# Iris Recognition III

COMP 388-002/488-002 Biometrics

**Daniel Moreira**

Fall 2024

LOYOLA
UNIVERSITY CHICAGO

# Today we will...

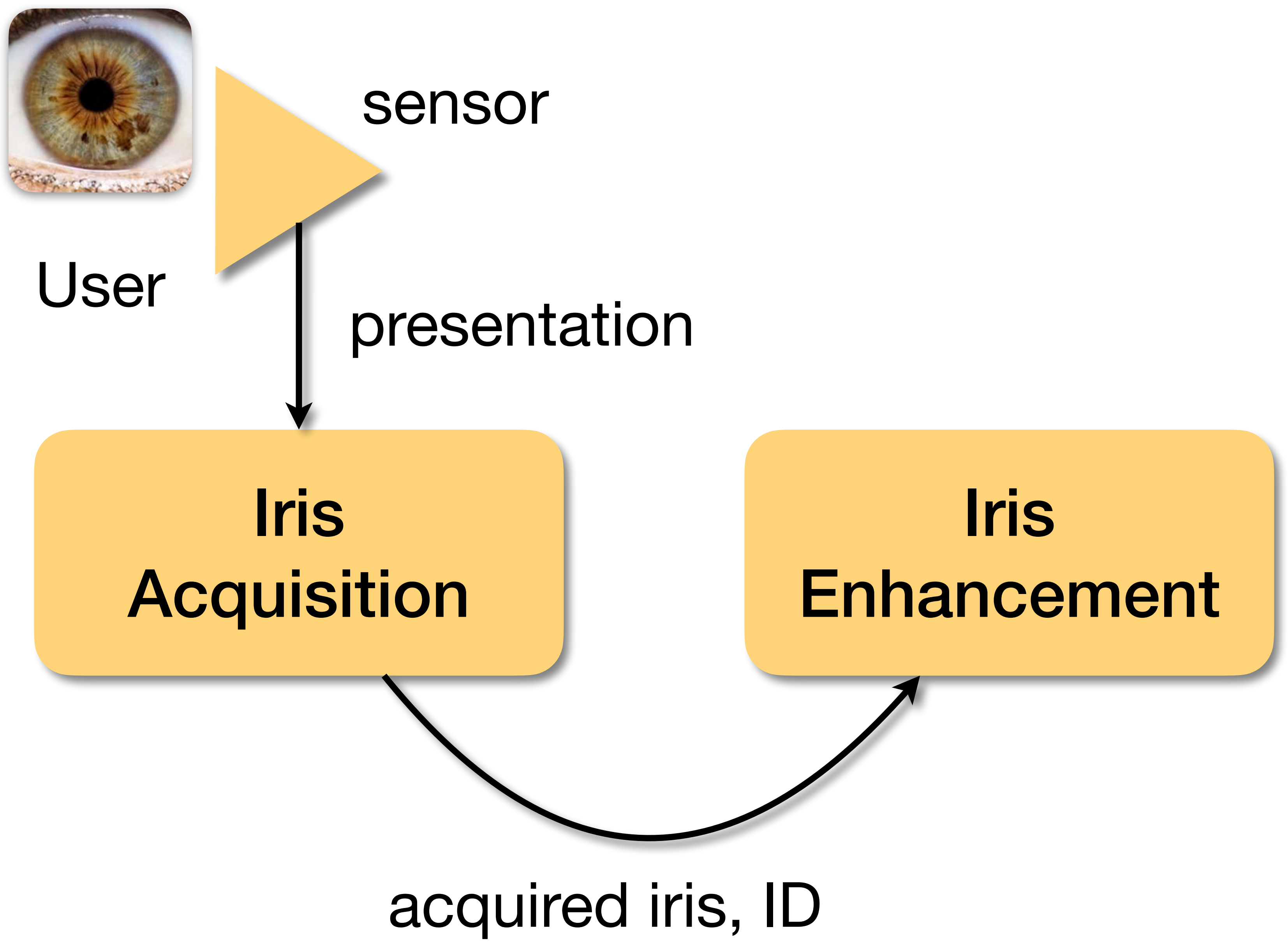
*Get to know*
Iris description and matching.

