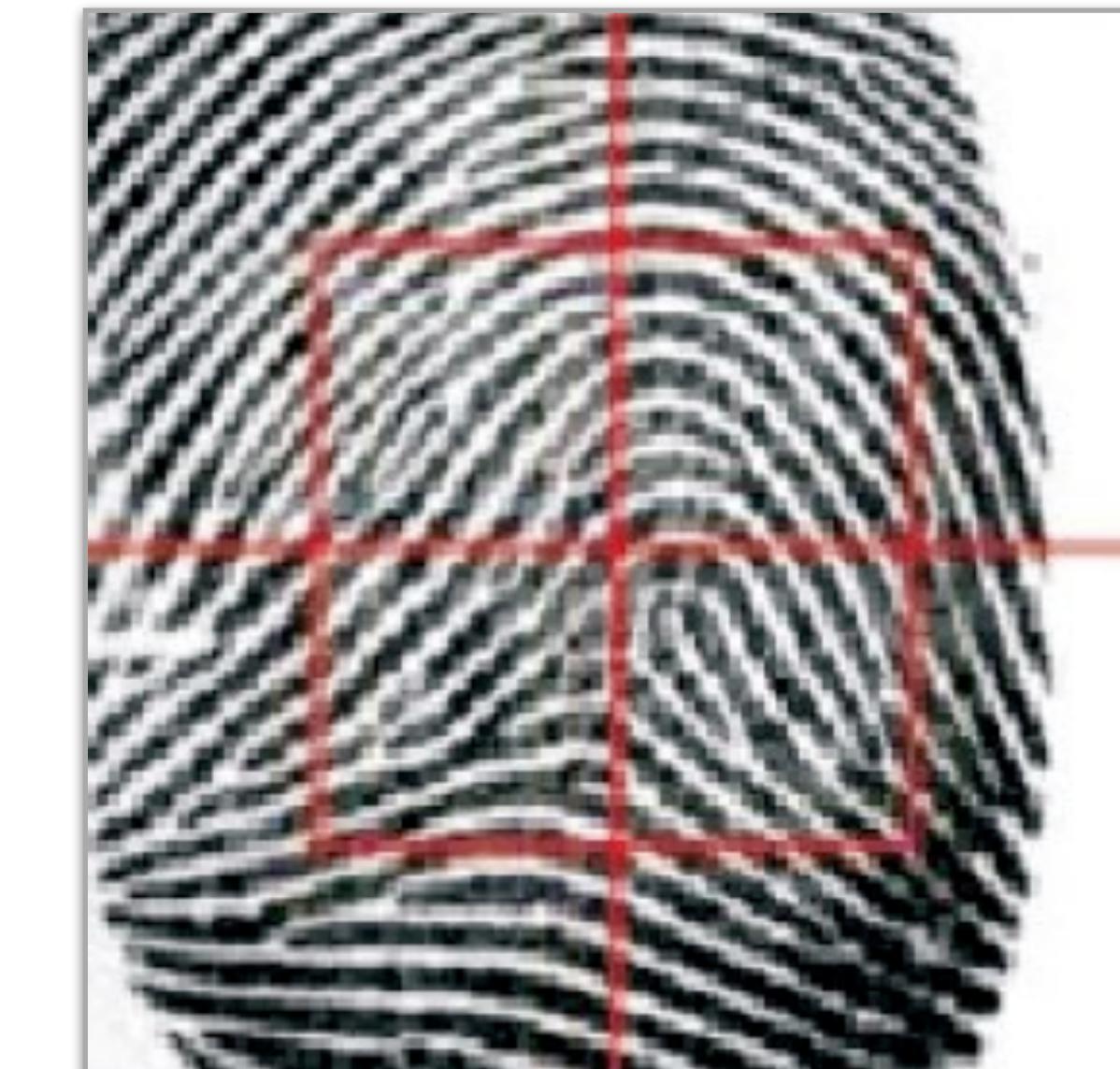
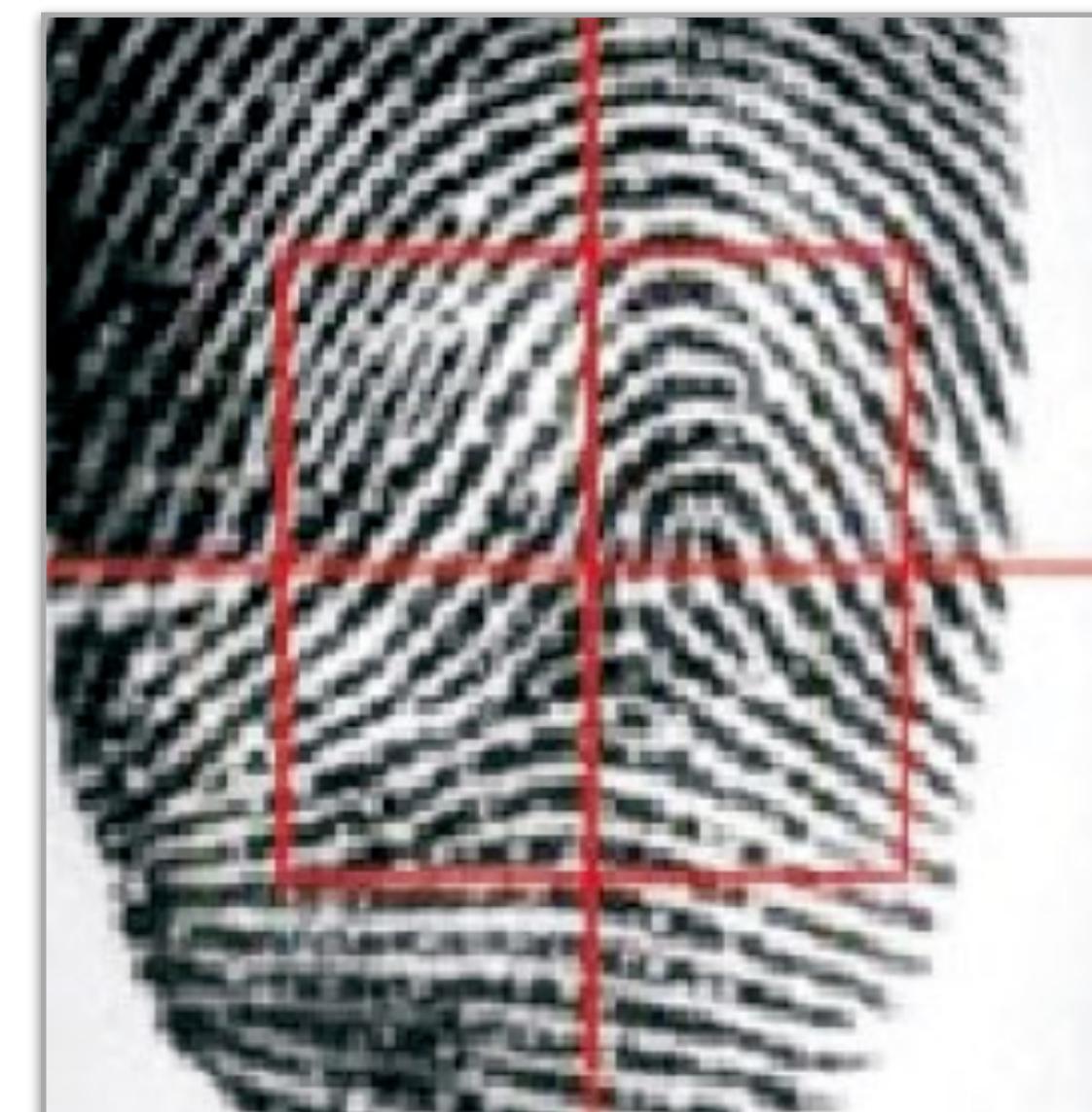
authentic



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?

