# Fingerprint Recognition III

COMP 388-002/488-002 Biometrics

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LOYOLA
UNIVERSITY CHICAGO

# Today you will…

*Get to know*
Minutiae detection, description, and matching.

# Today’s attendance

**Please fill out the form**

https://forms.gle/A1XcvMo6nB5qXWRk9



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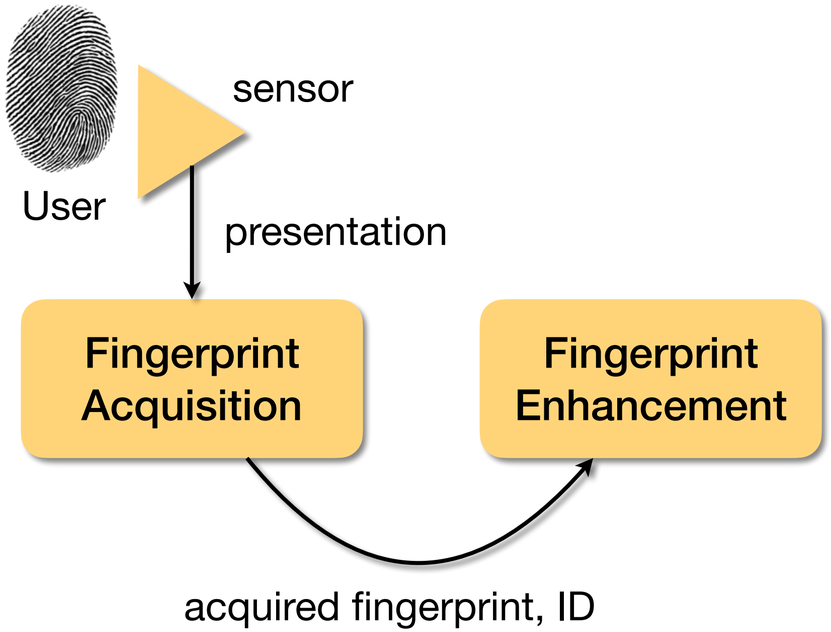
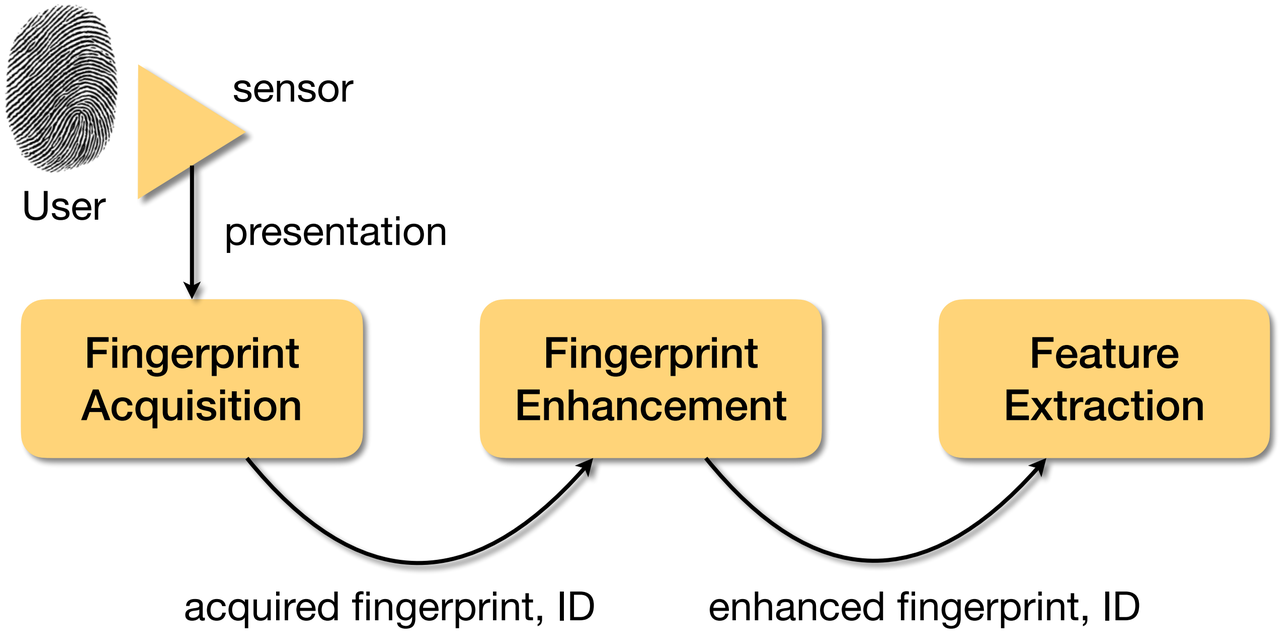
# Fingerprint Recognition



# Fingerprint Recognition



# Feature Extraction

**Three Levels of Features**

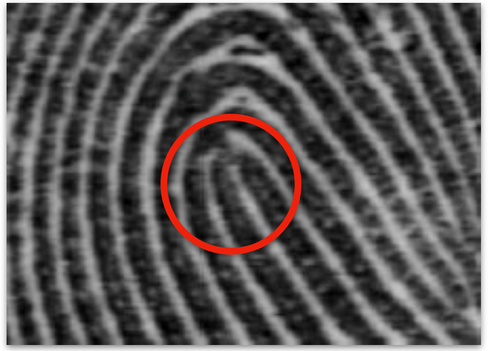
From coarse to fine:

- Level-1 Features
- Level-2 Features
- Level-3 Features

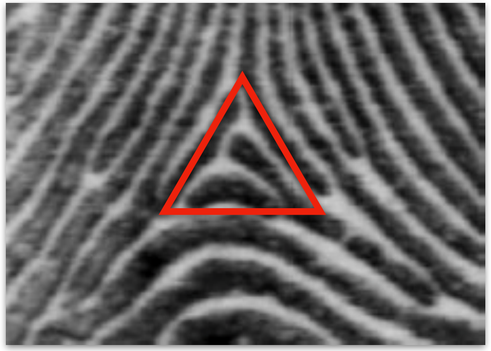
# Feature Extraction

**Level-1 Features**
Singular points and core.
Recommended capture resolution: 250 ppi (pixels per inch).
Useful for fingerprint classification, indexing, and alignment.

**Singular Points**



loop



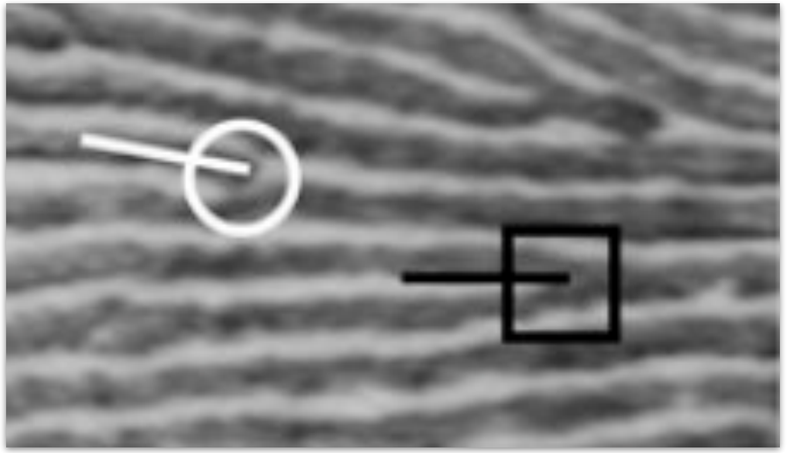
delta

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

**Core**
Up-most singular point
*or* (in case of no singular point)
Point of maximum ridge curvature.

# Features

**Level-2 Features**
Minutiae (Galton's details).
Recommended capture resolution: 500 ppi.
Useful for fingerprint matching.

Ridge Ending  Ridge Bifurcation

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

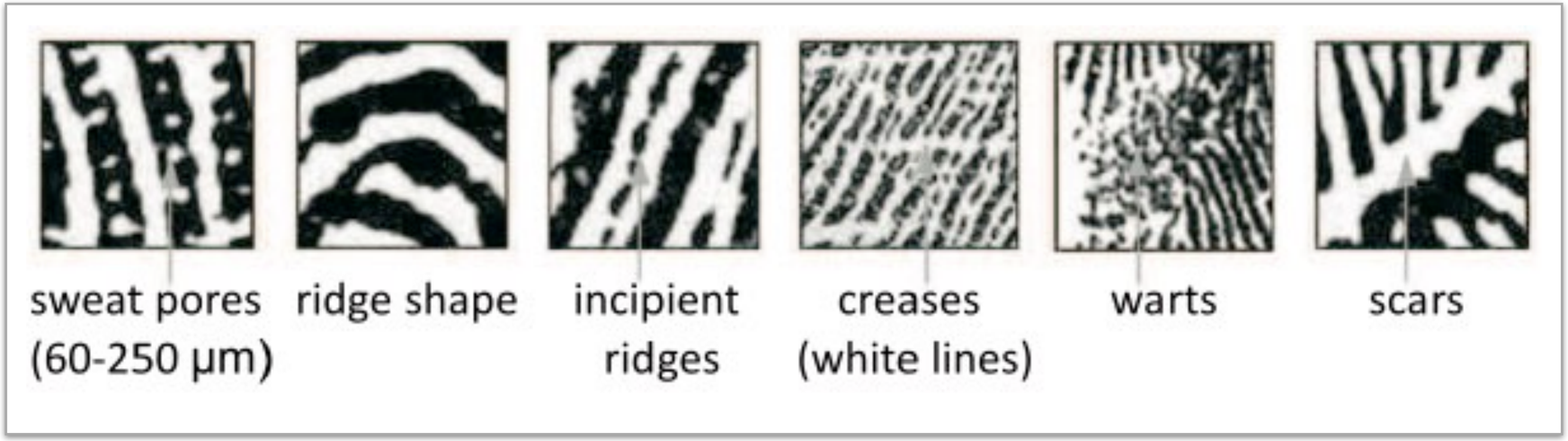
# Features

**Level-3 Features**

Sweat pores, ridge shape, and lifetime acquired marks.