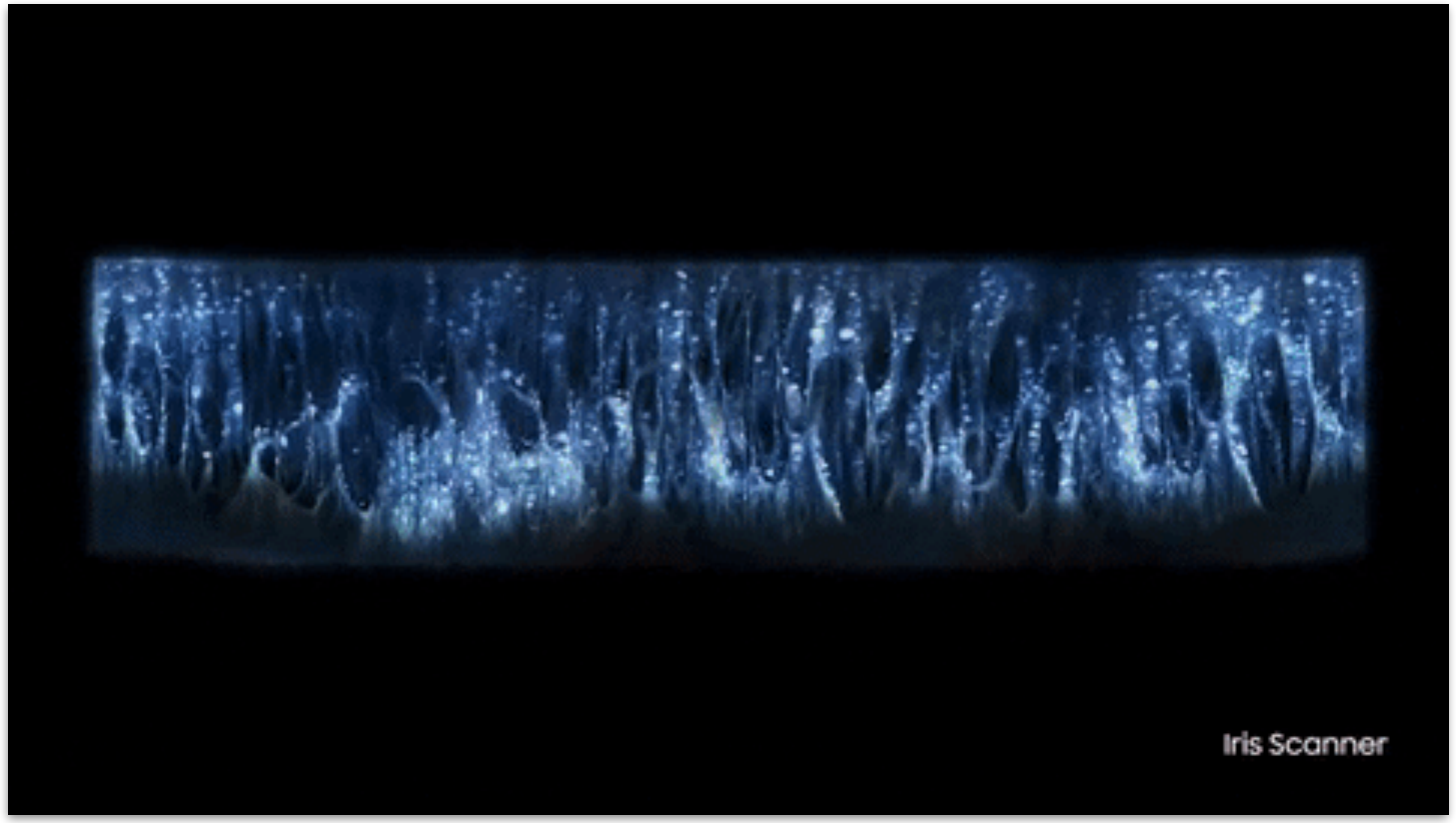
# Today's Attendance

**Please fill out the form**

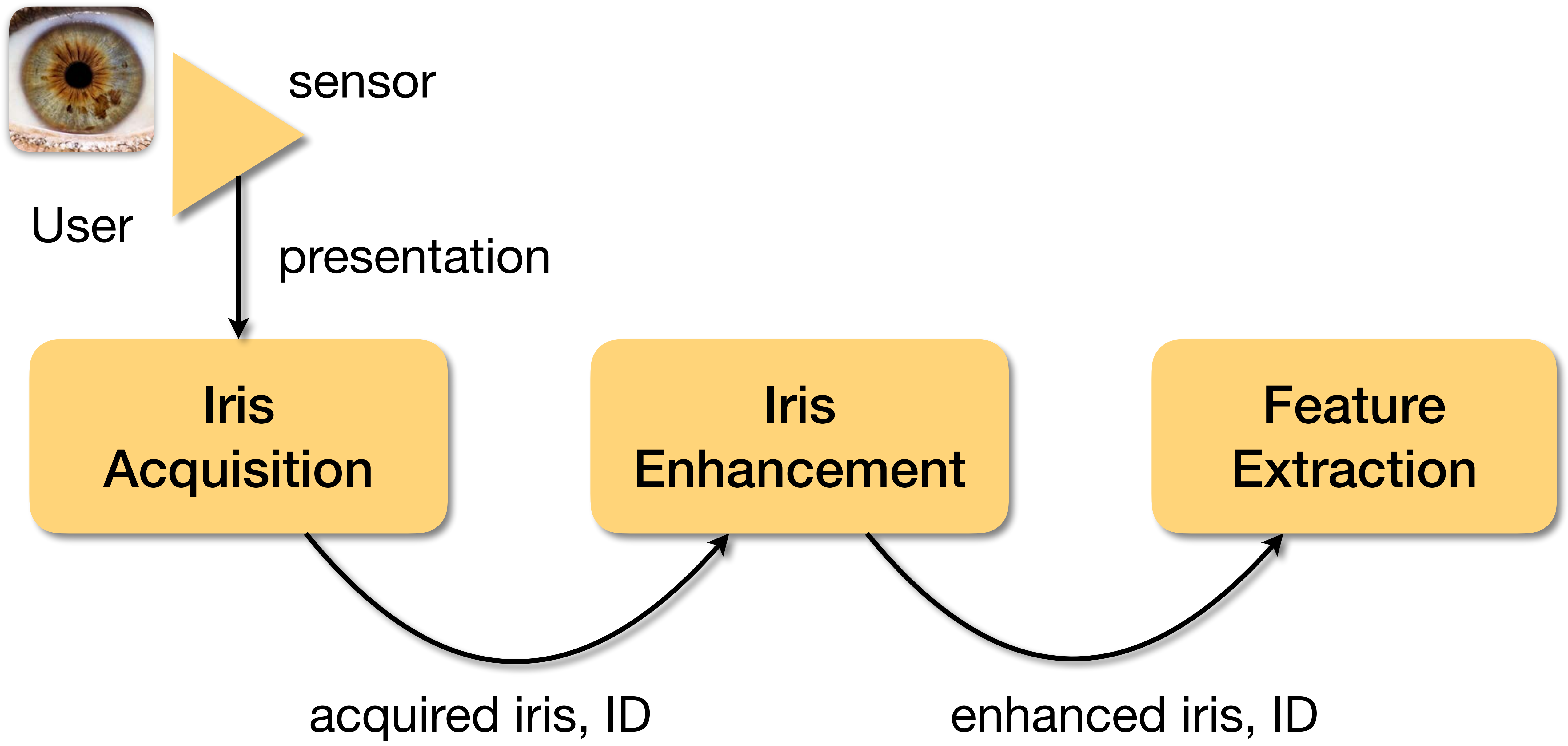
https://forms.gle/LwQxV9ZoKeVwwnWZ8

# Iris Recognition



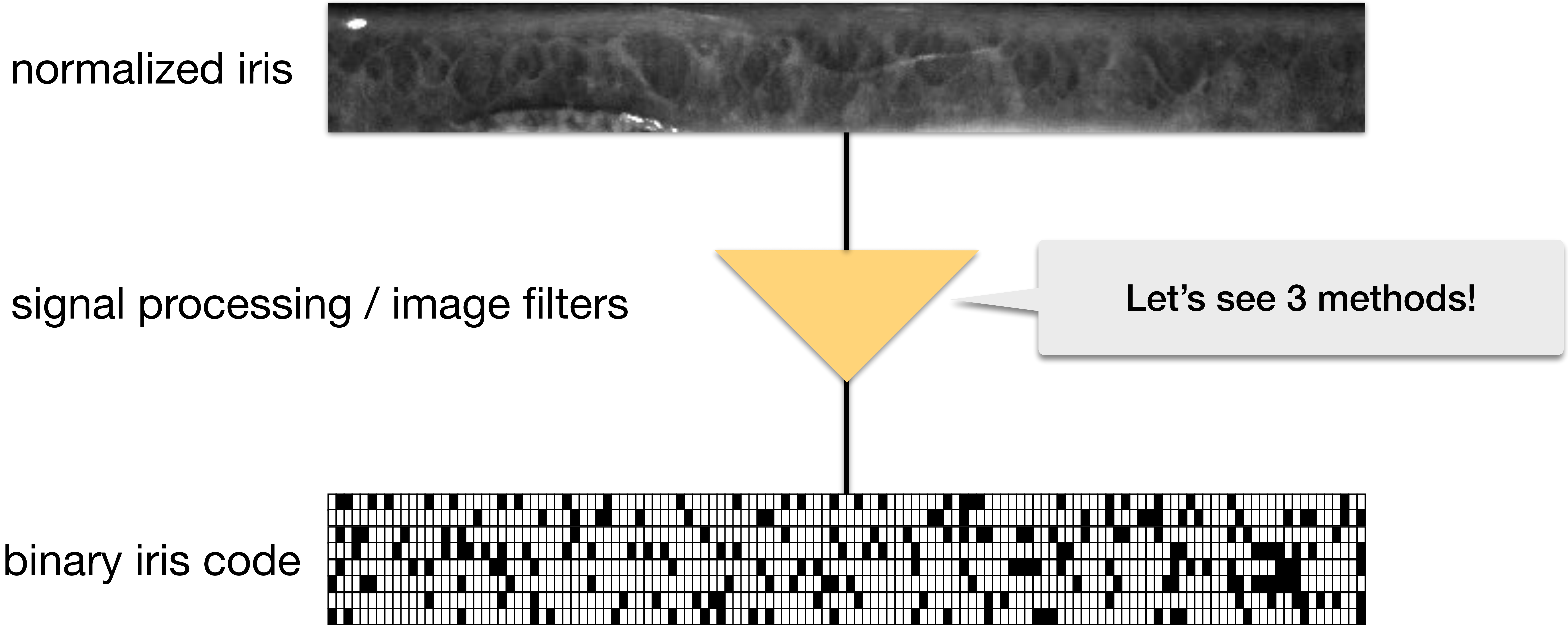



# Iris Recognition



# Feature Extraction

## Typical Description Framework

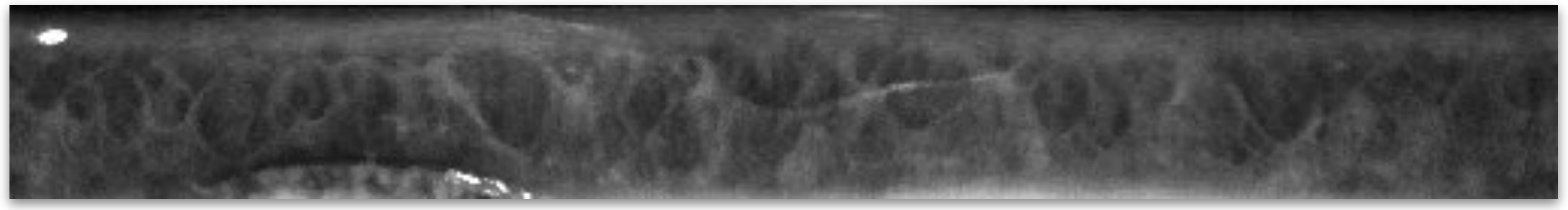


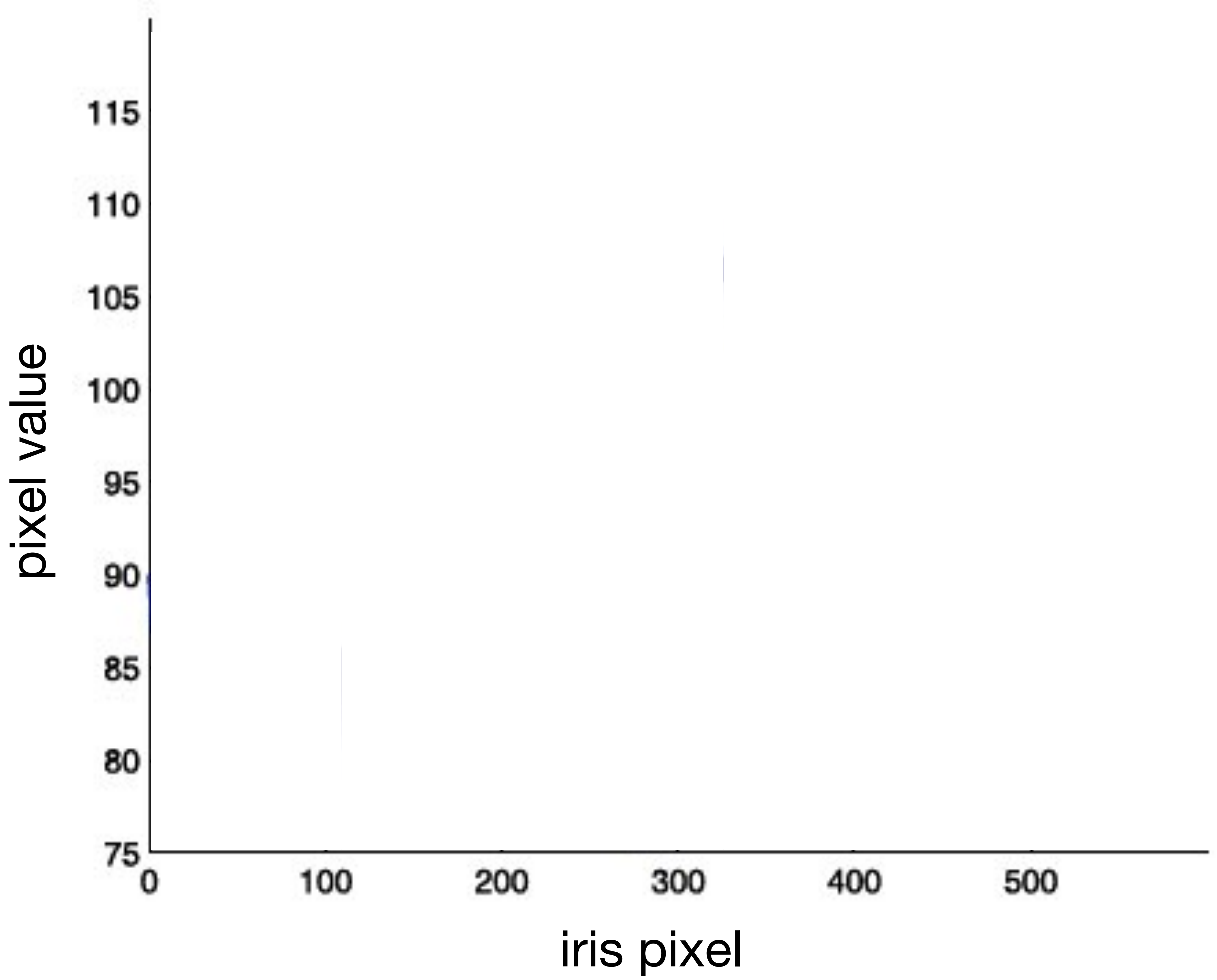
# Feature Extraction

**Zero-Crossing Approach (1/3)**

Proposed by W. W. Boles.

Iris image is treated as a 1D signal (iris signature).