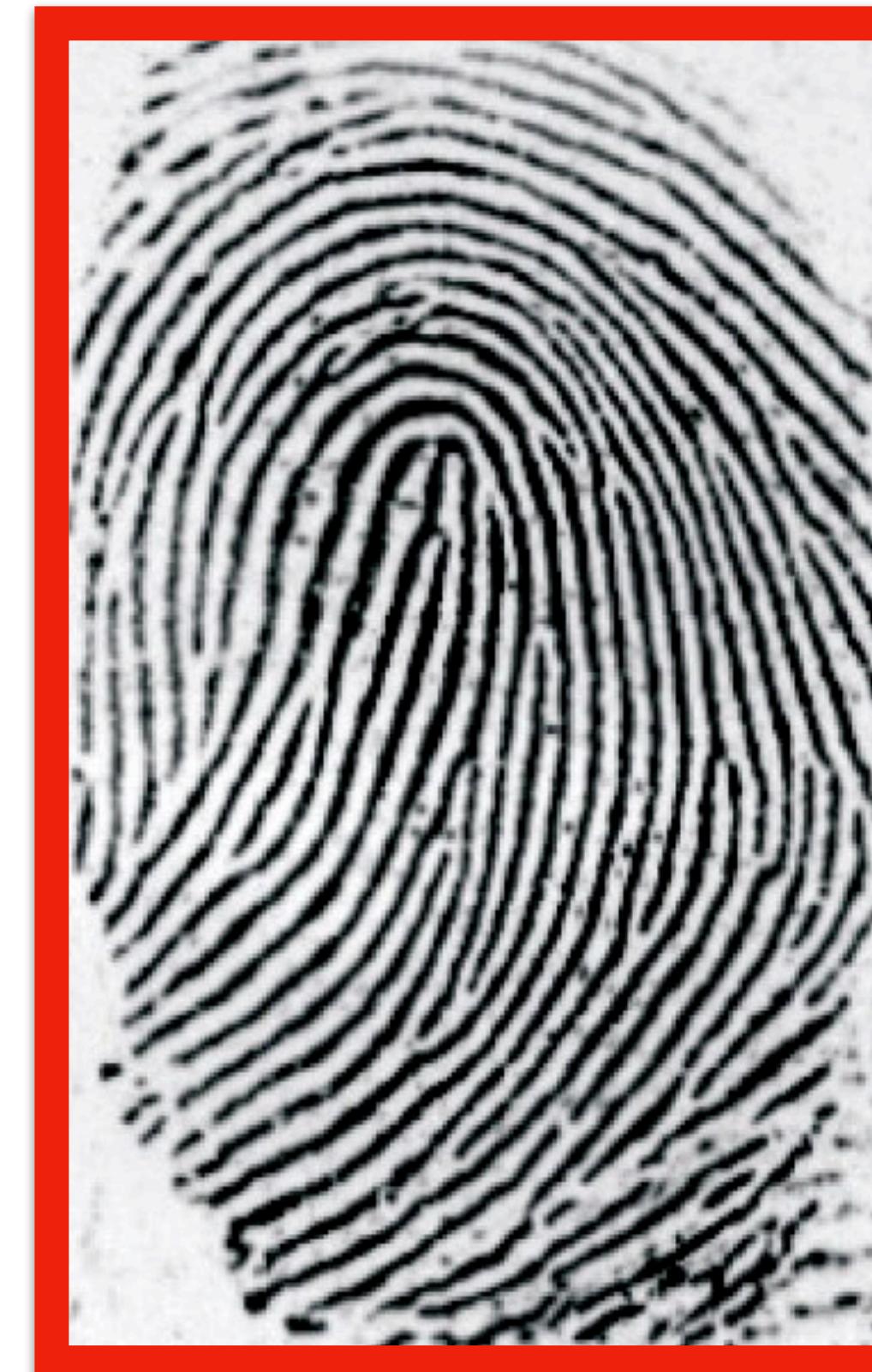
From optical sensor



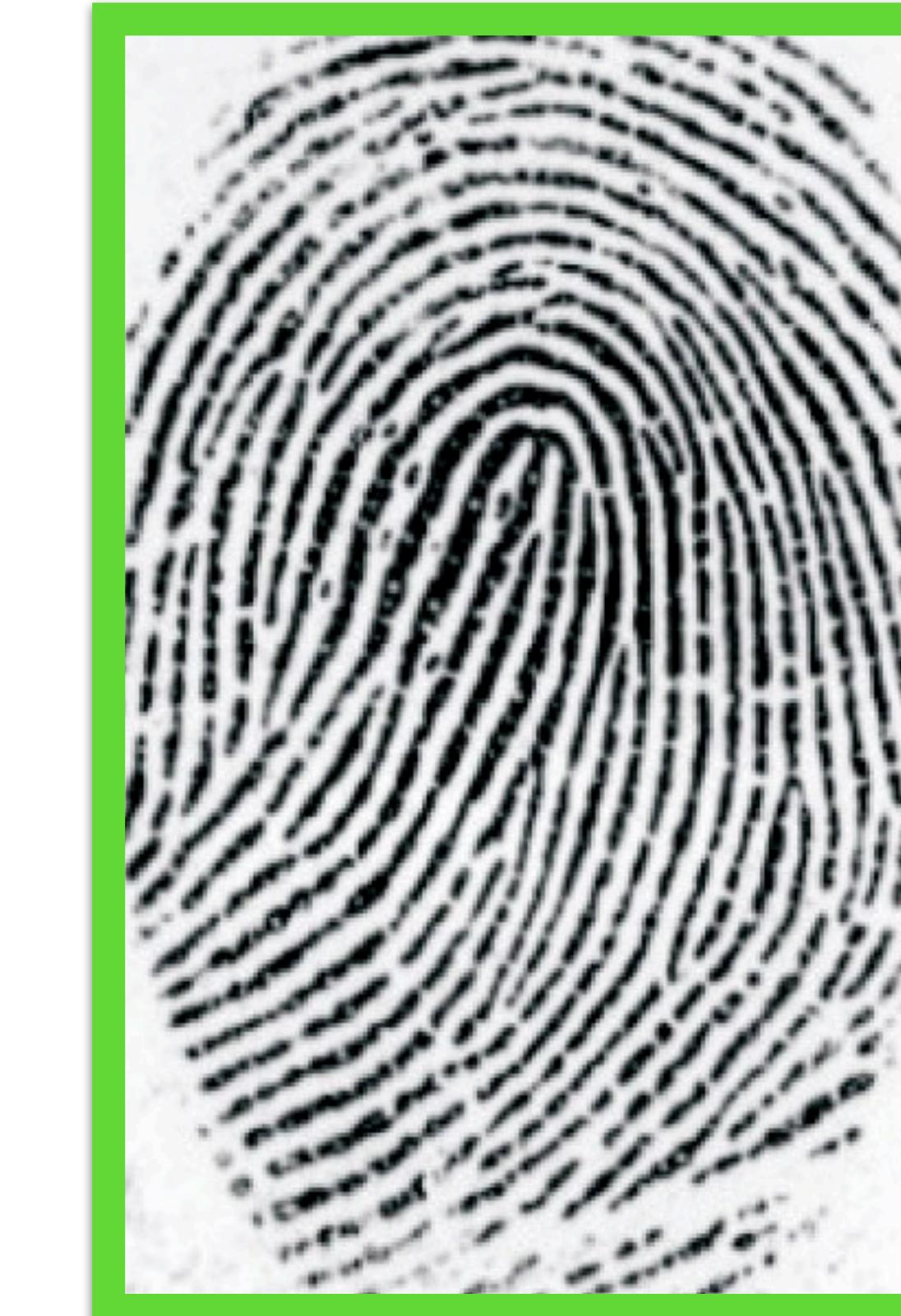
# Fake or authentic?