Recommended capture resolution: 1000 ppi.

Useful for liveness and spoofing detection.




Jain, Chen, and Demirkus
*Pores and Ridges: High-Resolution Fingerprint Matching Using Level 3 Features*
IEEE T-PAMI, 2007

# Feature Extraction

**Three Levels of Features**

From coarse to fine:

- Level-1 Features
- **Level-2 Features**
- Level-3 Features

Let’s dive into it…

# Feature Extraction

**But First, Further References for Level-1 Features**
Jain, Ross, and Nandakumar
*Introduction to Biometrics,*
*Section 2.4.2*
Springer Books, 2011

**Level-3 Features**
Jain, Chen, and Demirkus
*Pores and Ridges: High-Resolution Fingerprint Matching Using Level 3 Features*
IEEE T-PAMI, 2007

# Feature Extraction

**Three Levels of Features**

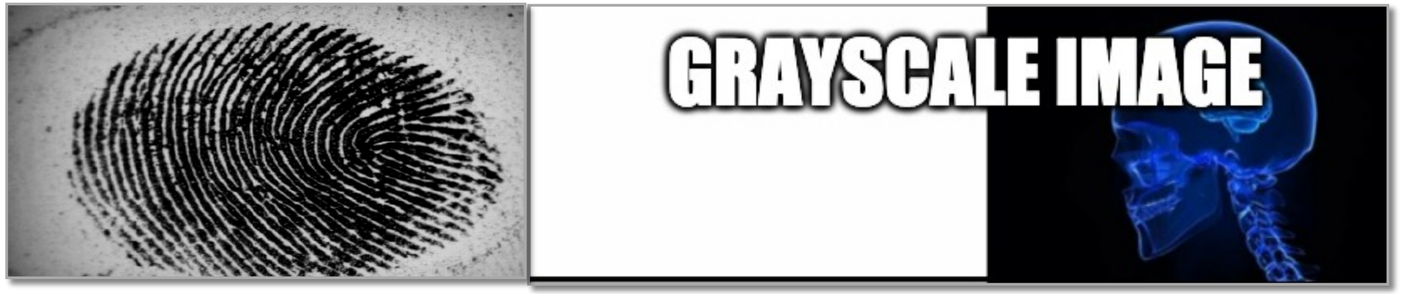
From coarse to fine:

- Level-1 Features
- **Level-2 Features**
- Level-3 Features

Let's dive into…

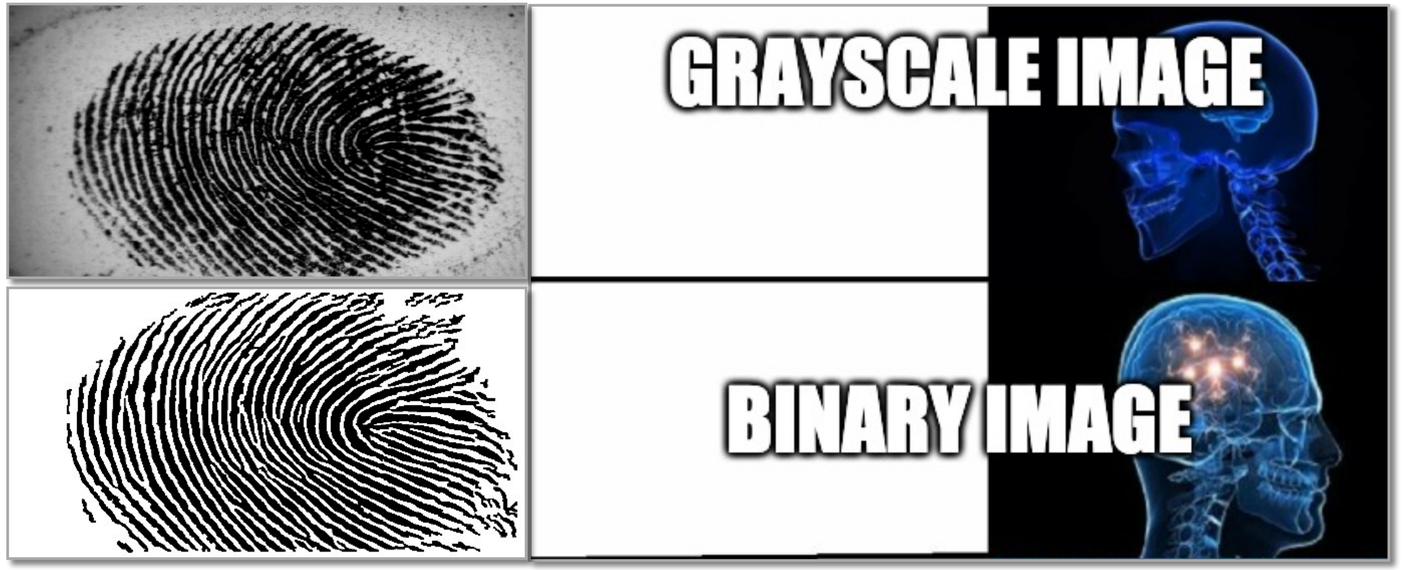
# Minutiae Detection

**Three Stages**
Start from…



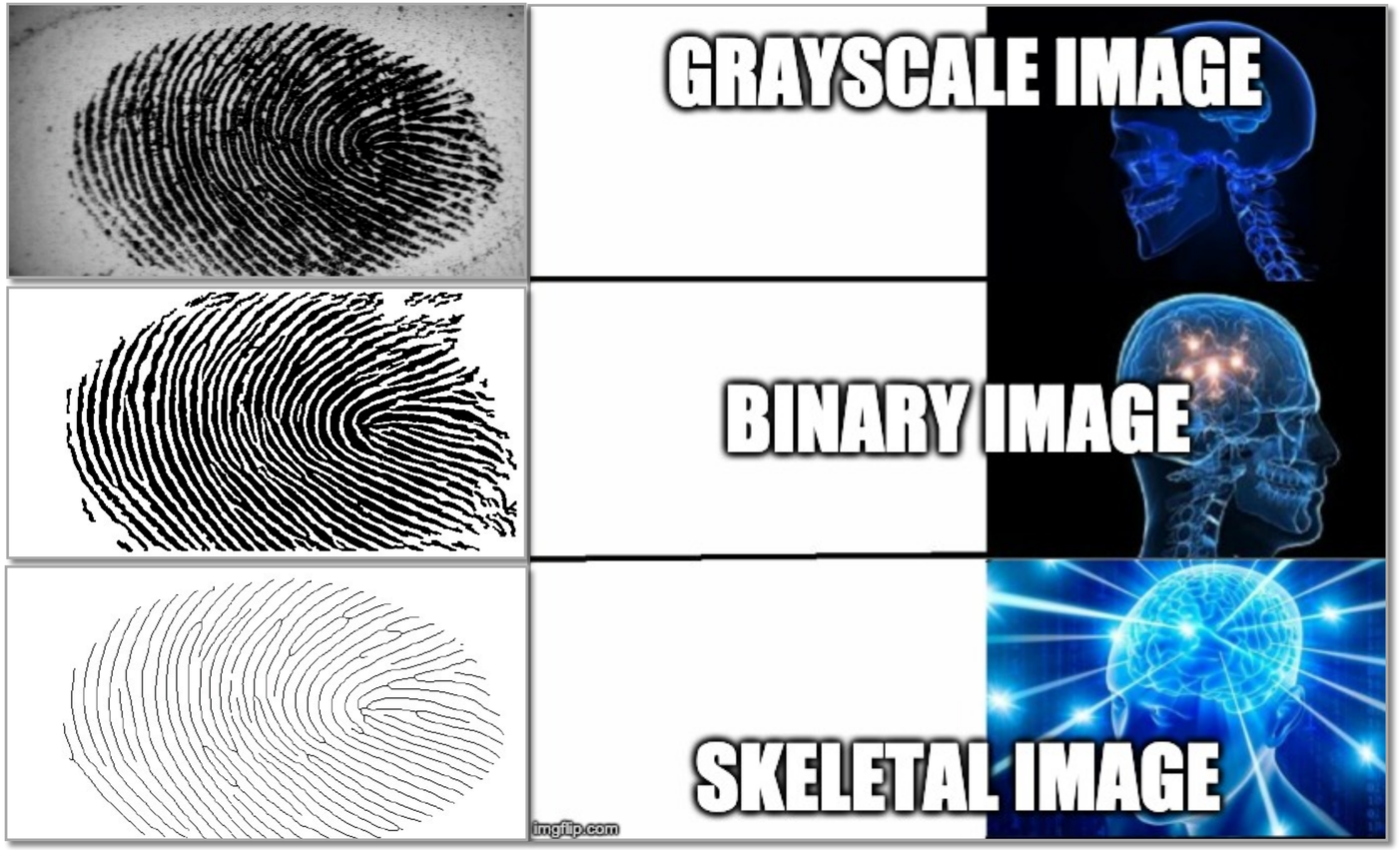
# Minutiae Detection

**Three Stages**
Start from…



# Minutiae Detection

**Three Stages**
Start from…

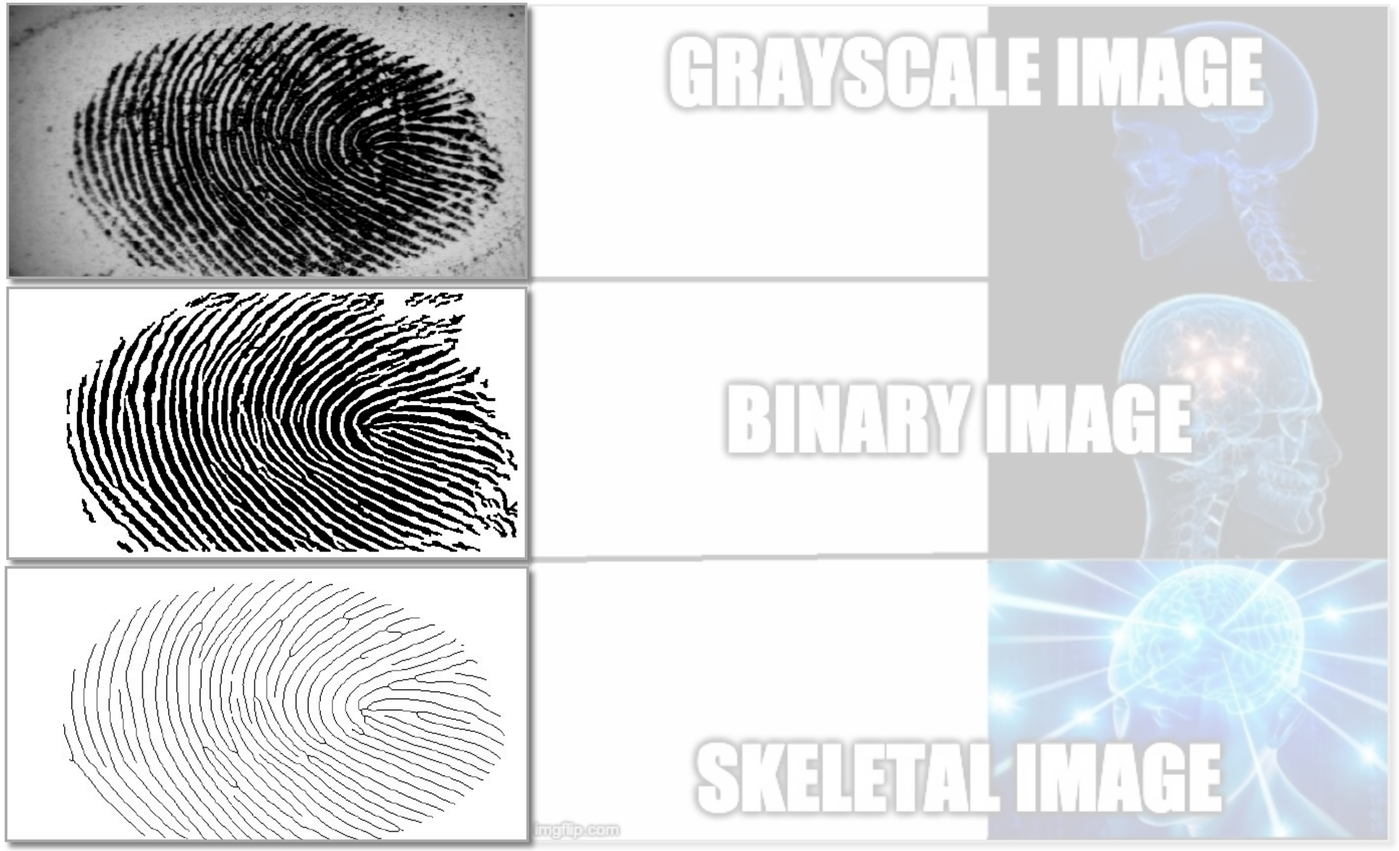



Source: Dr. Adam Czajka

# Minutiae Detection

**Three Stages**
Start from…

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




Source: Dr. Adam Czajka

# Minutiae Detection

**Grayscale Images**
Need for only basic enhancement (e.g., contrast improvement).

Source: Dr. Adam Czajka

**Solution Examples**

**Classification of Gabor filters' response**
*Fingerprint image processing using neural networks*
IEEE TENCON, 1990

**Ridge tracking**
Maio and Maltoni
*Direct Gray-Scale Minutiae Detection In Fingerprints*
IEEE T.PAMI, 1997

# Minutiae Detection

Source: Dr. Adam Czajka

**Binary Images**

Need for binarization enhancement.

Ridge tracking becomes easier.

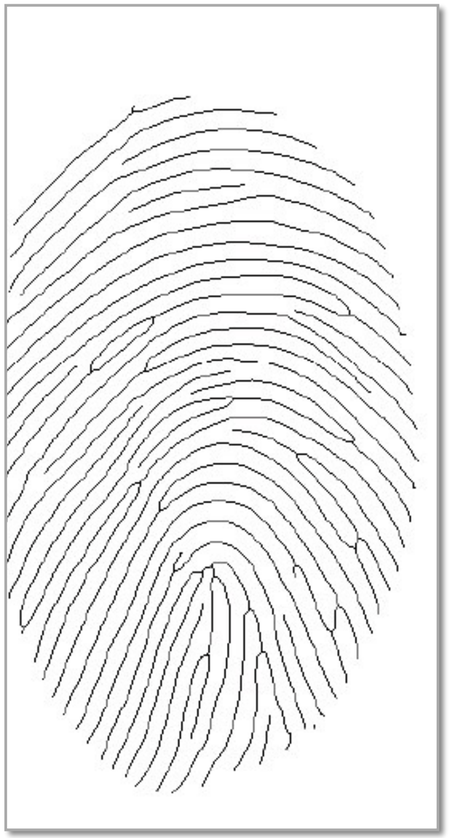
**How to perform binarization?**

**Image Processing**

Ridge and valley enhancement, through the application of Gabor filters, followed by filter response thresholding.

# Minutiae Detection

Source: Dr. Adam Czajka



**Skeletal Images**

Need for binarization enhancement
followed by skeletonization enhancement.

**How to perform skeletonization?**

**Image Processing**

After binarization, apply sequences of morphological operations, such as erosion.

Source: https://scikit-image.org/docs/dev/auto_examples/edges/plot_skeleton.html

# Minutiae Detection

**Three Strategies**

Source: Dr. Adam Czajka


Let’s dive into it…

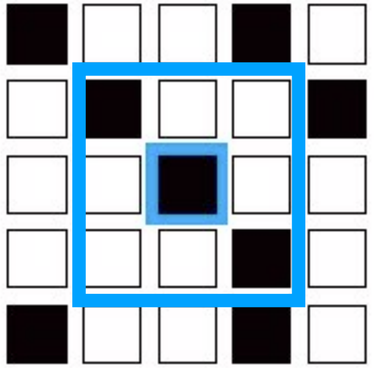
# Minutiae Detection

**Skeletal Images**

Analyze each ridge pixel neighborhood.

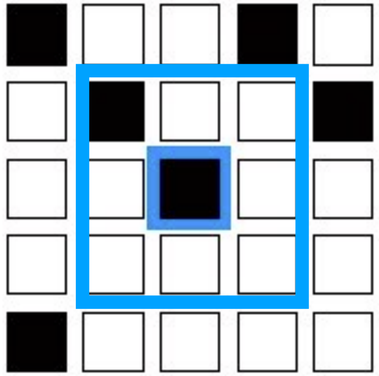
Count the number of ridge pixels (*#RP*).

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



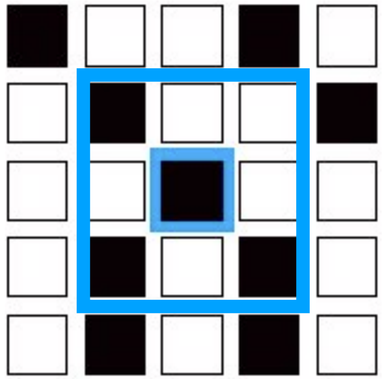
*#RP = 3*

No minutiae



*#RP < 3*

Ridge end



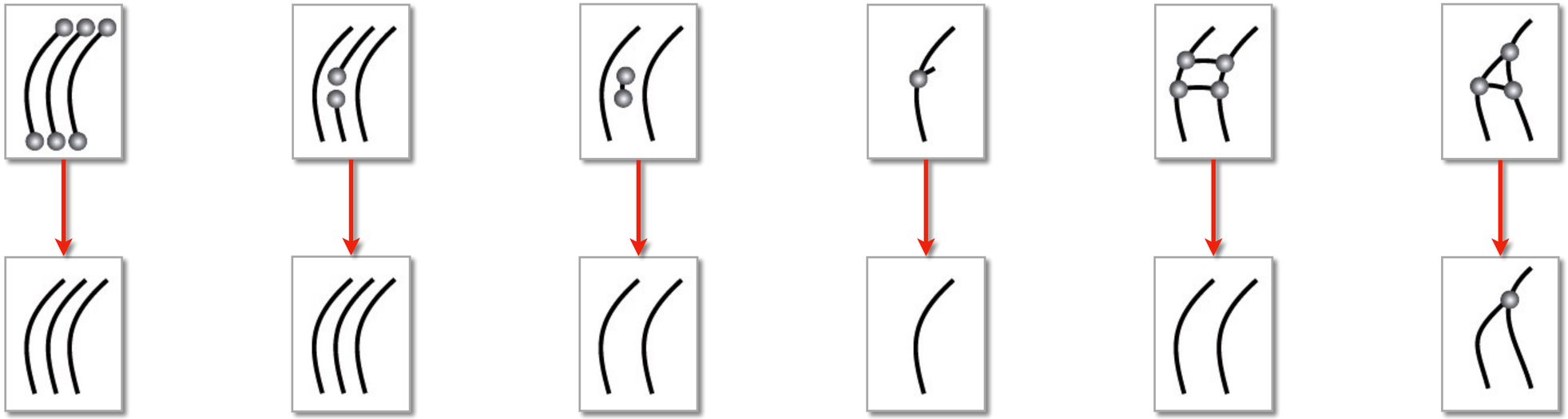
*#RP > 3*

Ridge bifurcation

# Minutiae Detection

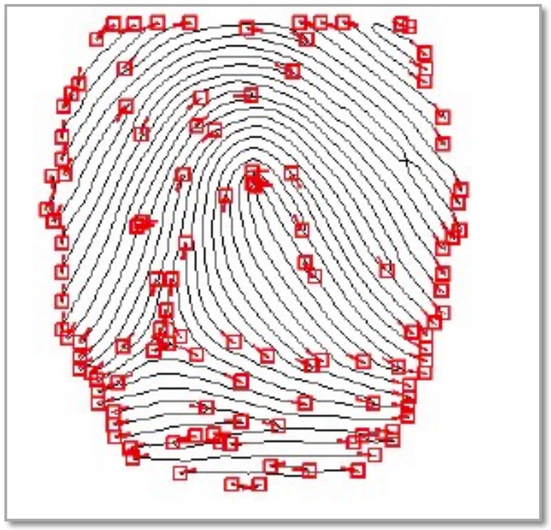
**Skeletal Images**
Remove false positive minutiae.
Example Heuristics:

Source: Dr. Adam Czajka

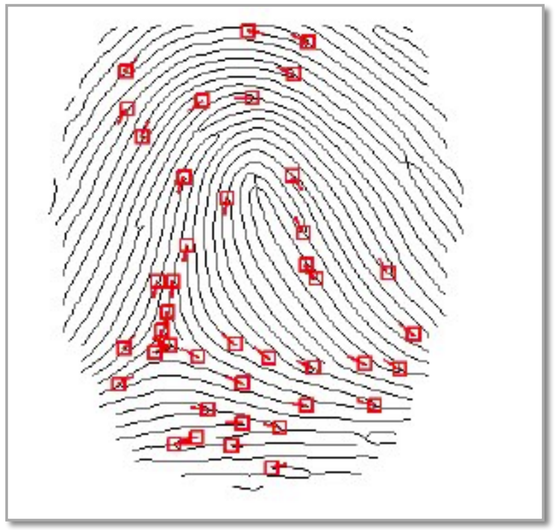


# Minutiae Detection

**Skeletal Images**
Remove false positive minutiae.



before



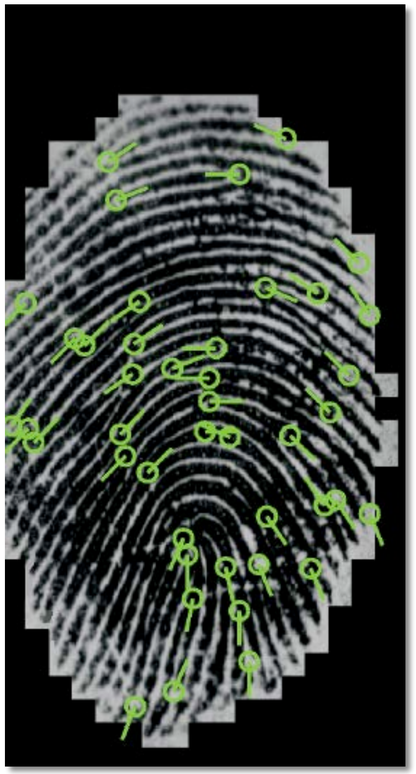
after

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

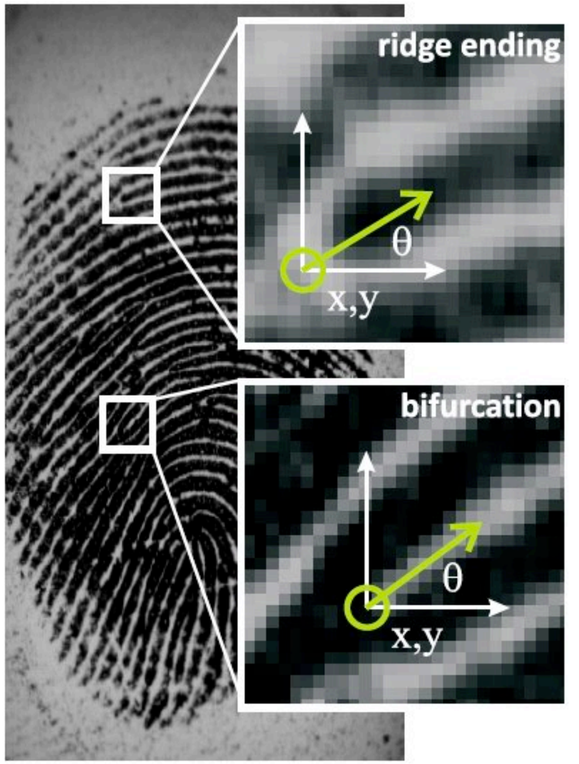
# Minutiae Description

**ISO/IEC FDIS 19794-2 (2011)**
For each minutiae,
store position $(x, y)$ and
angle $\theta$.

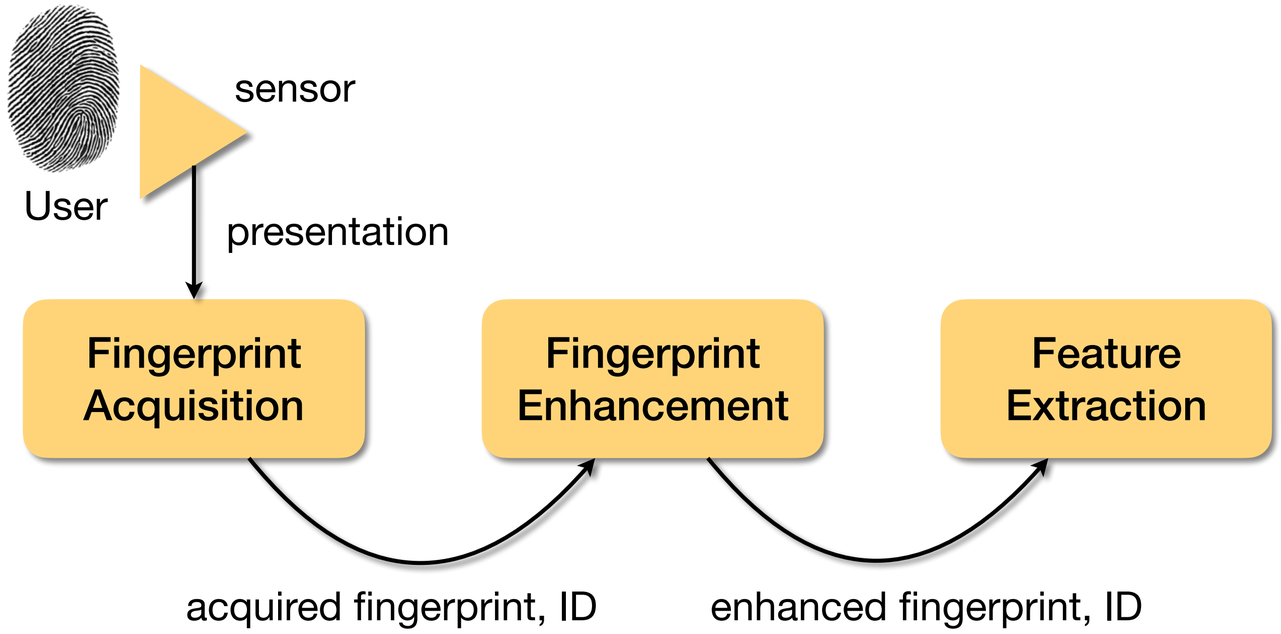
Possible extra information:
Minutiae type (either ridge end or bifurcation).