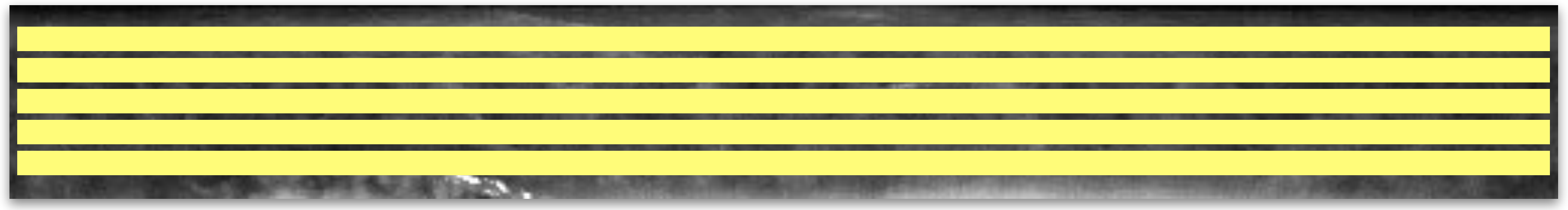

LOYOLA UNIVERSITY CHICAGO

# Feature Extraction

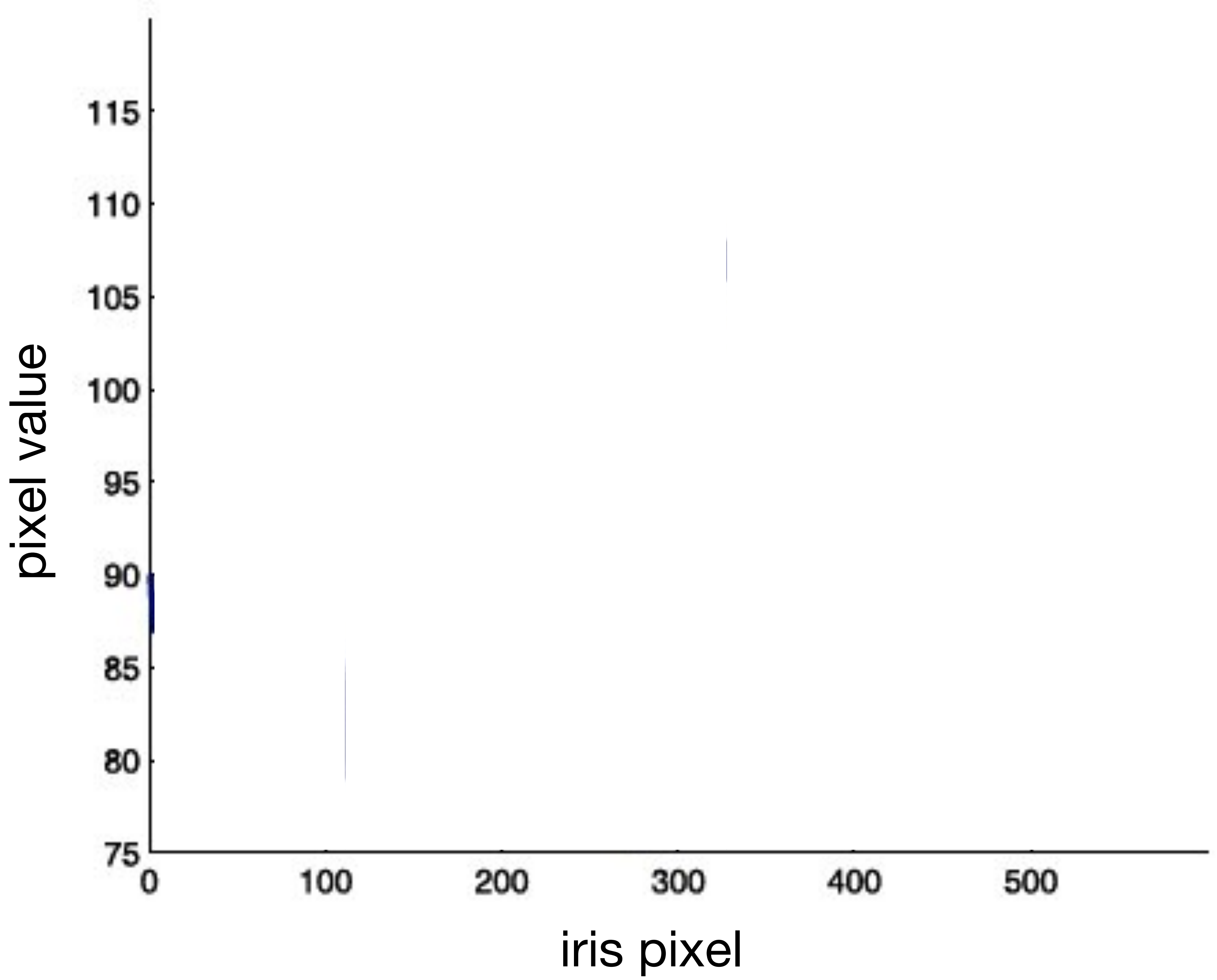
**Zero-Crossing Approach (1/3)**

Proposed by W. W. Boles.

Iris image is treated as a 1D signal (iris signature).



Dr. Adam Czajka

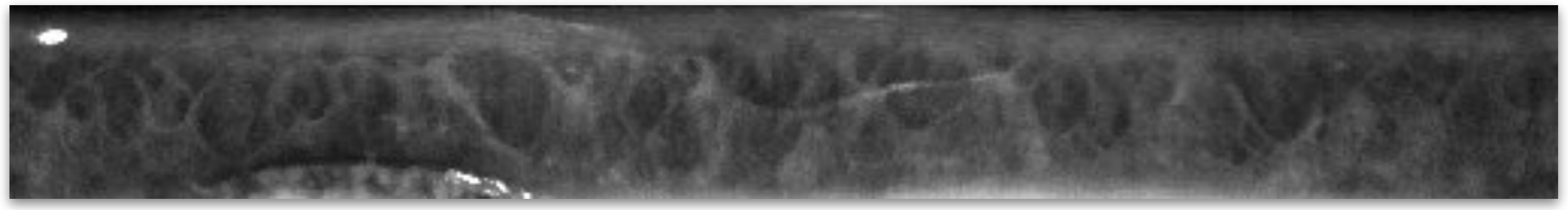


# Feature Extraction

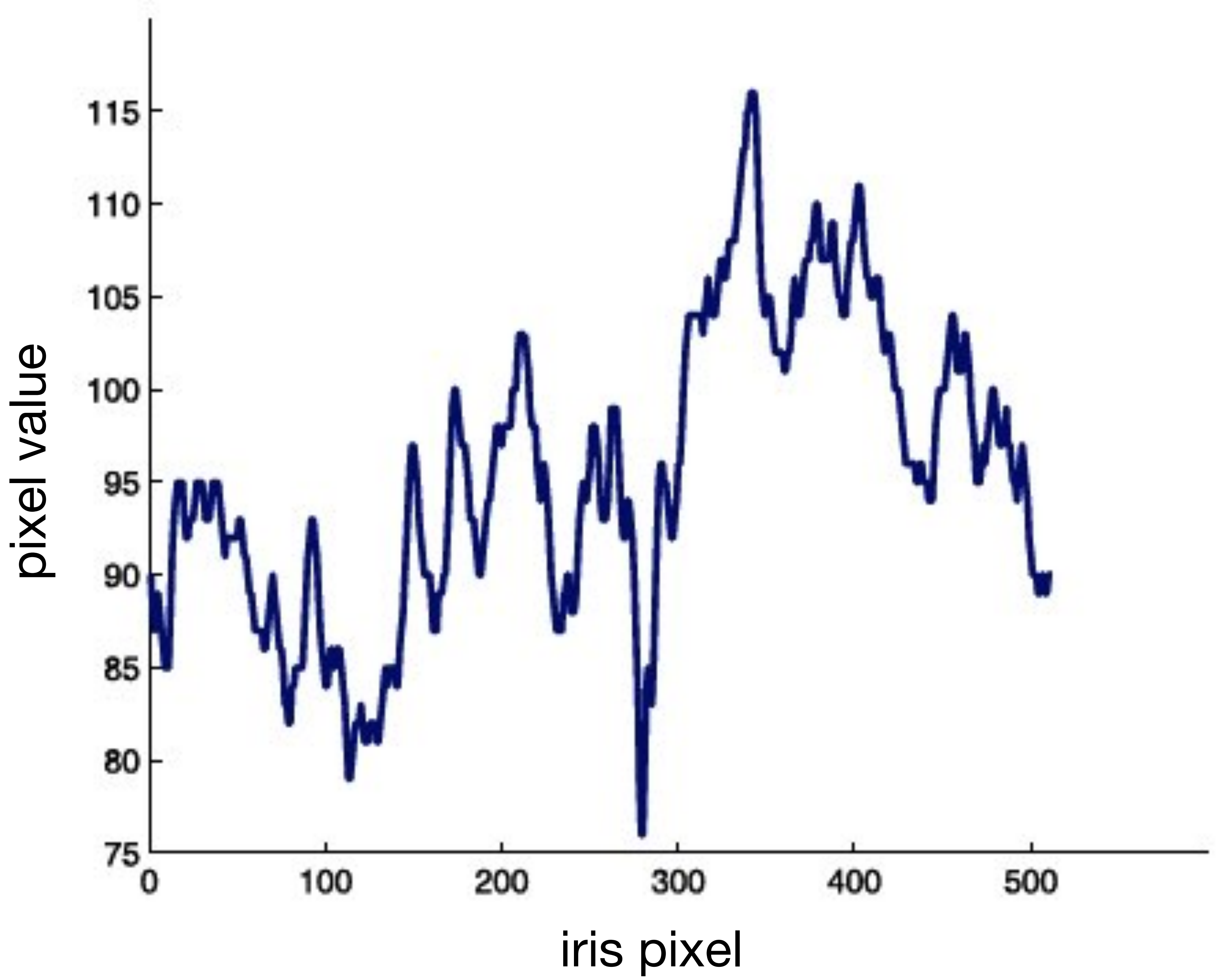
**Zero-Crossing Approach (1/3)**

Proposed by W. W. Boles.