From optical sensor

wood glue

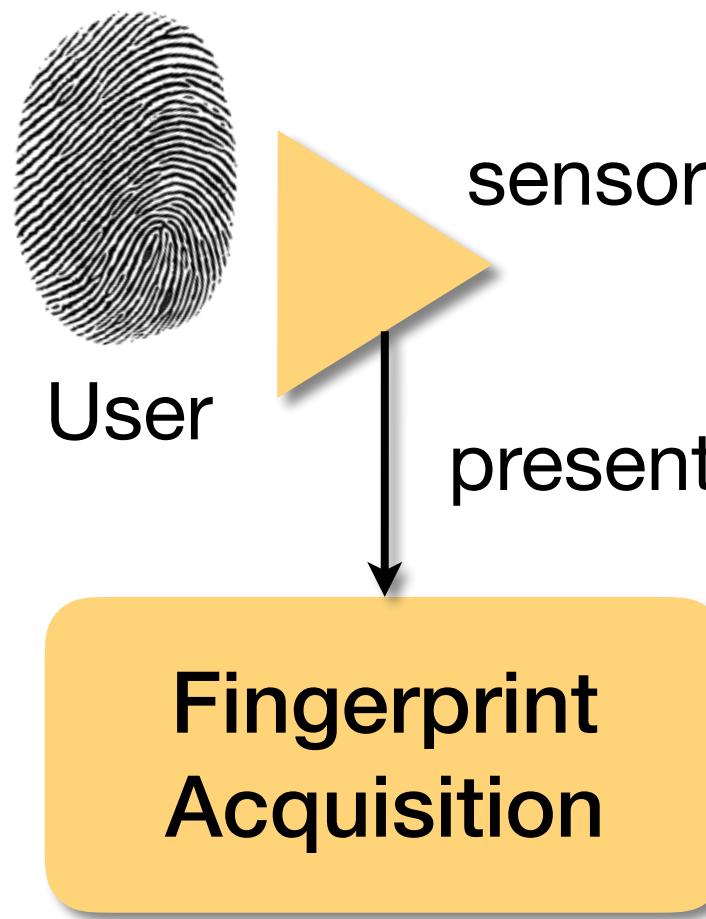


Source: Dr. Adam Czajka

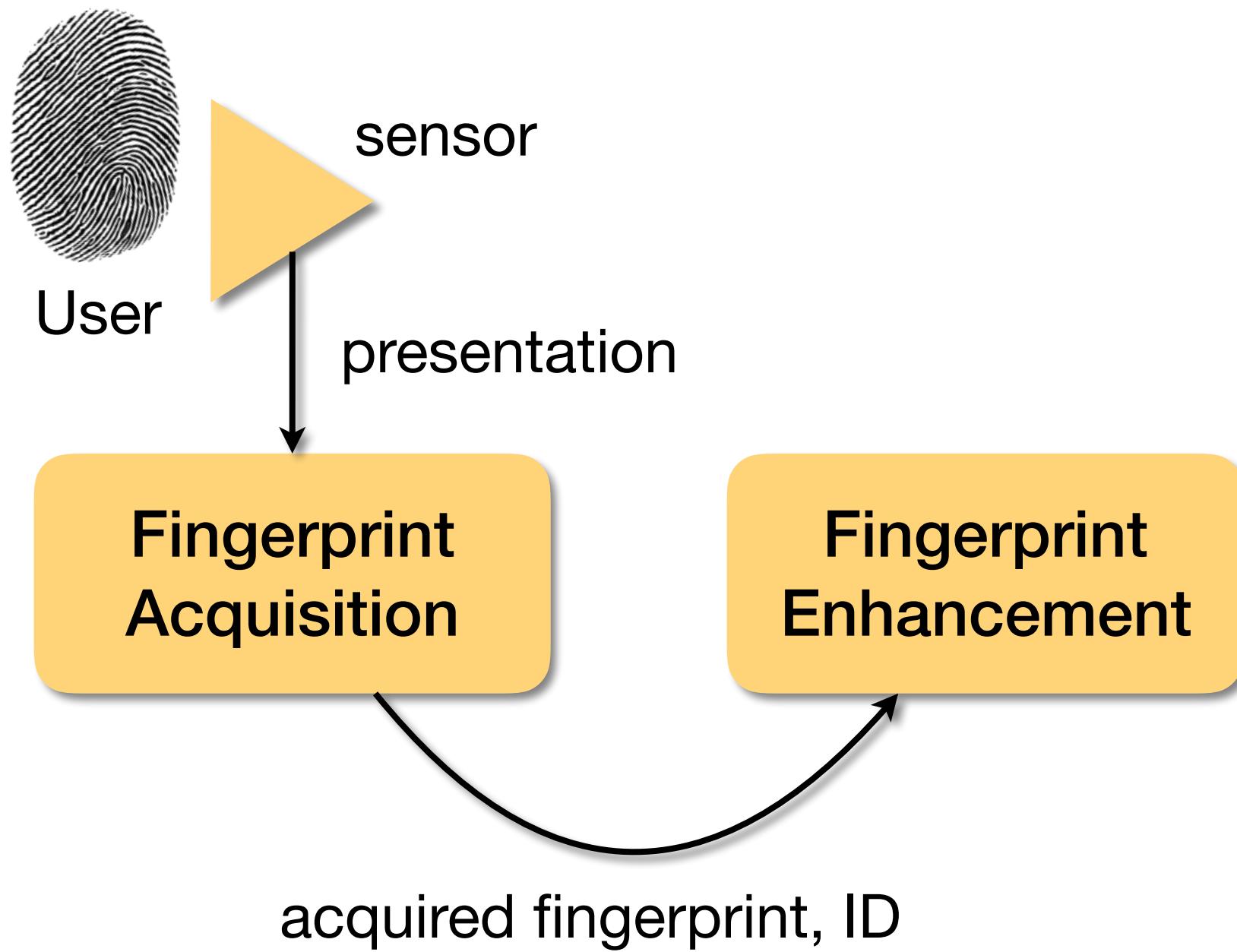


authentic

# 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

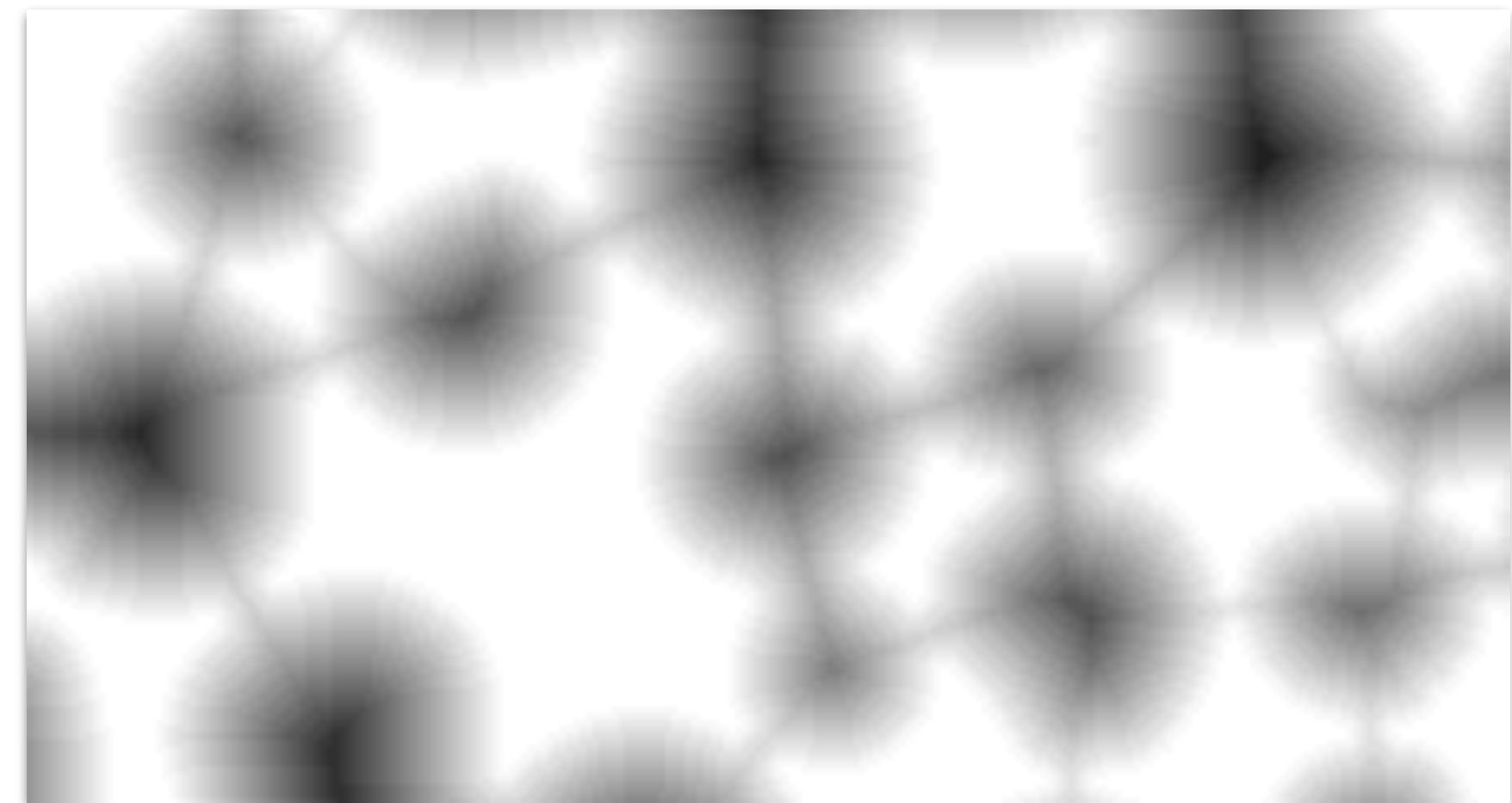
## Image Processing Solutions

### Tasks

Enhancement of image contrast.