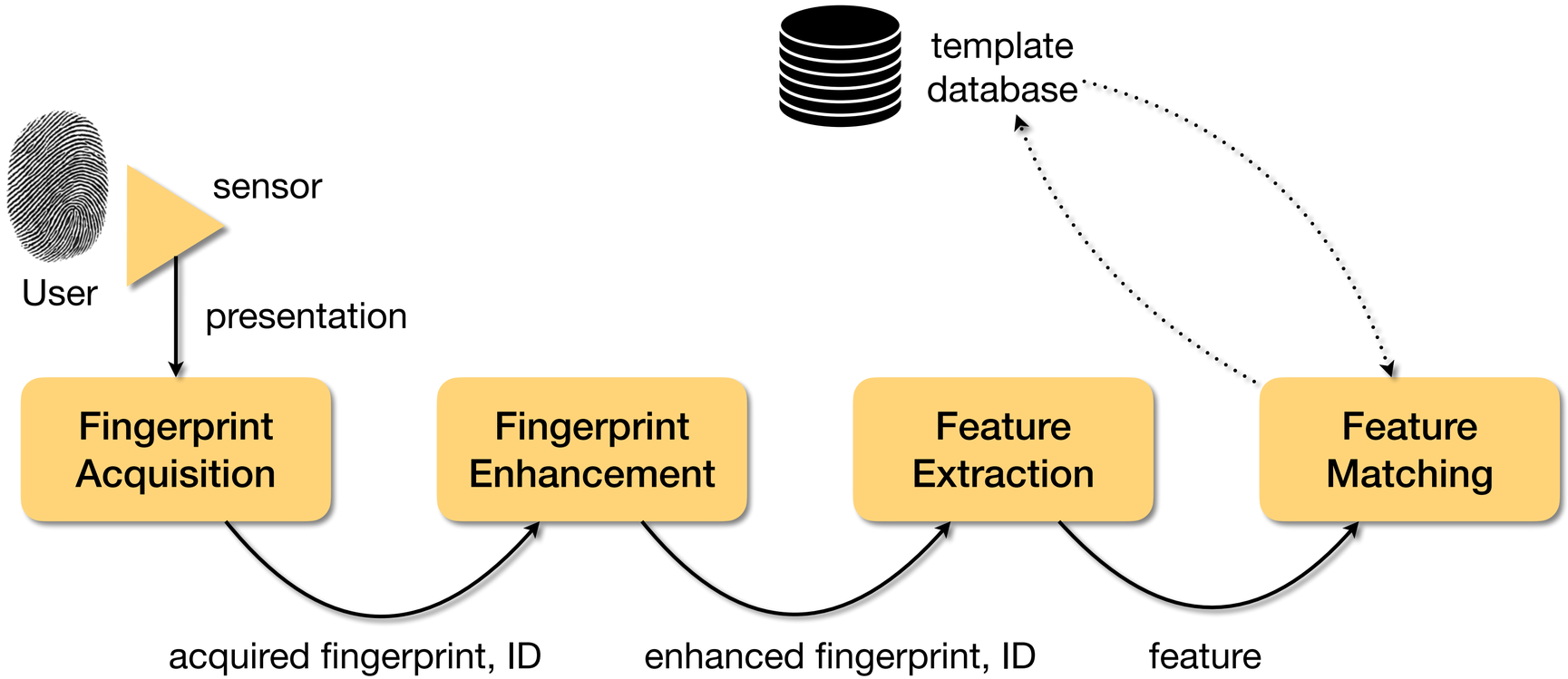
Source: Dr. Adam Czajka



# Fingerprint Recognition



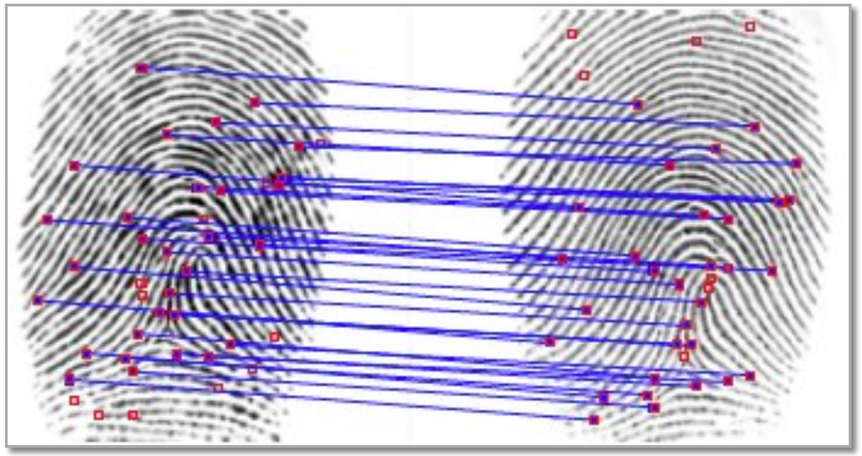
# Fingerprint Recognition



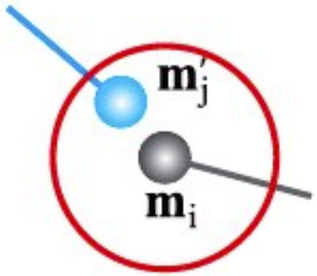
# Feature Matching

**How to establish pairs of corresponding minutiae between two samples?**

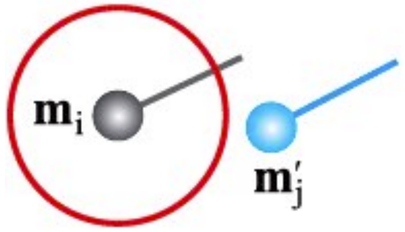
Check for agreements between both $(x, y)$ **positions** and $\theta$ **angles**.



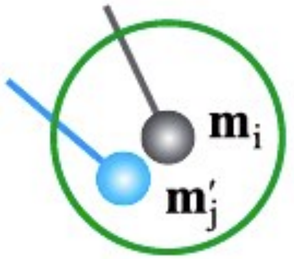
Jain, Ross, and Nadakumar
*Introduction to Biometrics*
Springer Books, 2011




✗ Positions agree, but angles do not.




✗ Angles agree, but positions do not.



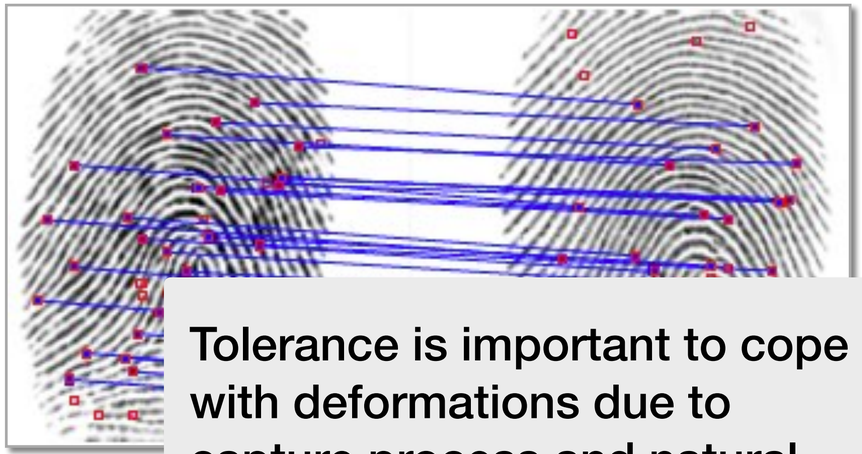

✓ Both angles and positions agree.

$m_i$ : i-th minutiae from image $i$.
$m'_j$ : j-th minutiae from image $j$.
Source: Dr. Adam Czajka

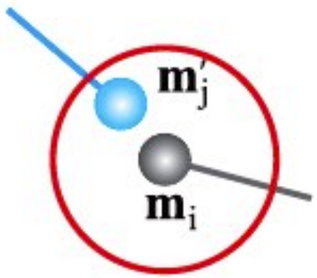
# Feature Matching

**How to establish pairs of corresponding minutiae between two samples?**

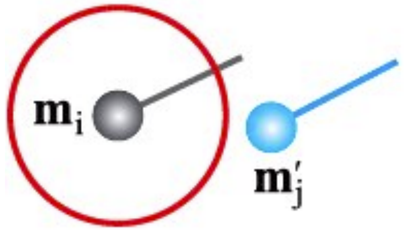
Check for agreements between both $(x, y)$ **positions** and $\theta$ **angles**.



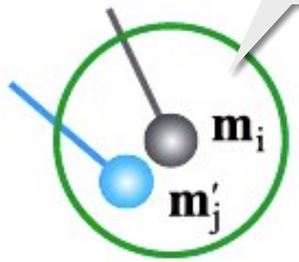
**Tolerance is important to cope with deformations due to capture process and natural skin deformations.**




✗ Positions agree, but angles do not.




✗ Angles agree, but positions do not.




✓ Both angles and positions agree.

$m_i$ : i-th minutiae from image $i$.
$m'_j$ : j-th minutiae from image $j$.
Source: Dr. Adam Czajka



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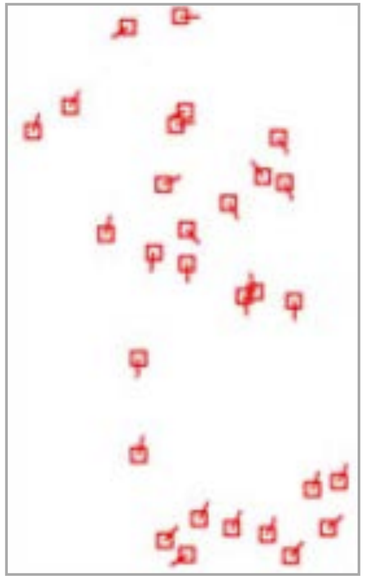
# Feature Matching

**Hough Transform**
**Objective:** find scale, rotation, and translation transformations that maximize the number of agreeing minutiae (a.k.a, **matches**).

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

query

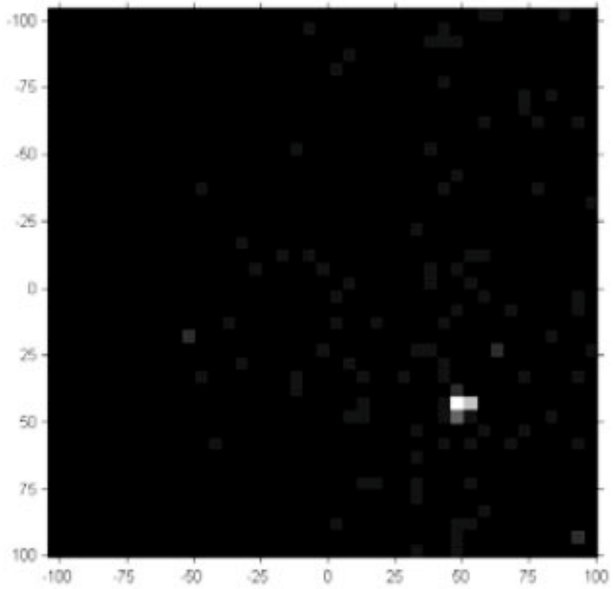


template

# Feature Matching

**Hough Transform**
**Solution**: define the **Hough Space** -
a space with all the meaningful
*(scale, rotation, translation)* solutions.
Take the sample from the space
that maximizes the number of matches.

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



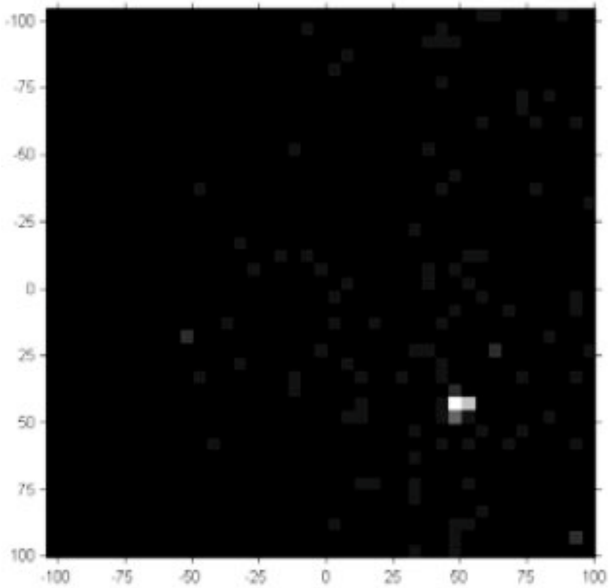

Hough-space 2D simplification with the number of matches expressed as gray scale (the more the matches, the whiter the space).