Iris image is treated as a 1D signal (iris signature).



Dr. Adam Czajka



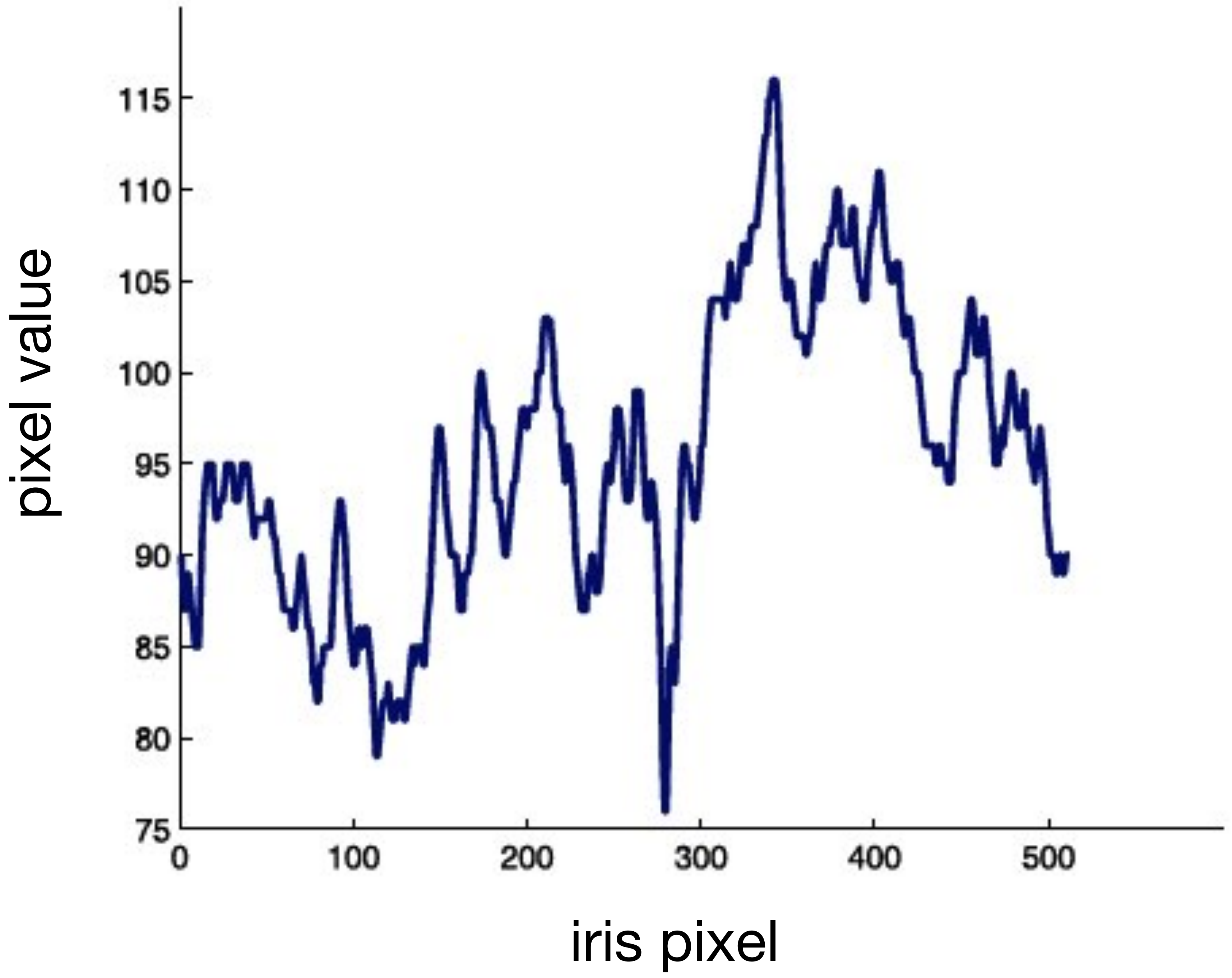


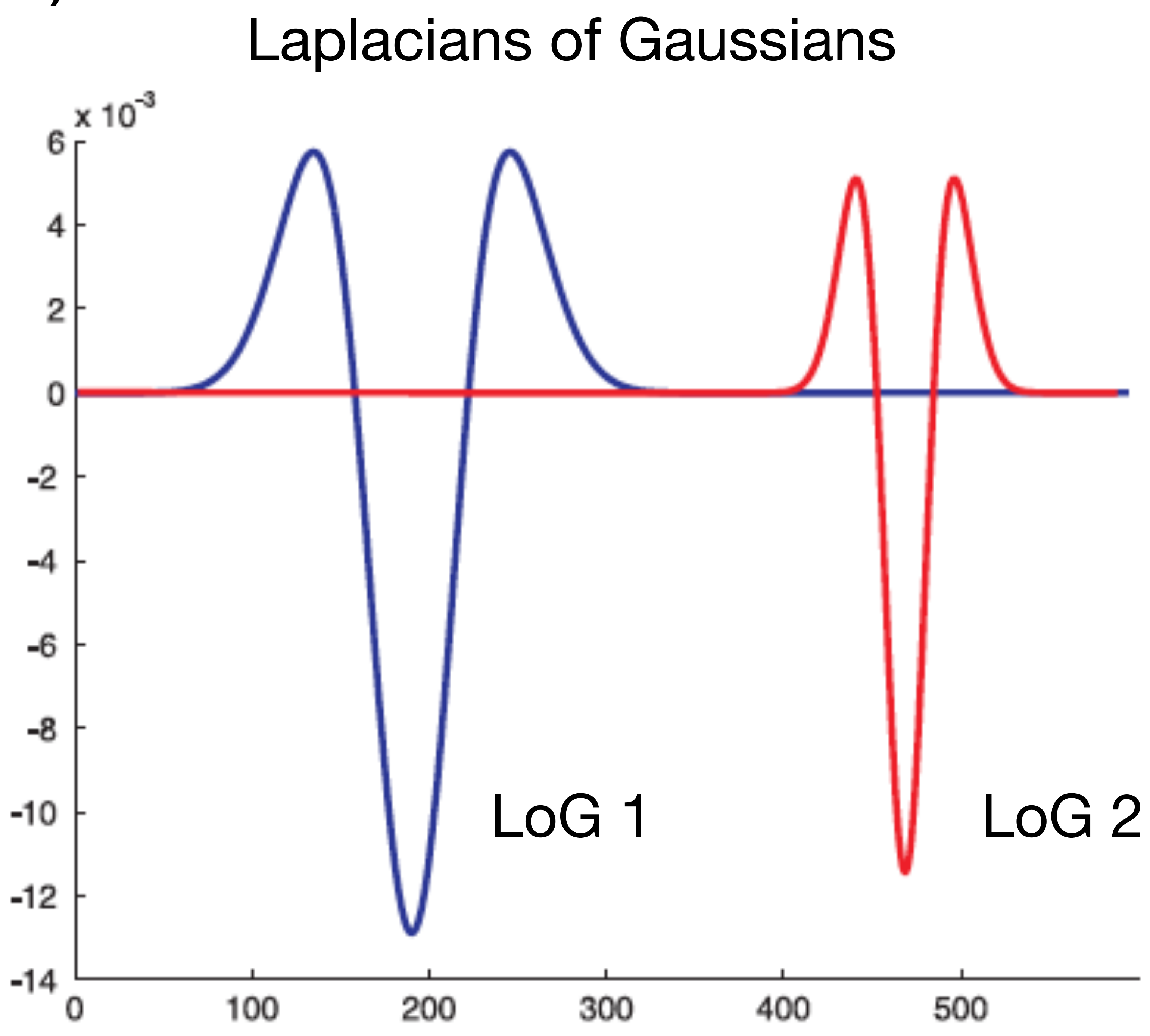

LOYOLA UNIVERSITY CHICAGO

# Feature Extraction

## Zero-Crossing Approach (1/3)

1. Iris signature is filtered by Laplacians of Gaussians (LoG) (second derivative of Gaussian).




Dr. Adam Czajka



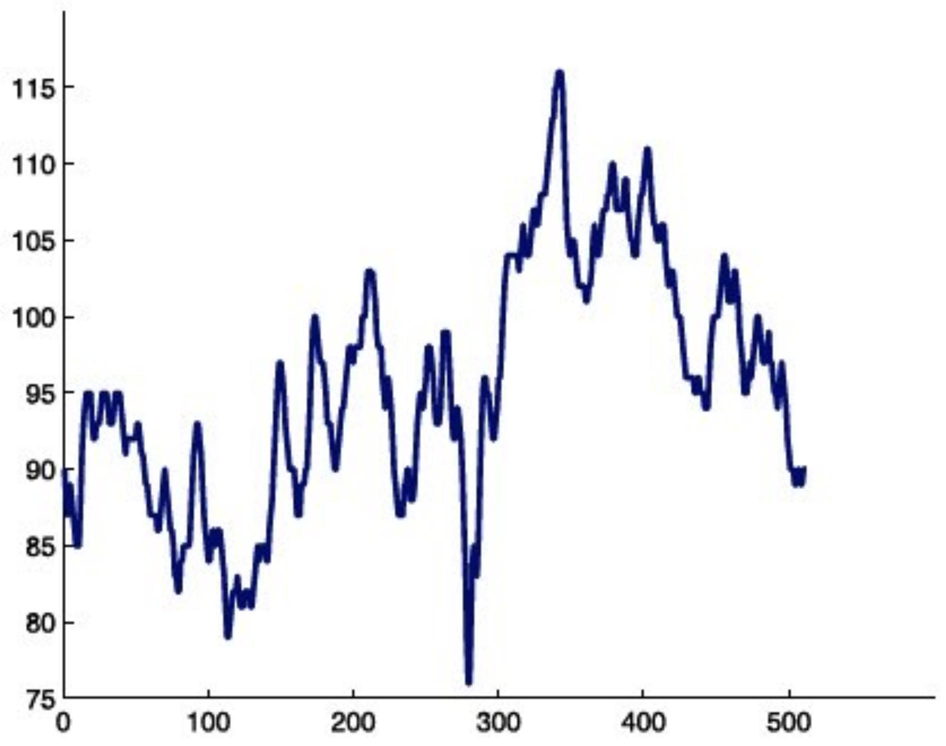
LOYOLA UNIVERSITY CHICAGO

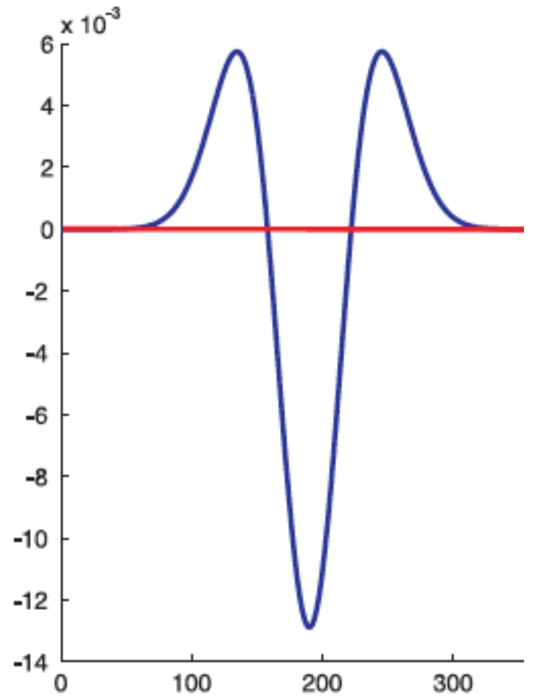
# Feature Extraction

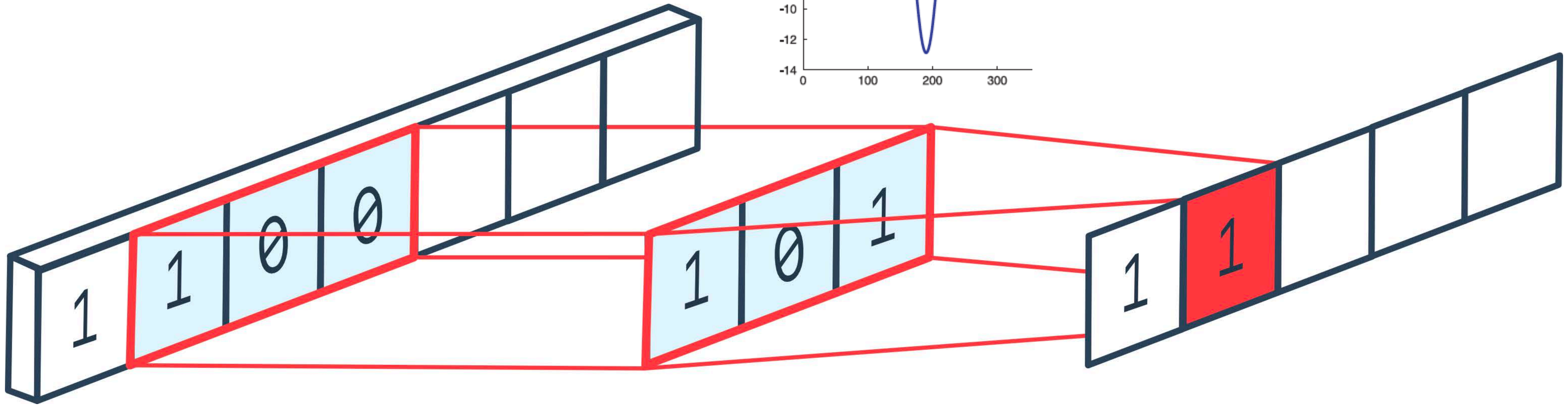
## Zero-Crossing Approach (1/3)