Enhancement of ridges and valleys.

Content segmentation.



# Enhancement

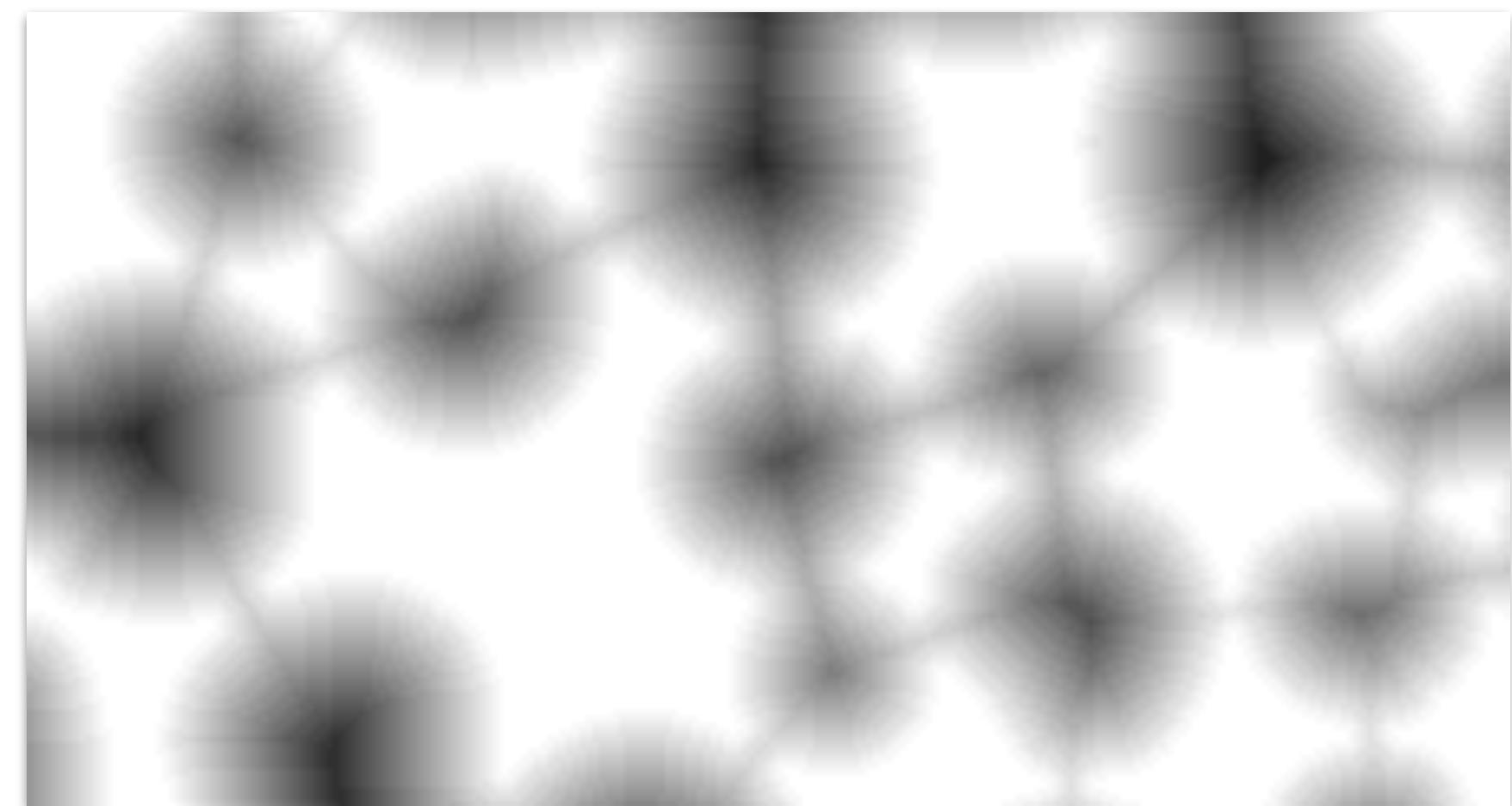
## Image Processing Solutions

### Tasks

**Enhancement of image contrast.**

Enhancement of ridges and valleys.

Content segmentation.