# Feature Matching

## Hough Transform

query

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

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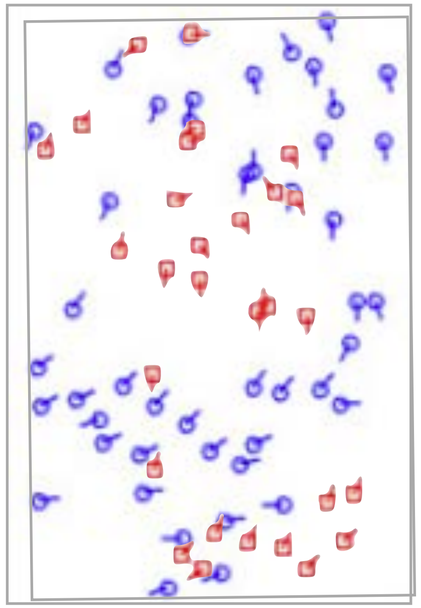
# Feature Matching

## Hough Transform

template



query

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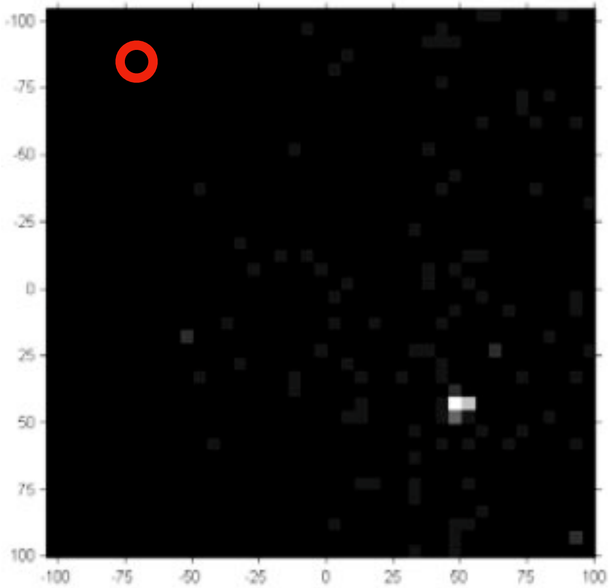


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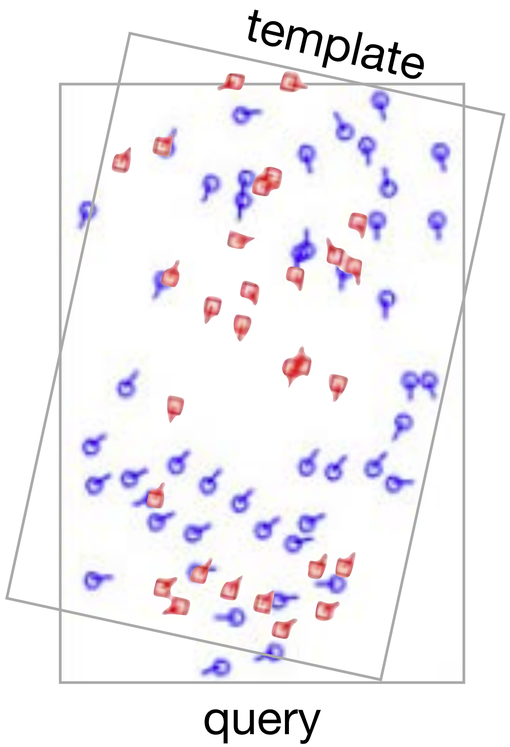
# Feature Matching

## Hough Transform

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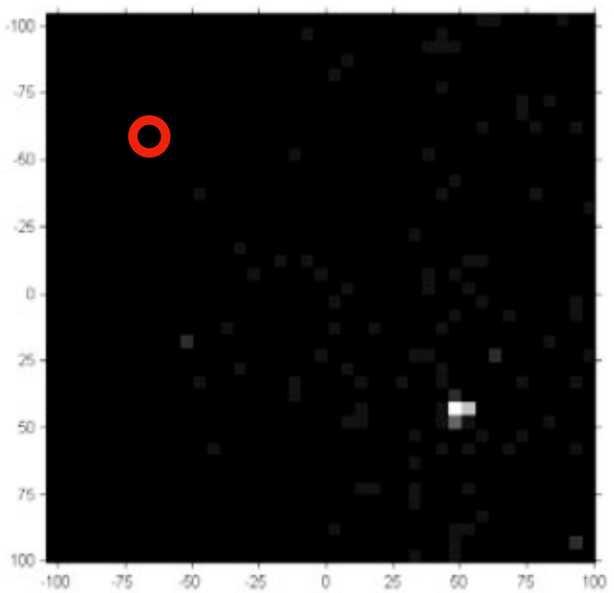
Springer Books, 2011

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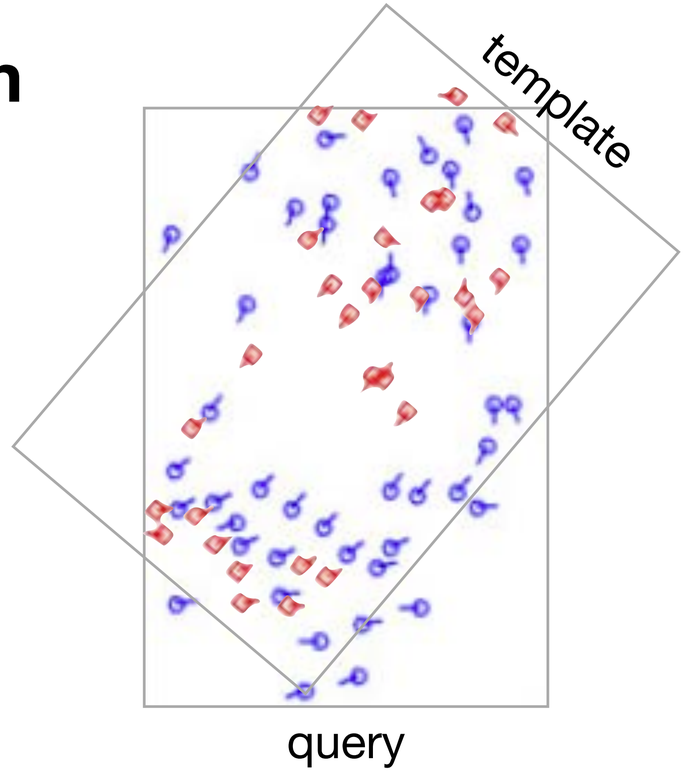
# Feature Matching

## Hough Transform

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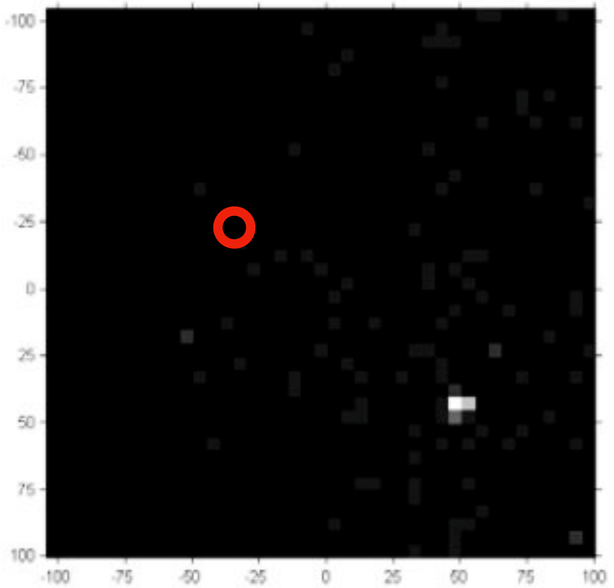
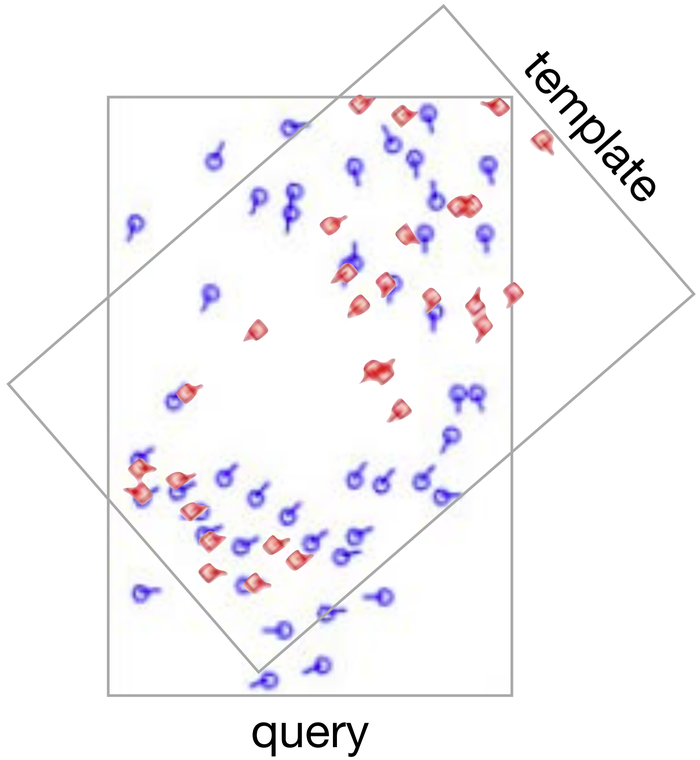
Springer Books, 2011




Hough-space 2D simplification with the number of matches expressed as gray scale (the more the matches, the whiter the space).