1. Iris signature is filtered by Laplacians of Gaussians (LoG) (second derivative of Gaussian).

1D Convolution

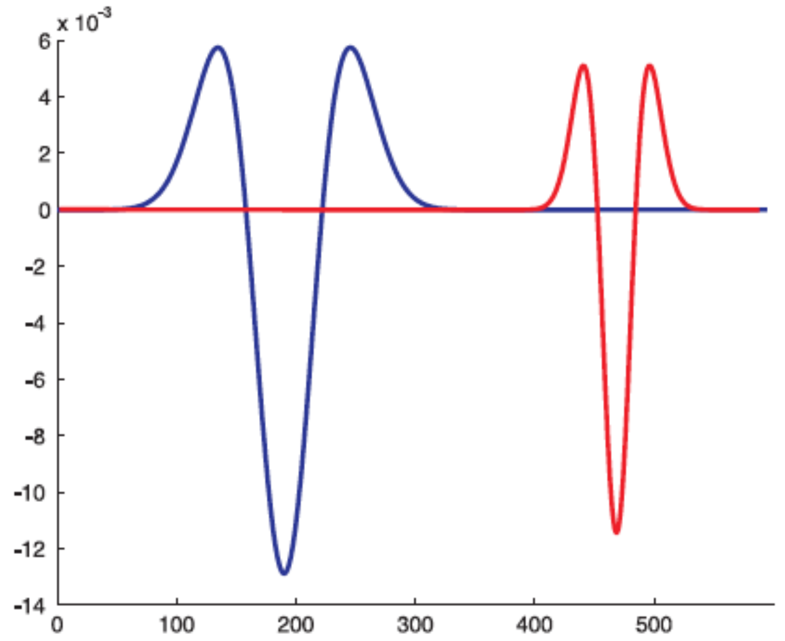


# Feature Extraction

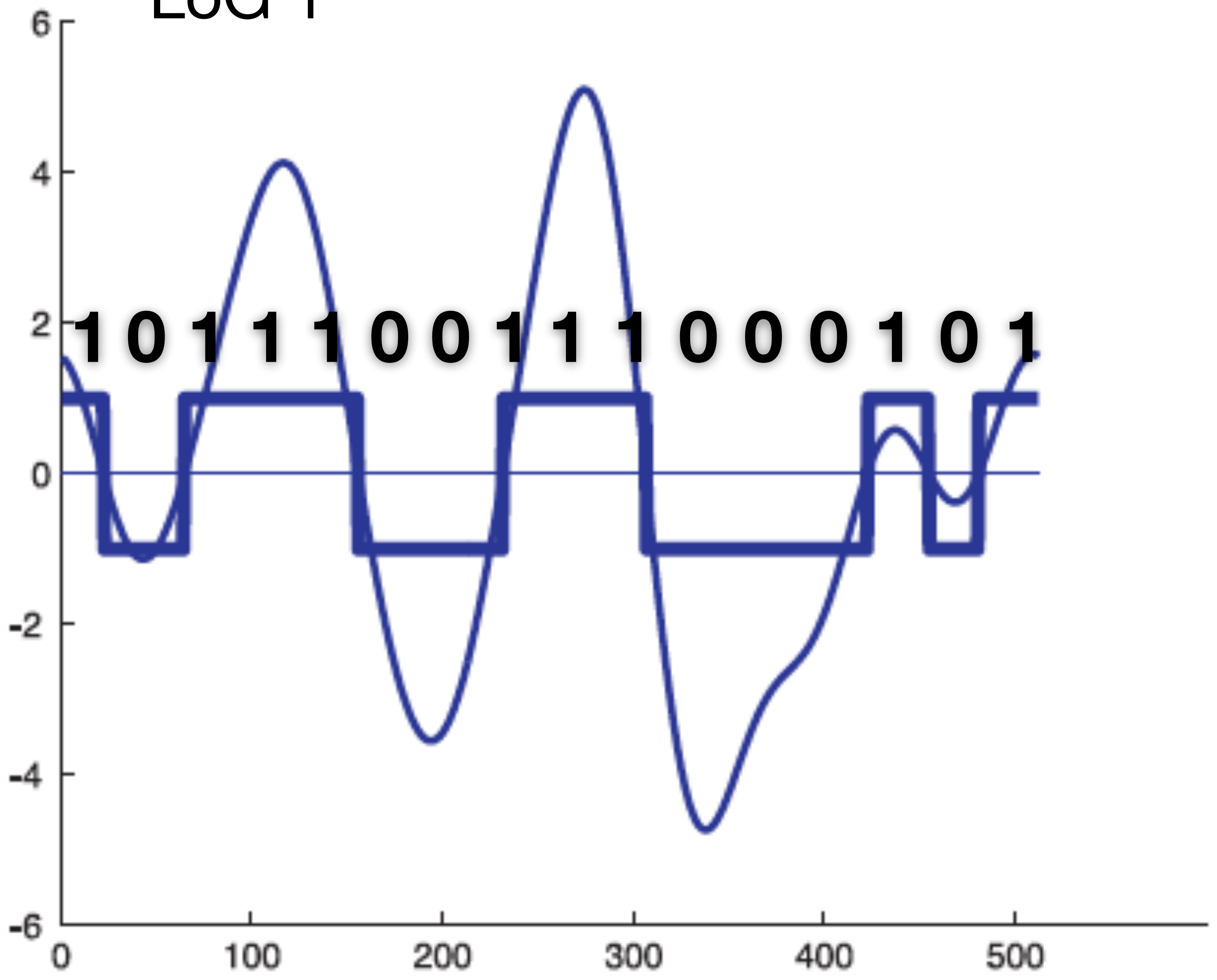
LoG 1 LoG 2



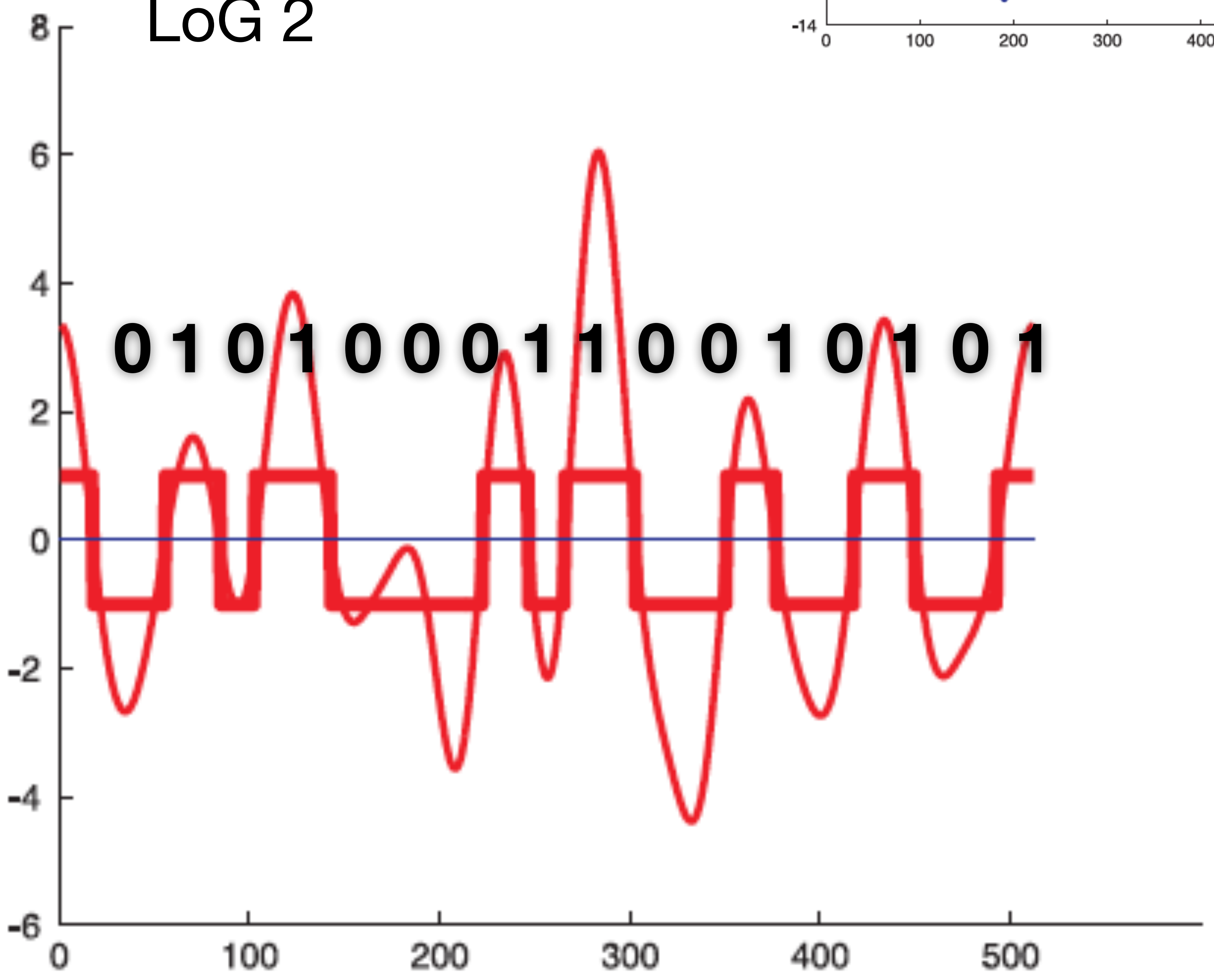
## Zero-Crossing Approach (1/3)

2. Zero-crossings lead to bits up; everything else is zero.

LoG 1




LoG 2

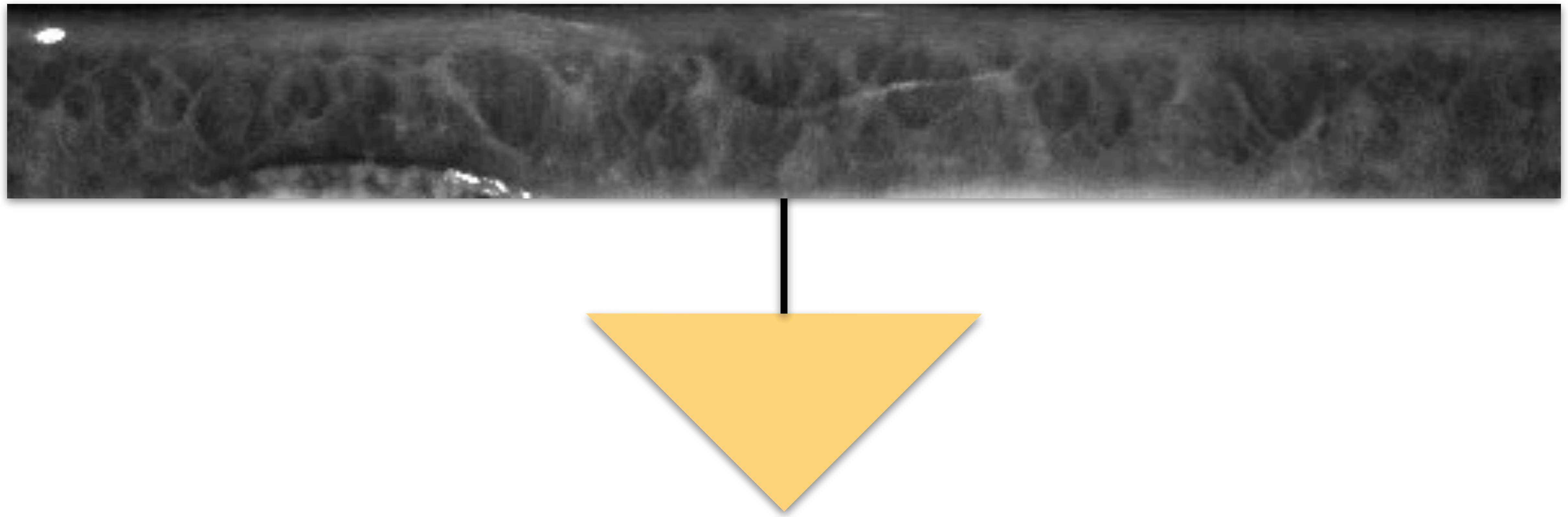