# Enhancement

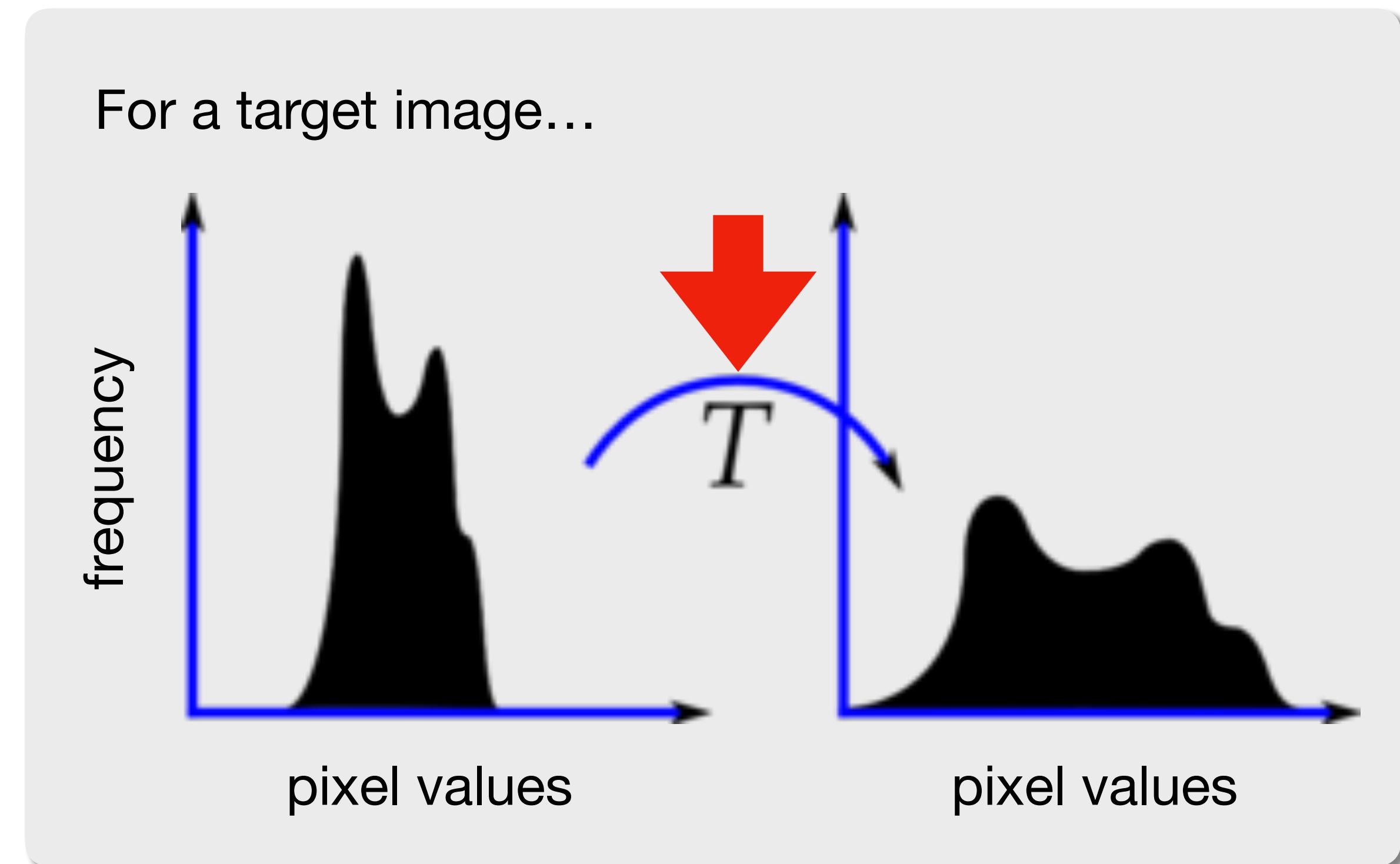
## Image Contrast

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

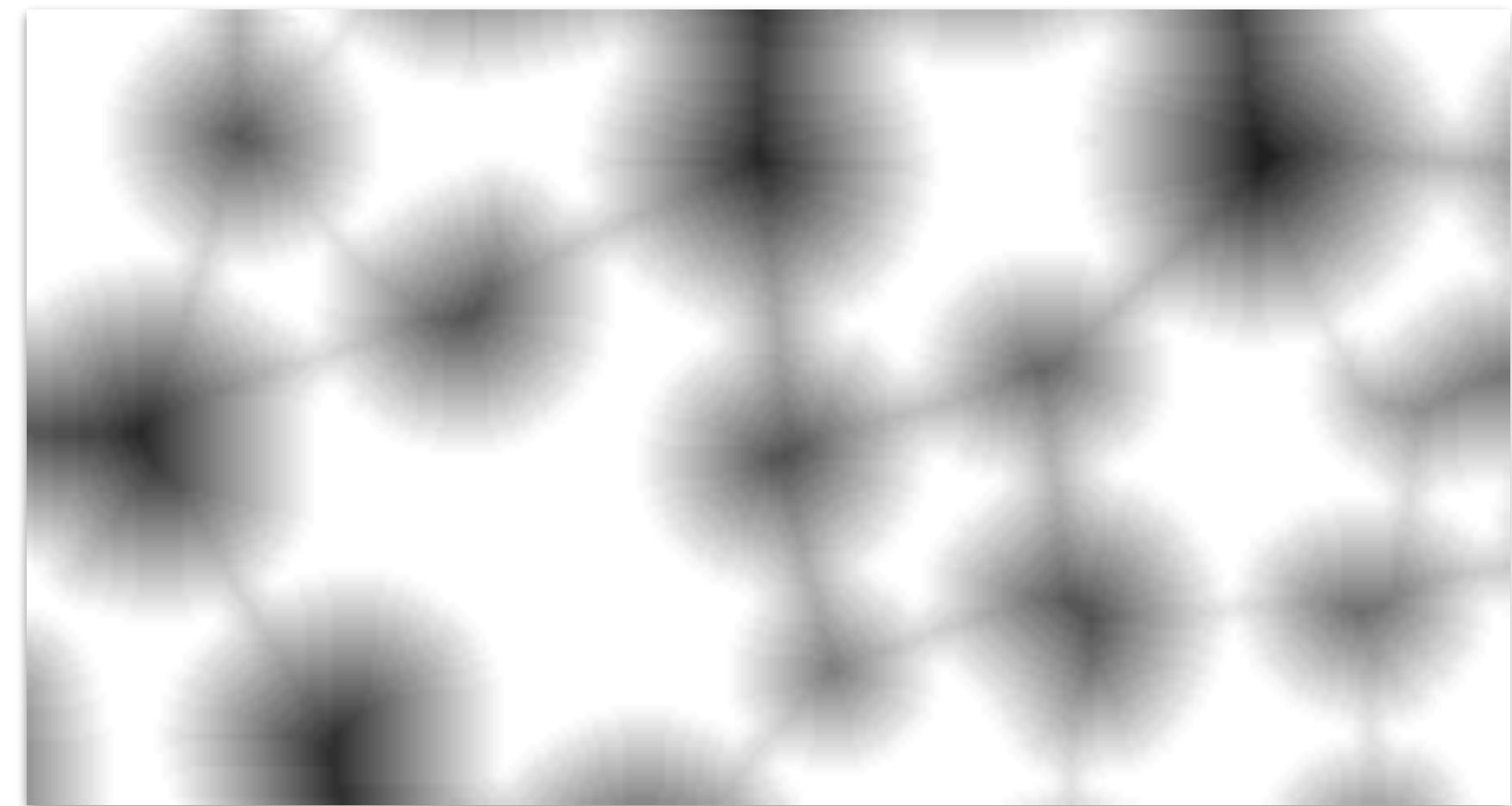
## Image Processing Solutions

### Tasks

Enhancement of image contrast.

**Enhancement of ridges and valleys.**

Content segmentation.