# Feature Matching

## Hough Transform

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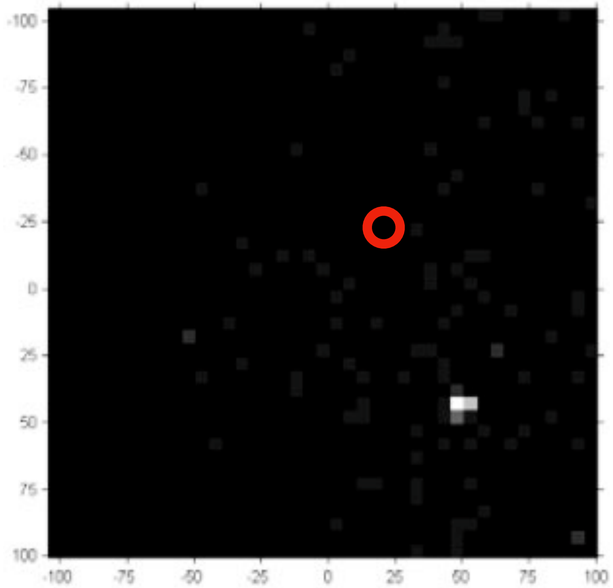
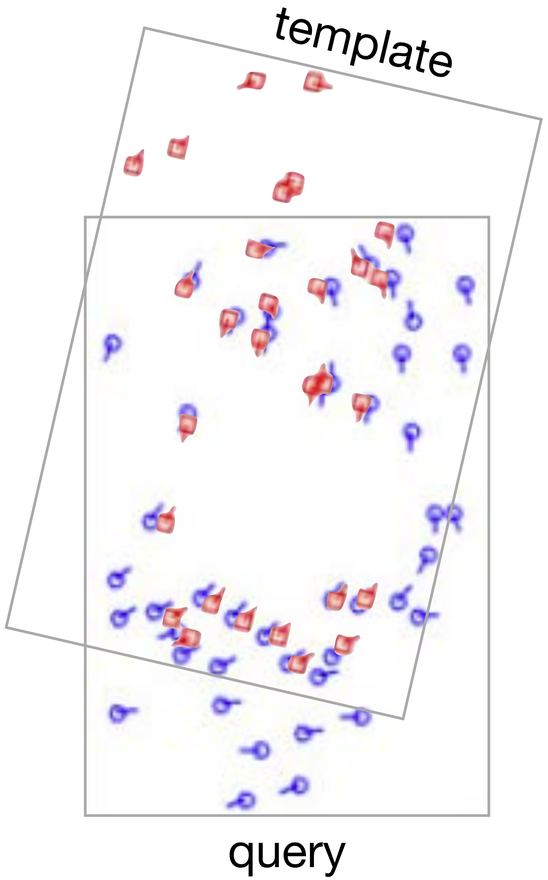
Springer Books, 2011




Hough-space 2D simplification with the number of matches expressed as gray scale (the more the matches, the whiter the space).

# Feature Matching

## Hough Transform

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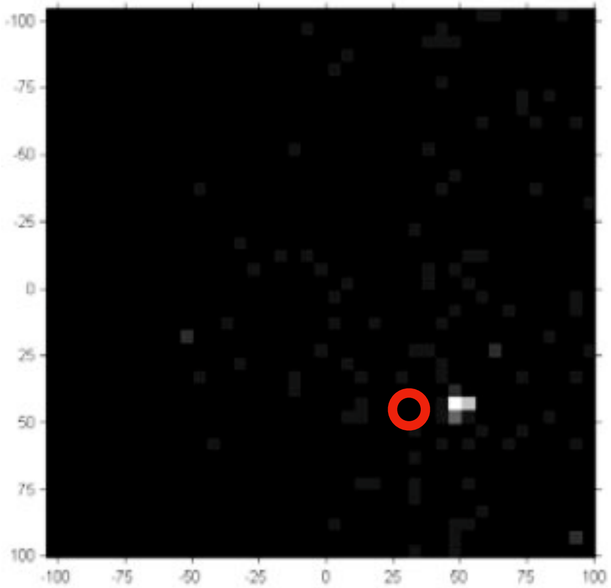
Springer Books, 2011

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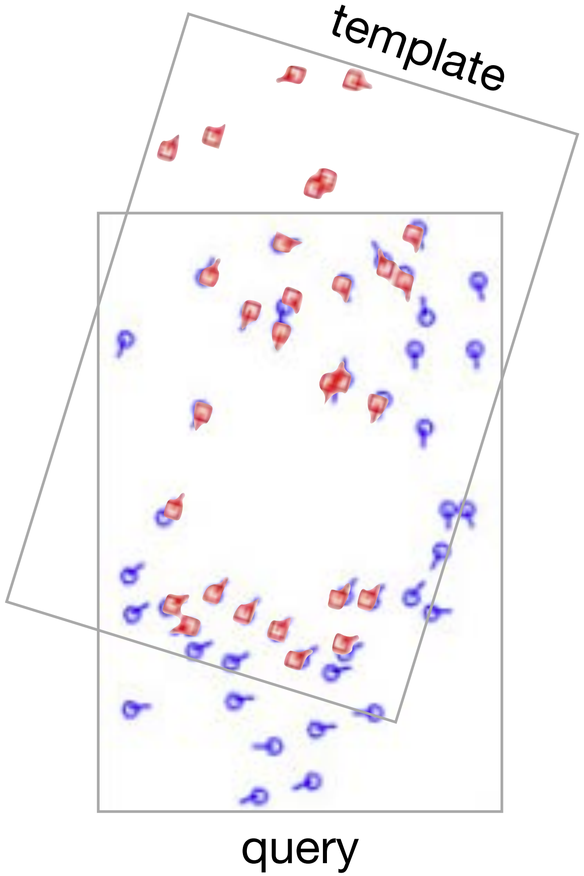
# Feature Matching

## Hough Transform

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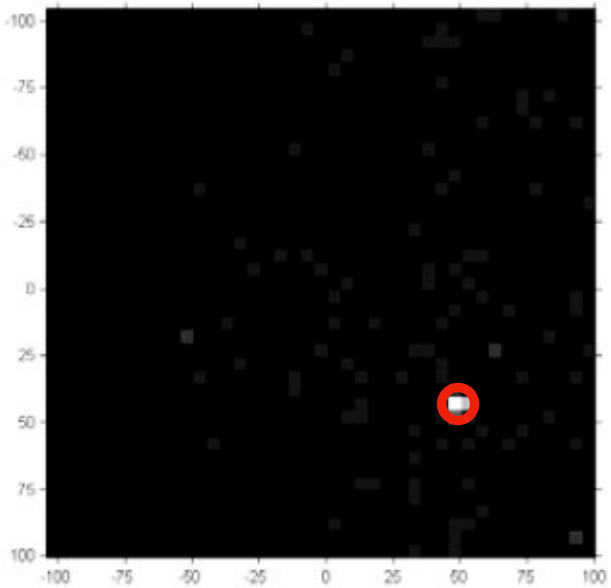
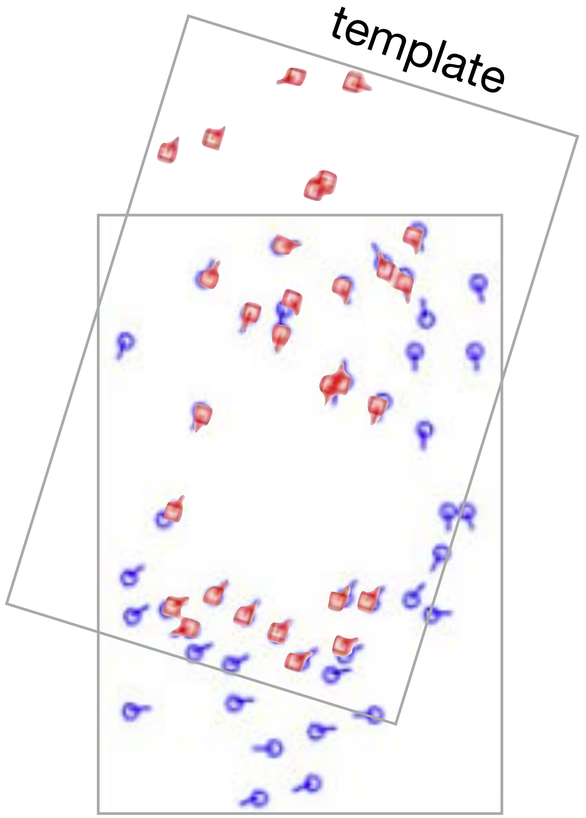


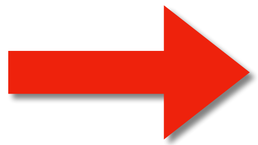

Hough-space 2D simplification with the number of matches expressed as gray scale (the more the matches, the whiter the space).