Dr. Adam Czajka

LOYOLA UNIVERSITY CHICAGO

# Feature Extraction

## Zero-Crossing Approach (1/3)



LoG 1 LoG 2

**1 0 1 1 1 0 0 1 1 1 0 0 0 1 0 1   0 1 0 1 0 0 0 1 1 0 0 1 0 1 0 1** concatenation

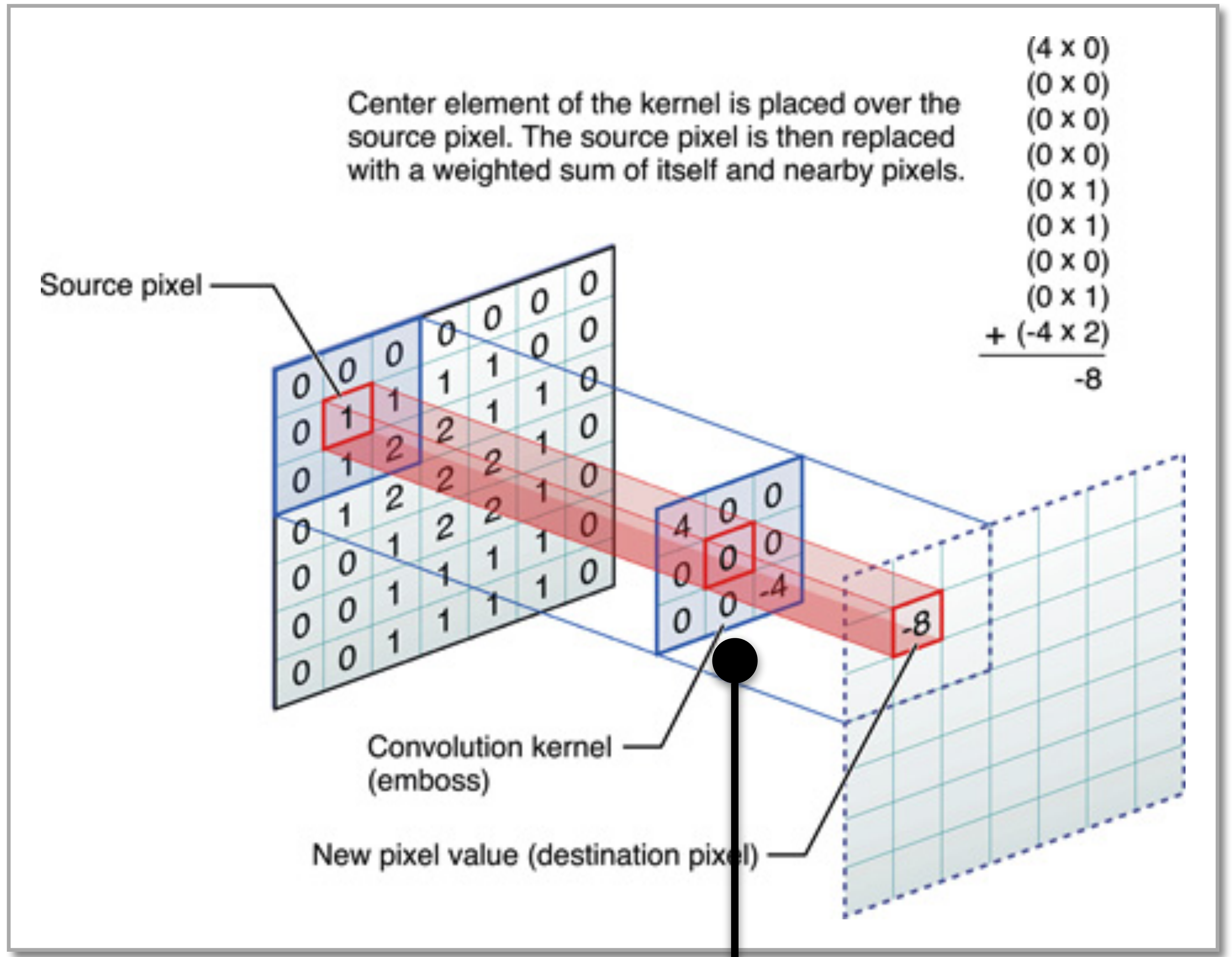
LOYOLA UNIVERSITY CHICAGO

# Feature Extraction

**2D-Gabor Filtering Approach (2/3)**
Proposed by John Daugman.

*De facto* iris description solution.
More complete and robust than zero-crossing.