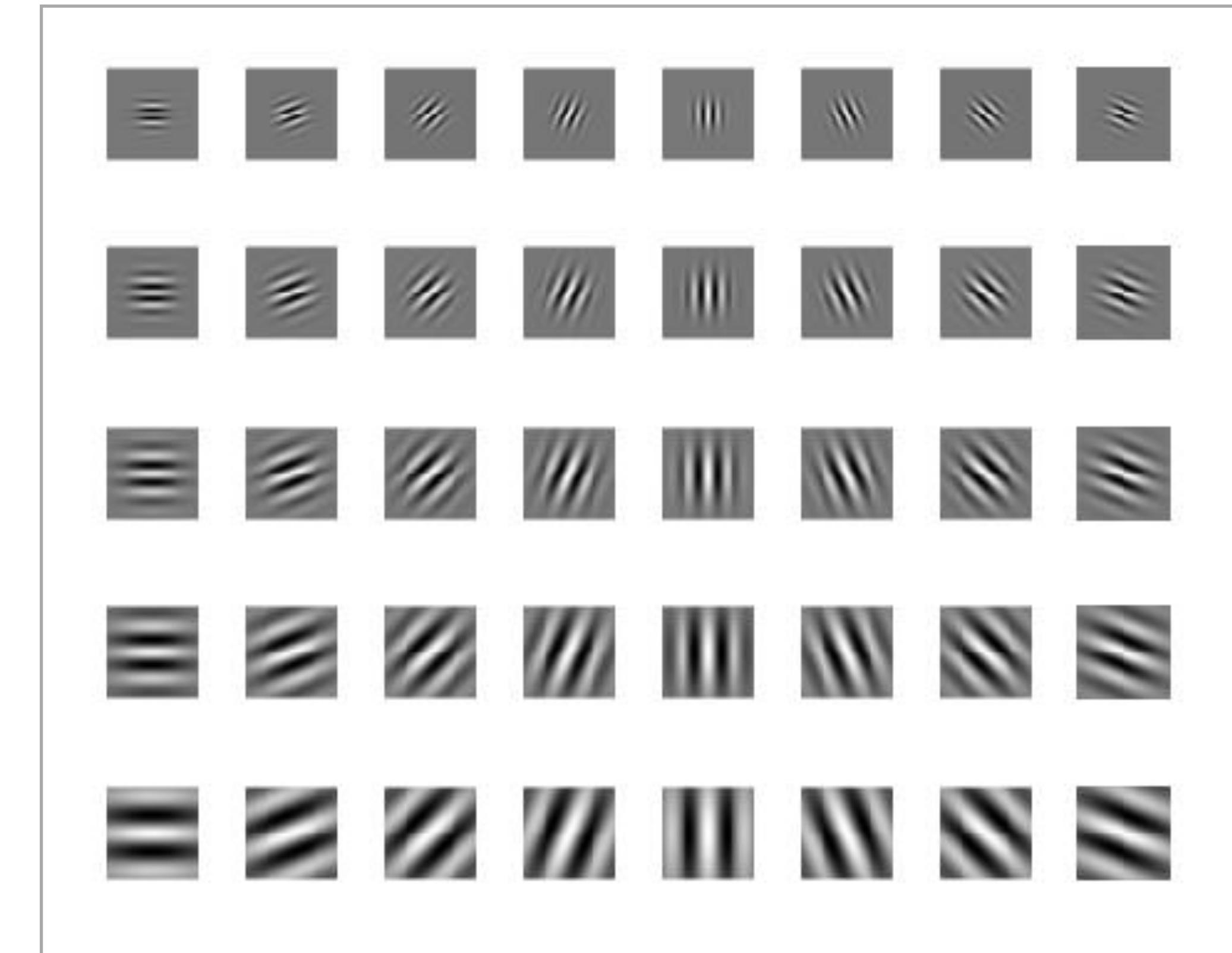
# Enhancement

## 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.



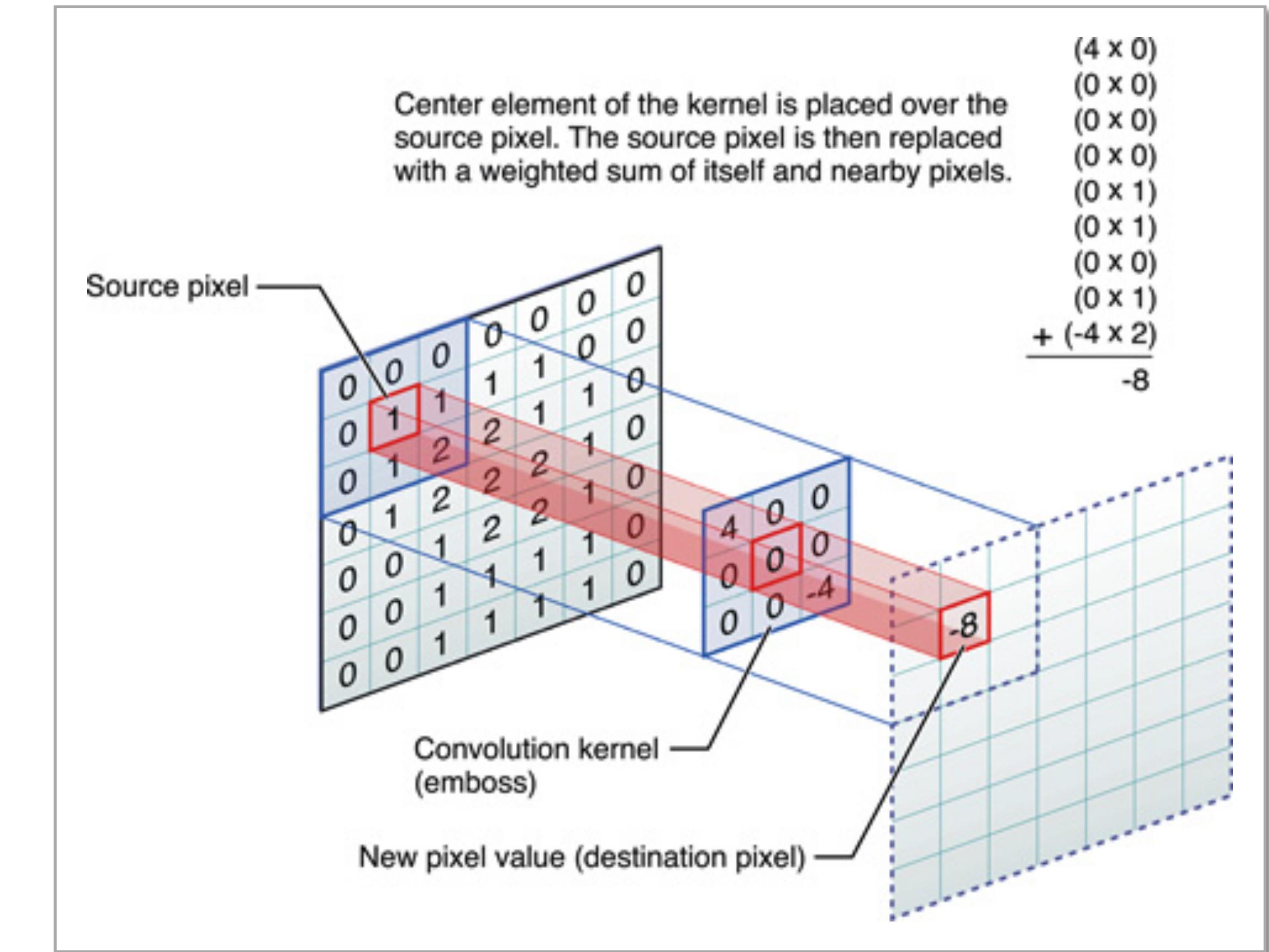
# Enhancement

## 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/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

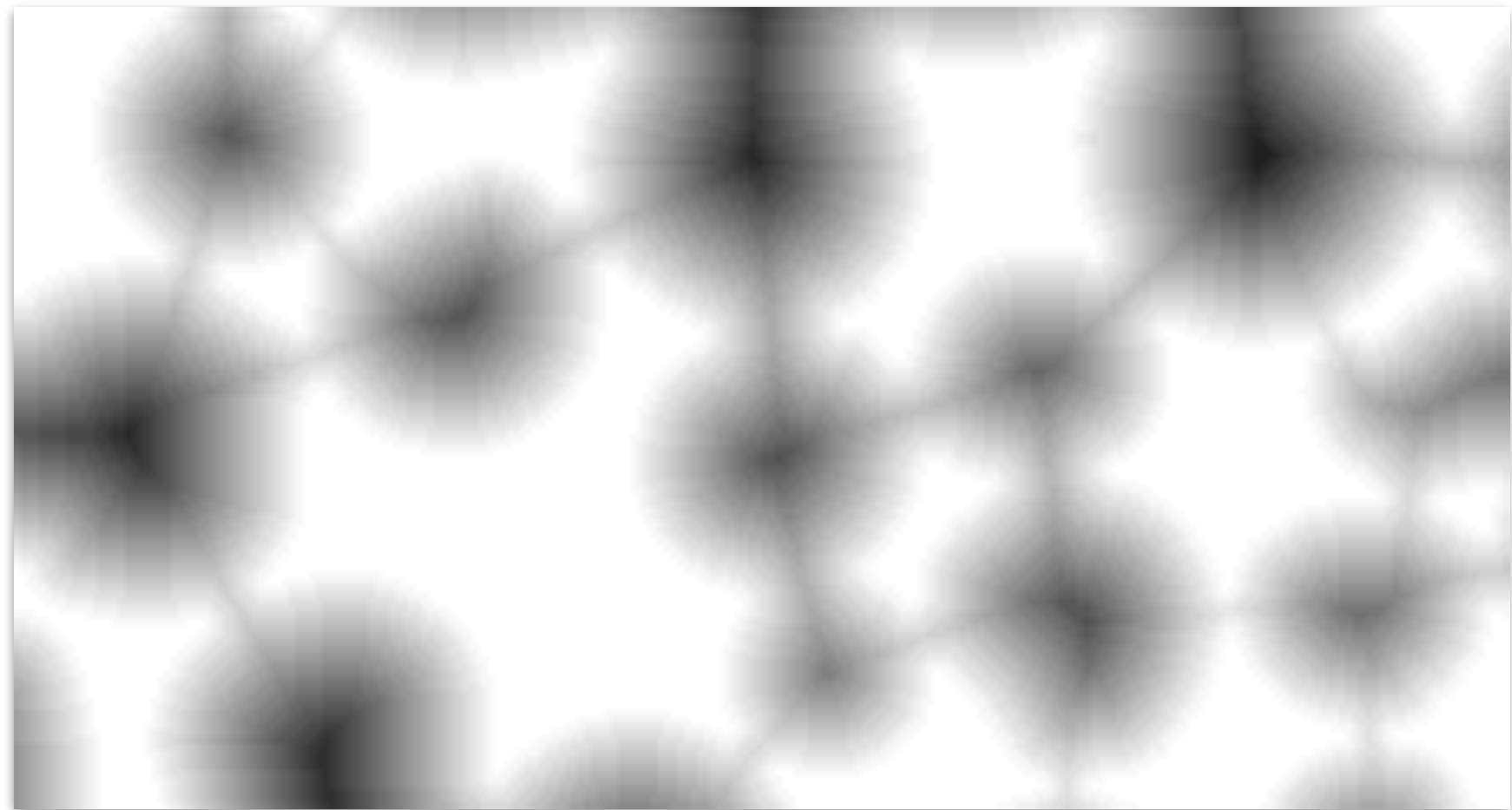
## Image Processing Solutions

### Tasks

Enhancement of image contrast.