# Feature Matching

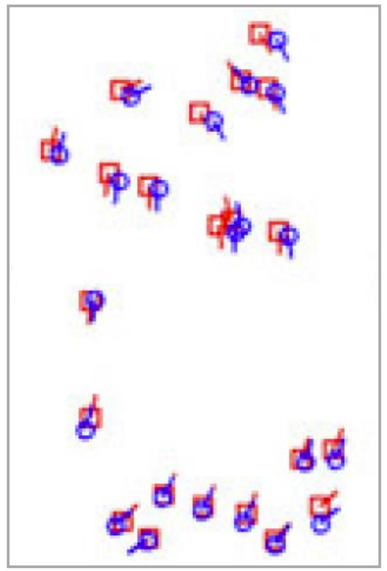
**Hough Transform**




query

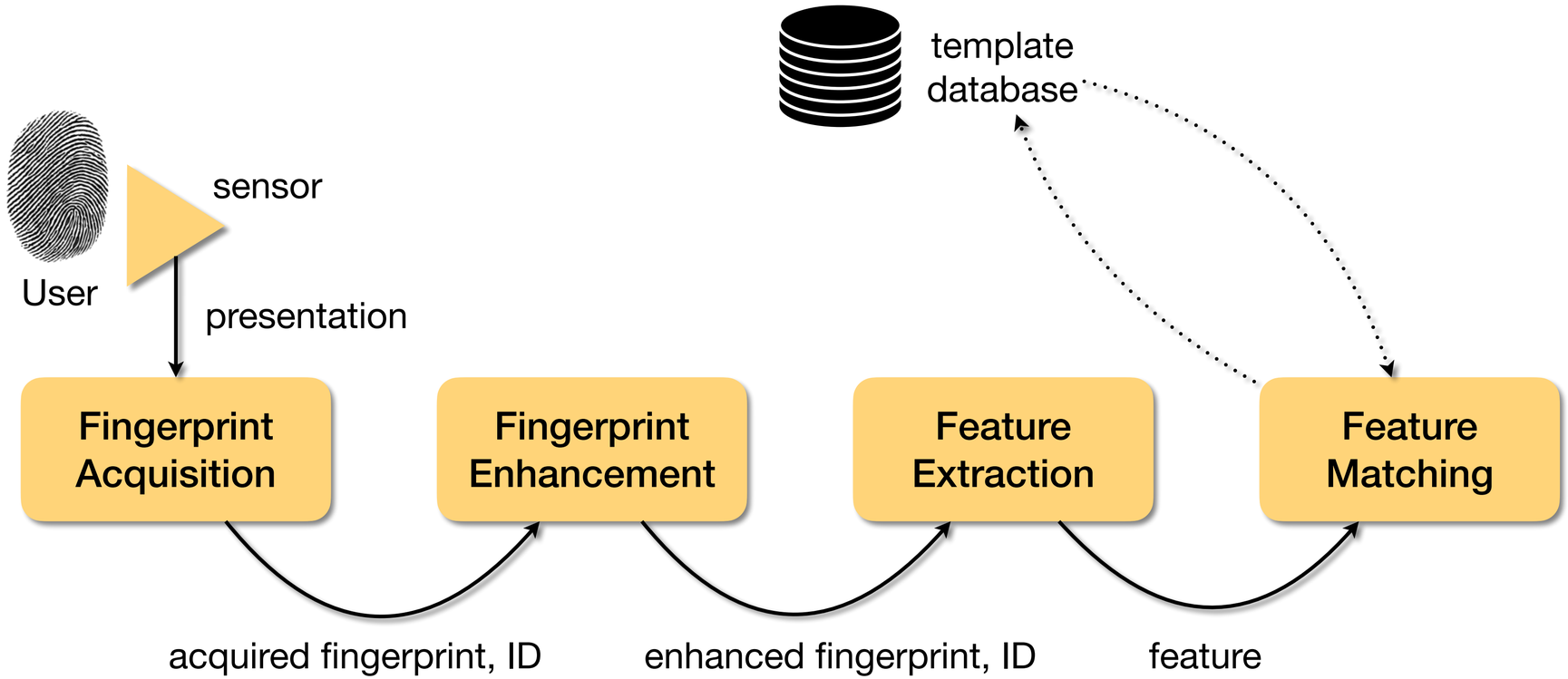


Jain, Ross, and Nadakumar
*Introduction to Biometrics*
Springer Books, 2011

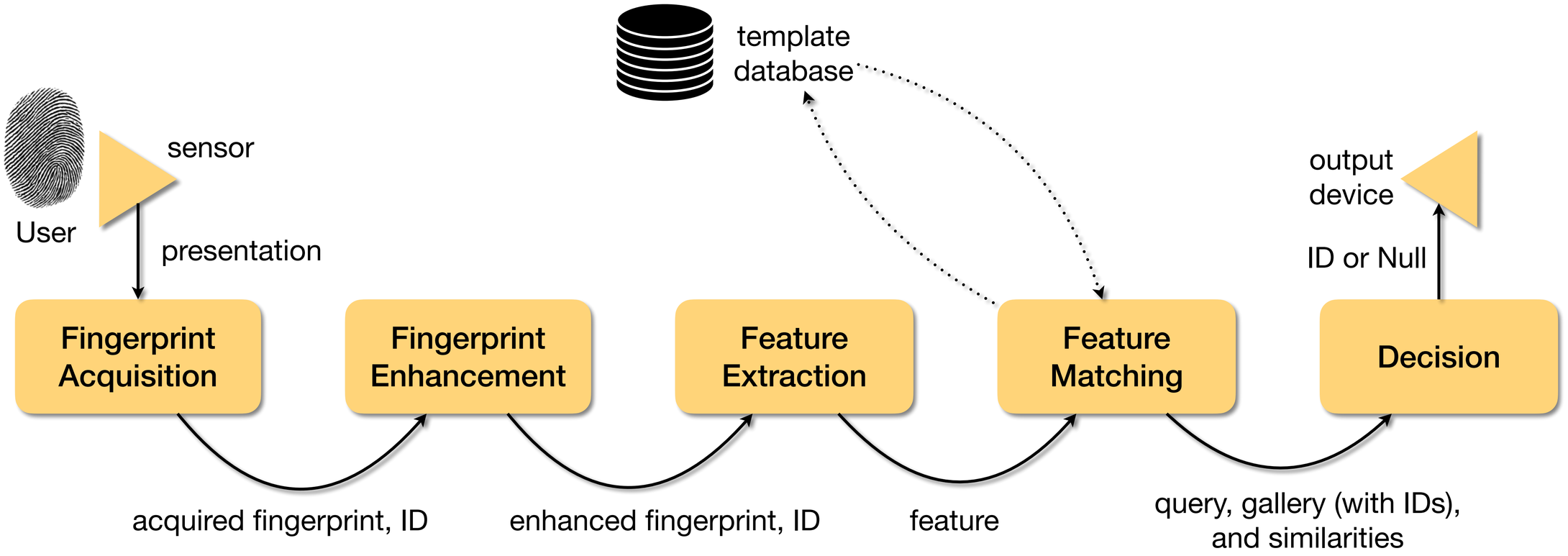


21 matches

# Fingerprint Recognition



# Fingerprint Recognition



# Decision

Jain, Ross, and Nadakumar
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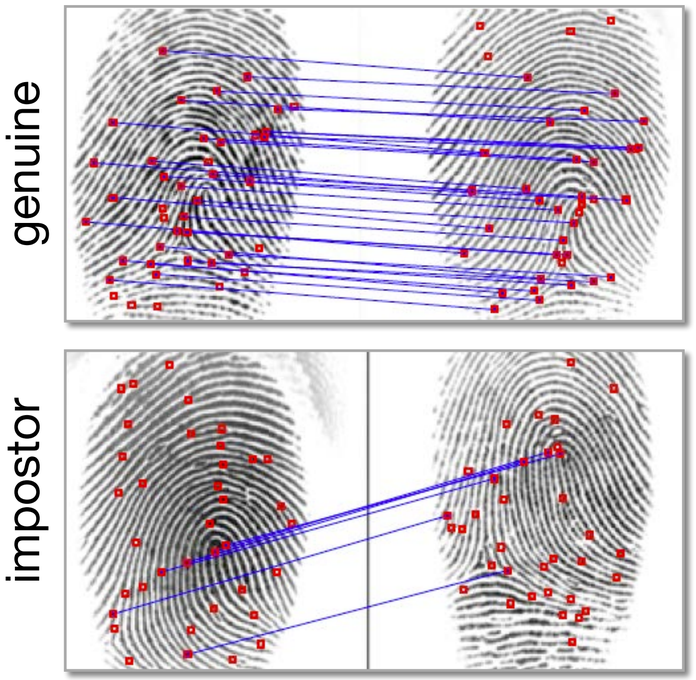
Springer Books, 2011

**Similarity-based Decision**

The number of minutiae matches express the **similarity** between two fingerprint samples.




**Simple score**

Let $M$ be the number of minutiae in image $i$.

Let $N$ be the number of minutiae in image $j$.

$$sim\_score = \frac{\#matches}{(M+N)/2}$$



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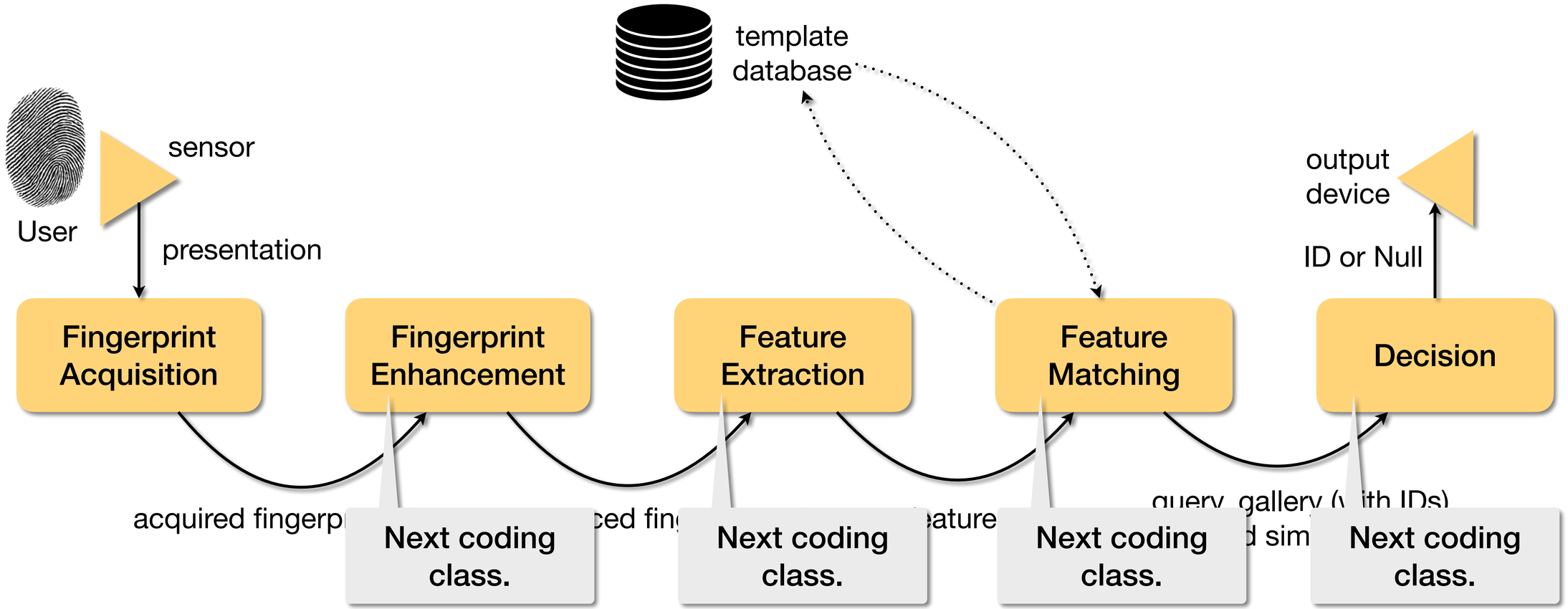
# Fingerprint Recognition



# What's Next?

**First data collection day**
We'll collect and store our fingerprints.

**Second coding class**
We'll experiment with some fingerprint recognition implementations.

**Fill out your *Today-I-missed* Statement**
Please visit https://sakai.luc.edu/x/PnQvIG.