2D Gabor filters are convolved with the normalized iris image.




Source:https://developer.apple.com/library/archive/documentation/Performance/Conceptual/vImage/ConvolutionOperations/ConvolutionOperations.html

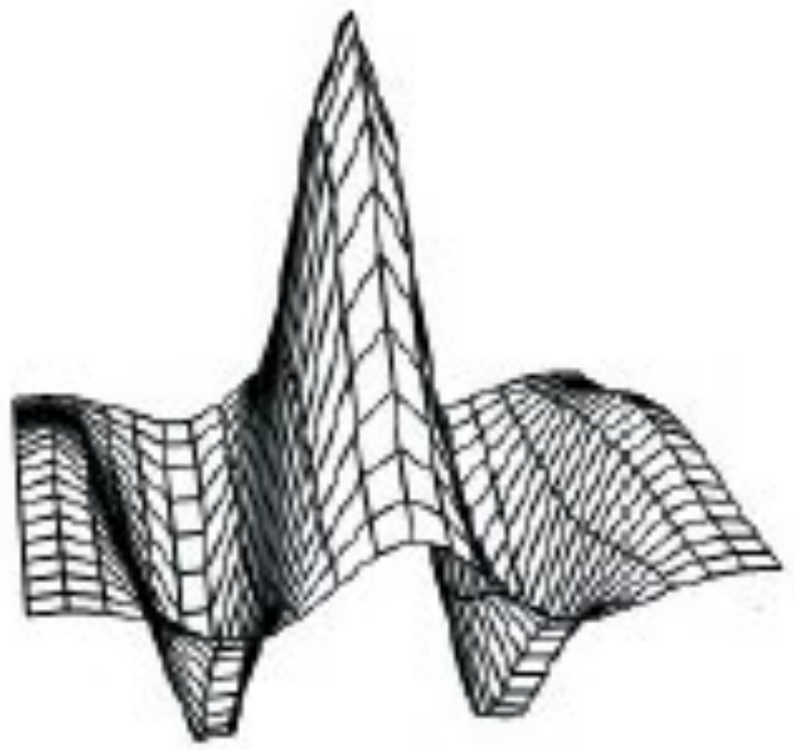
# Feature Extraction

**2D-Gabor Filtering Approach (2/3)**
Proposed by John Daugman.

*Empirical* selection of a proper Gabor wavelet (adequate to encode iris texture).

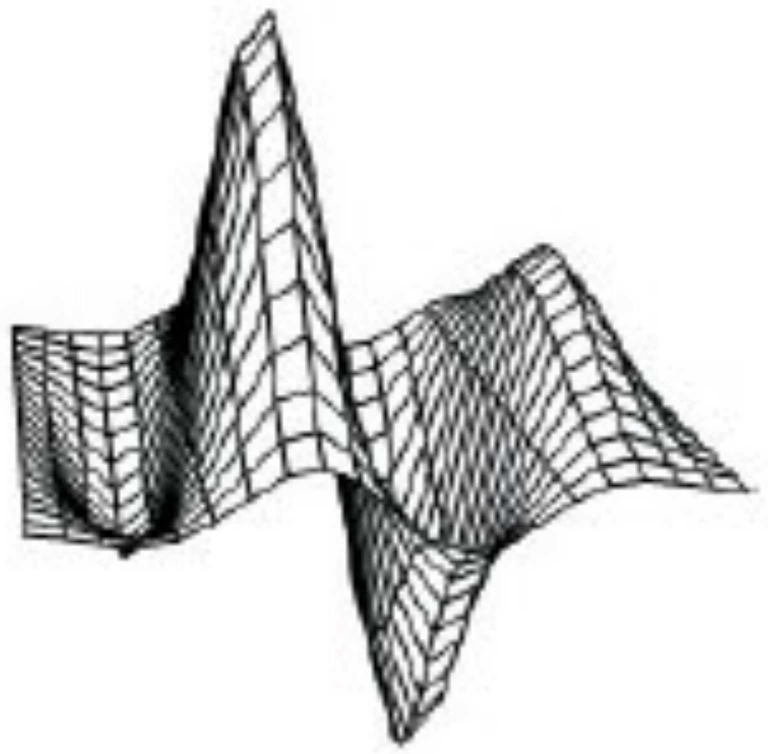
Gabor wavelets are a good model of neural receptive fields found in the visual cortex.

Filter 1



wavelet real component

Filter 2



wavelet imaginary component

J. Daugman
*Probing the Uniqueness and Randomness of IrisCodes: Results from 200 Billion Iris Pair Comparisons.*
IEEE Proceedings, 2006

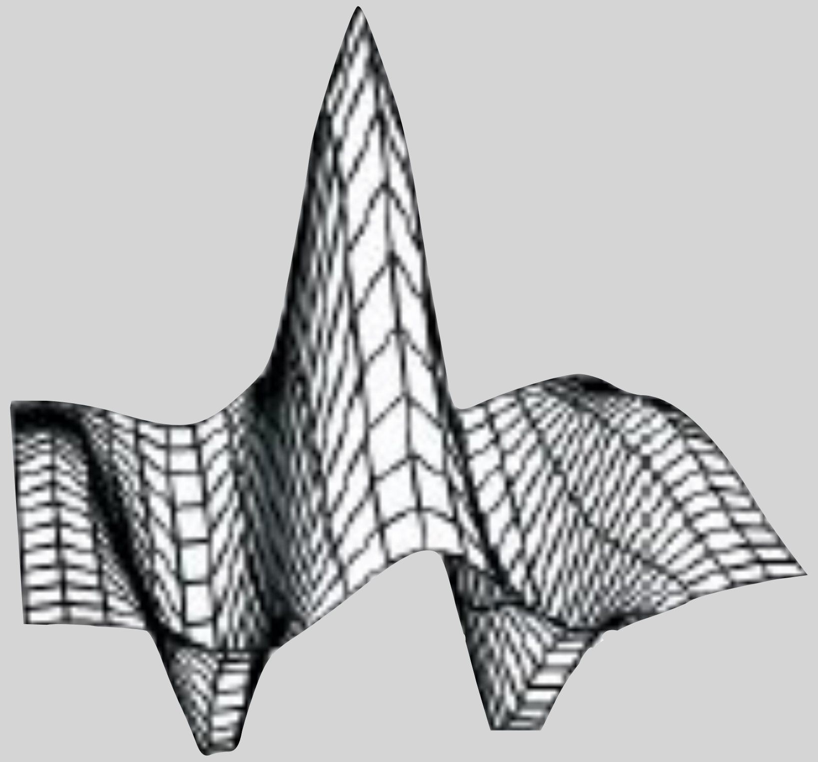
LOYOLA UNIVERSITY CHICAGO

# Feature Extraction

## 2D-Gabor Filtering Approach (2/3)

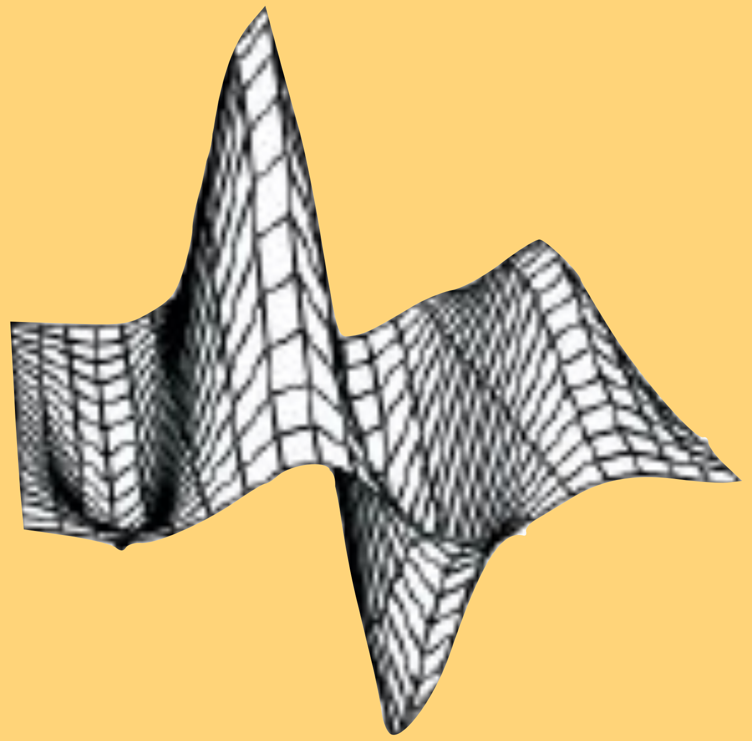
Jain, Ross, and Nadakumar
*Introduction to Biometrics*
Springer Books, 2011