Enhancement of ridges and valleys.

**Content segmentation.**



# Enhancement

## Segmentation

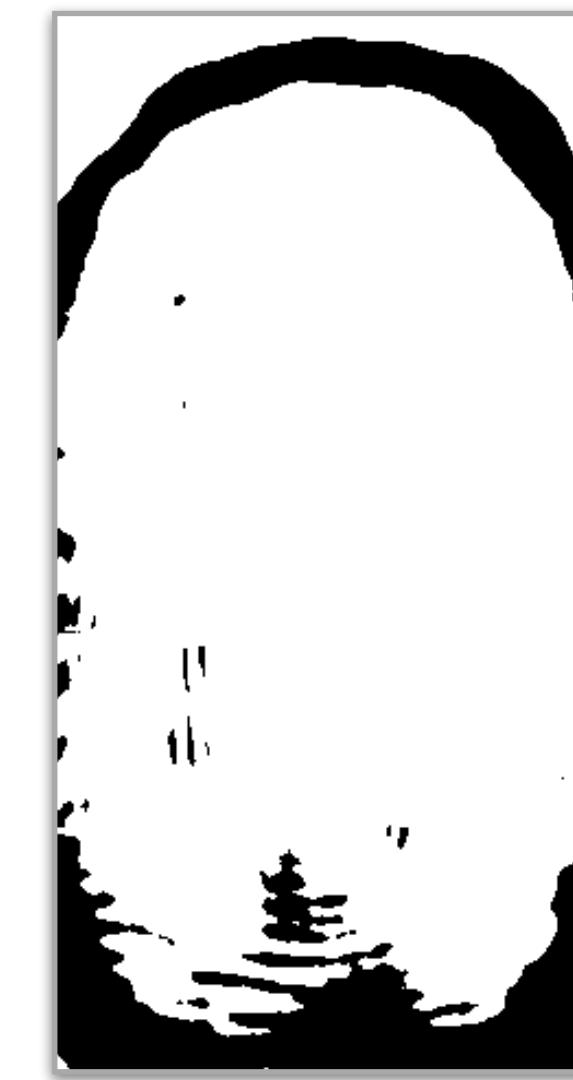
Example: blurring, thresholding, and morphological operations.



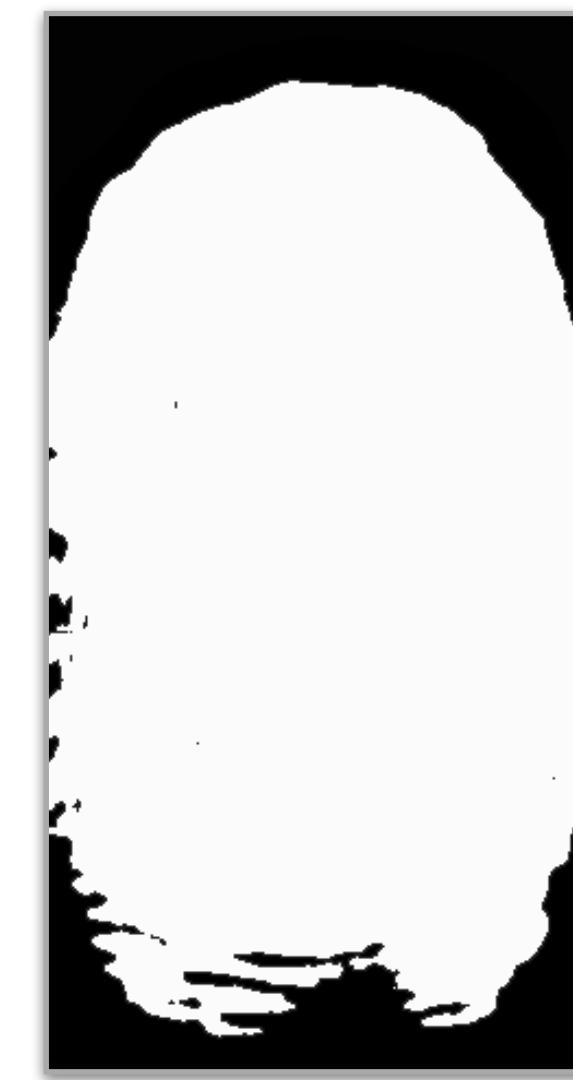
before



blur



threshold



open



after

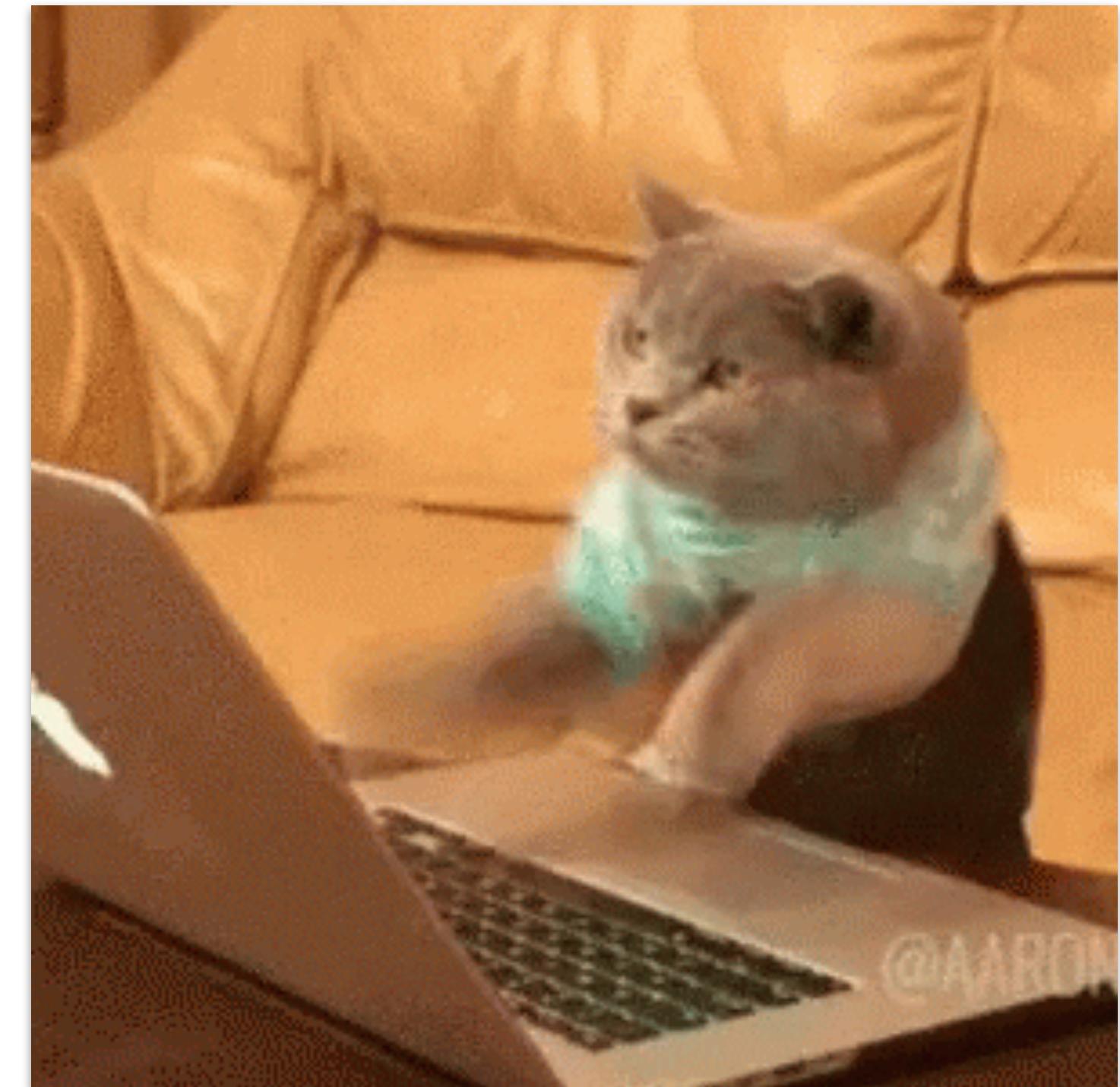
# Enhancement

## Image Processing Solutions

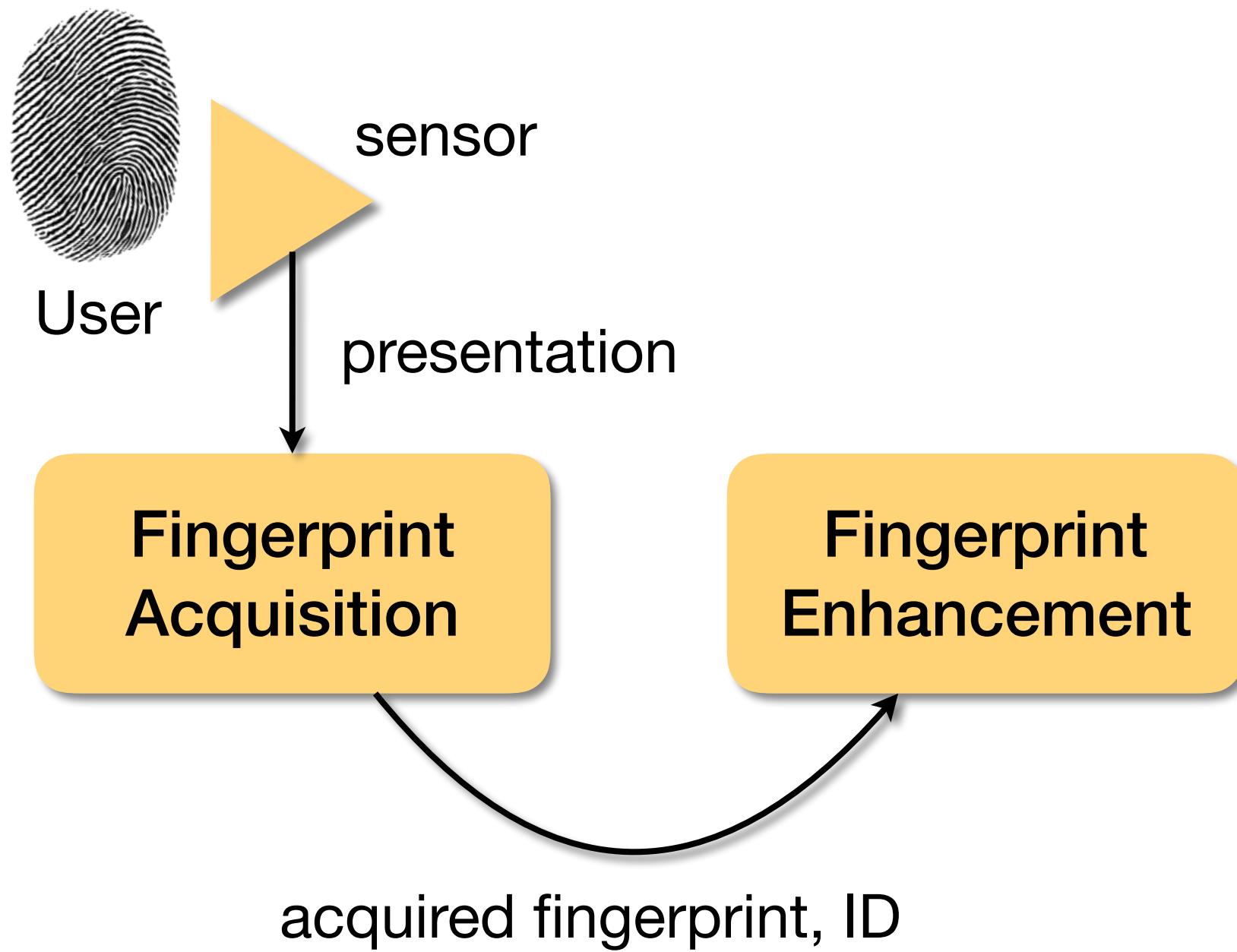
### Be Aware

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

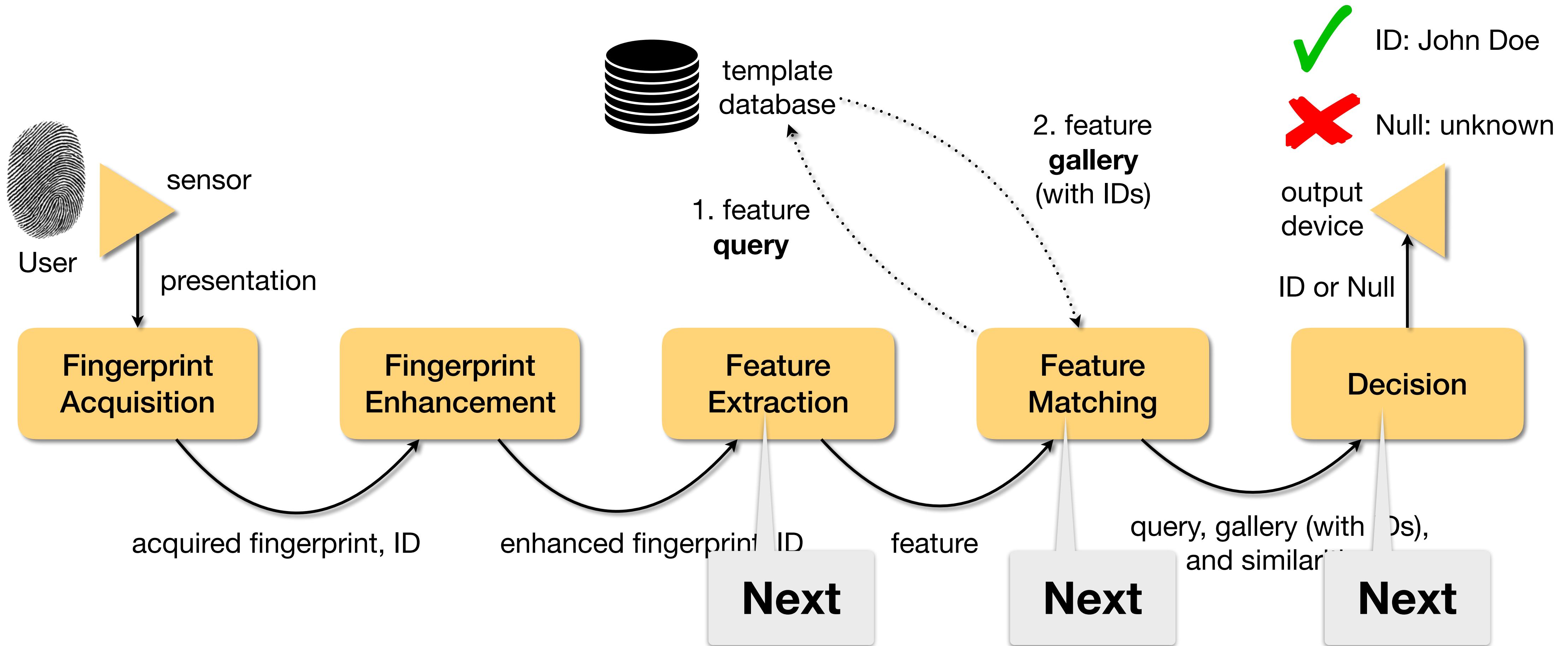
We'll see some of them in practice and with more details during our next coding class.



# Fingerprint Recognition



# Fingerprint Recognition



# S'up Next?

## **Even more about fingerprints**

Fingerprint feature extraction methods.

Fingerprint matching methods.

Visit to see fingerprint sensors.



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## **Acknowledgments**

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Thank you, professors, for kindly allowing me to use your material.

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