Filter 1



wavelet real component

Filter 2



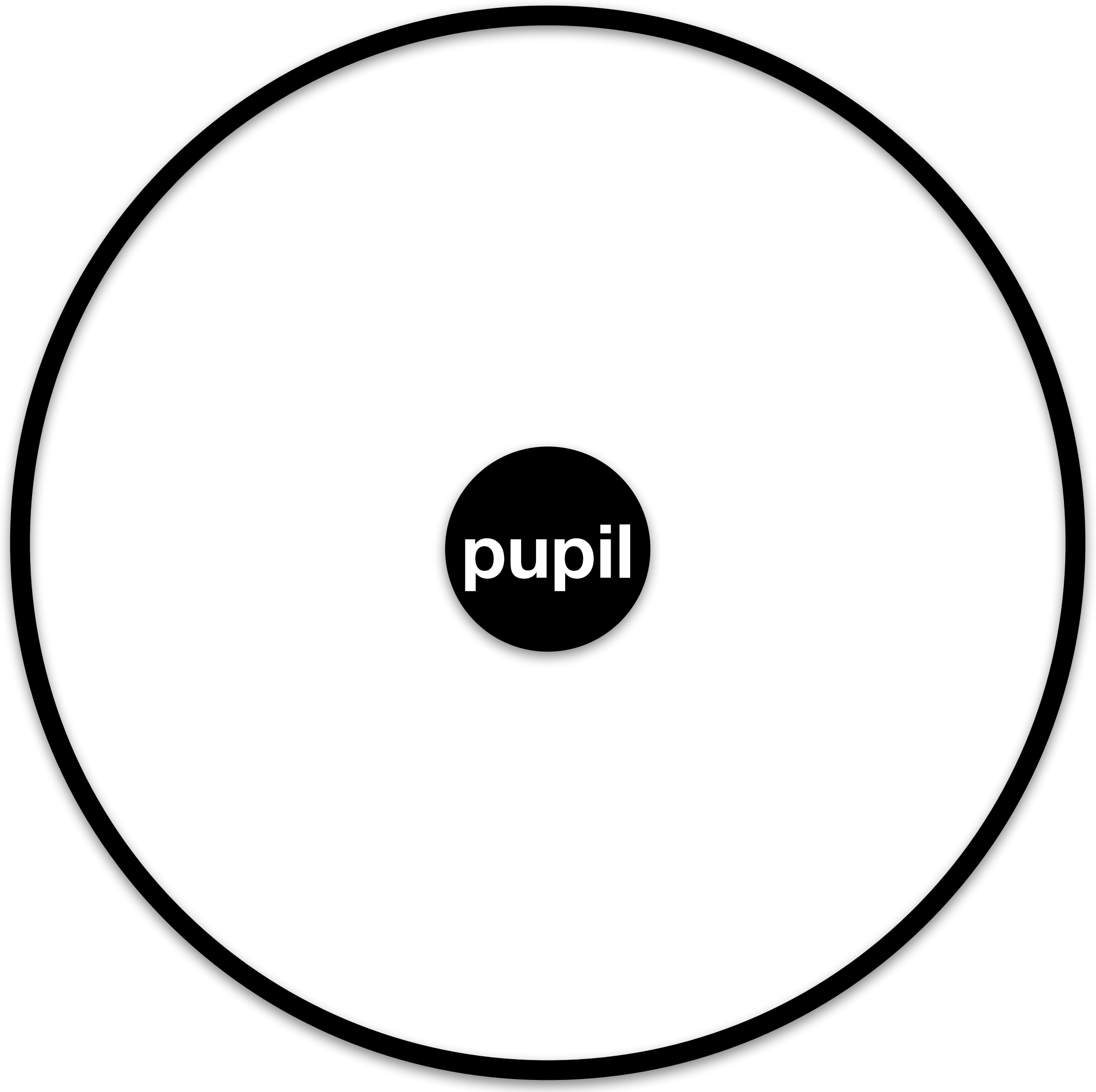
wavelet imaginary component

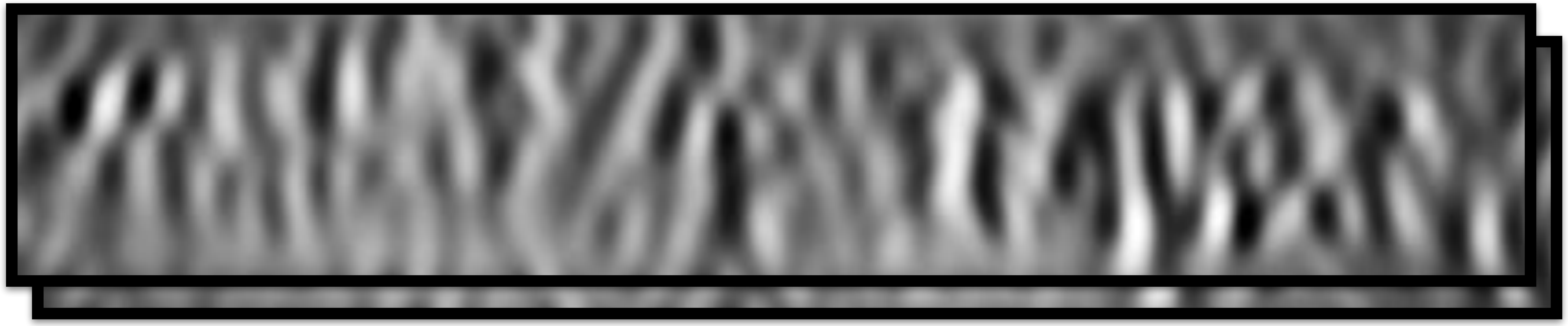


LOYOLA UNIVERSITY CHICAGO

# Feature Extraction

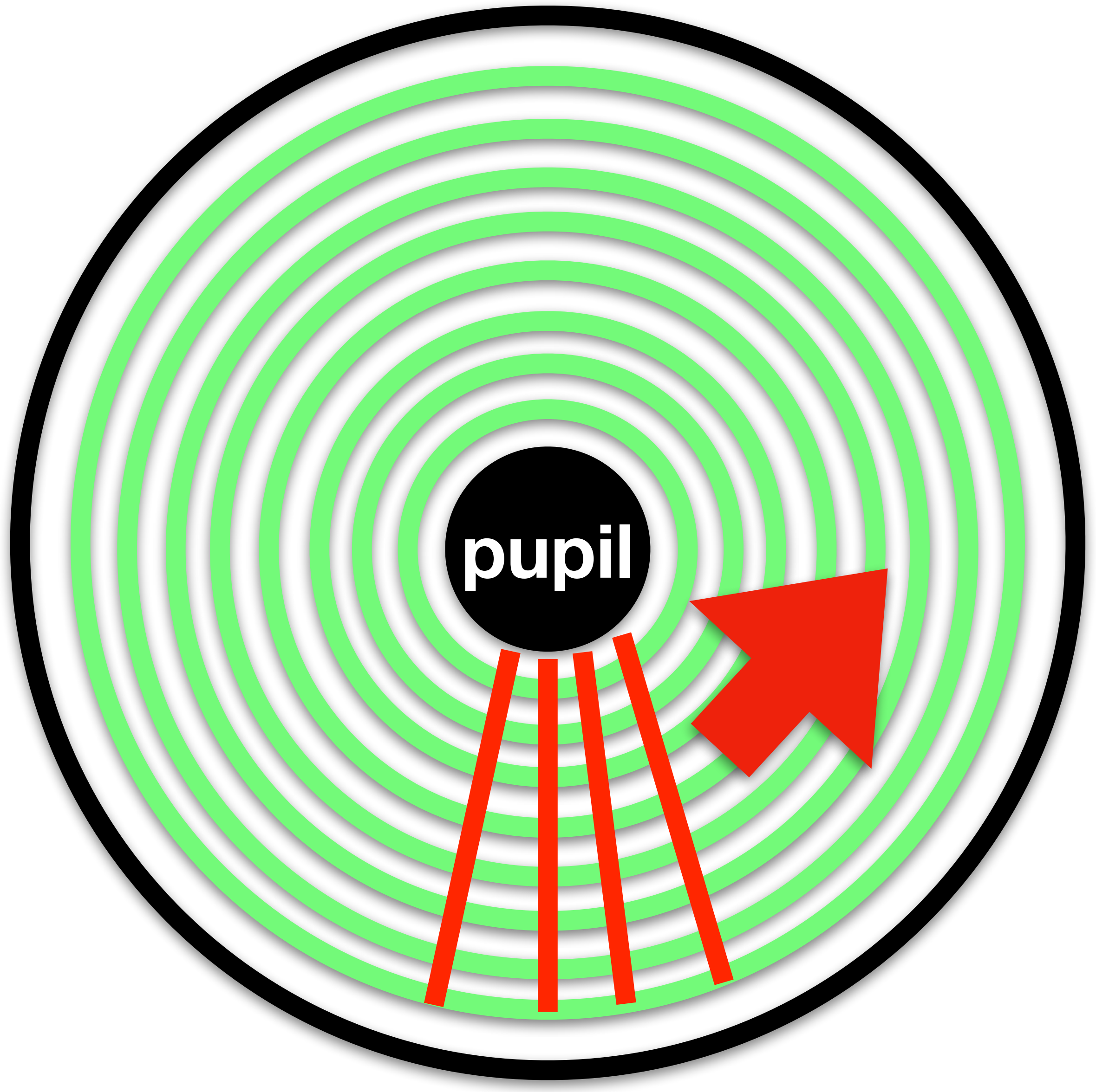
**2D-Gabor Filtering Approach (2/3)**

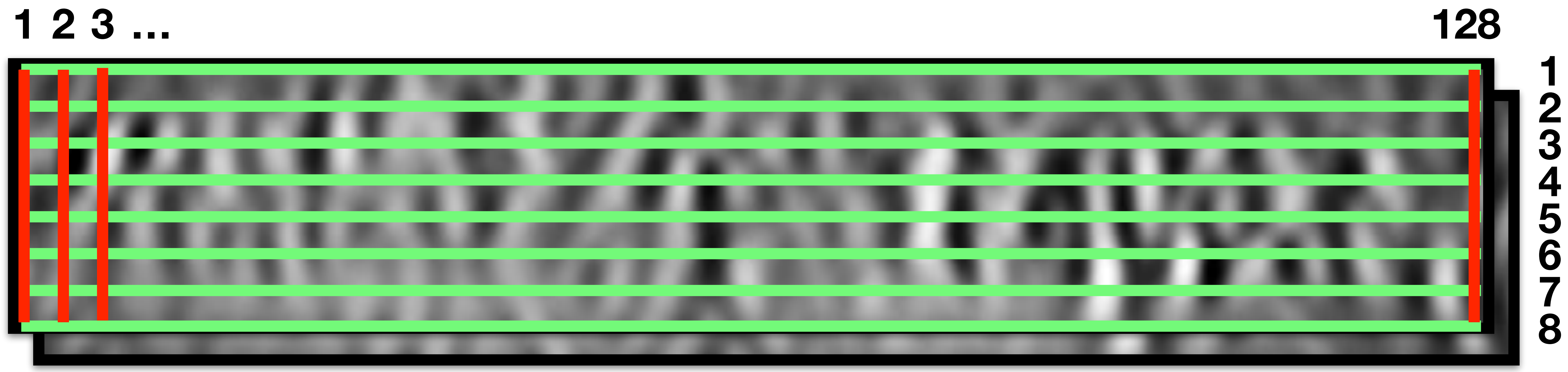


# Feature Extraction

## 2D-Gabor Filtering Approach (2/3)

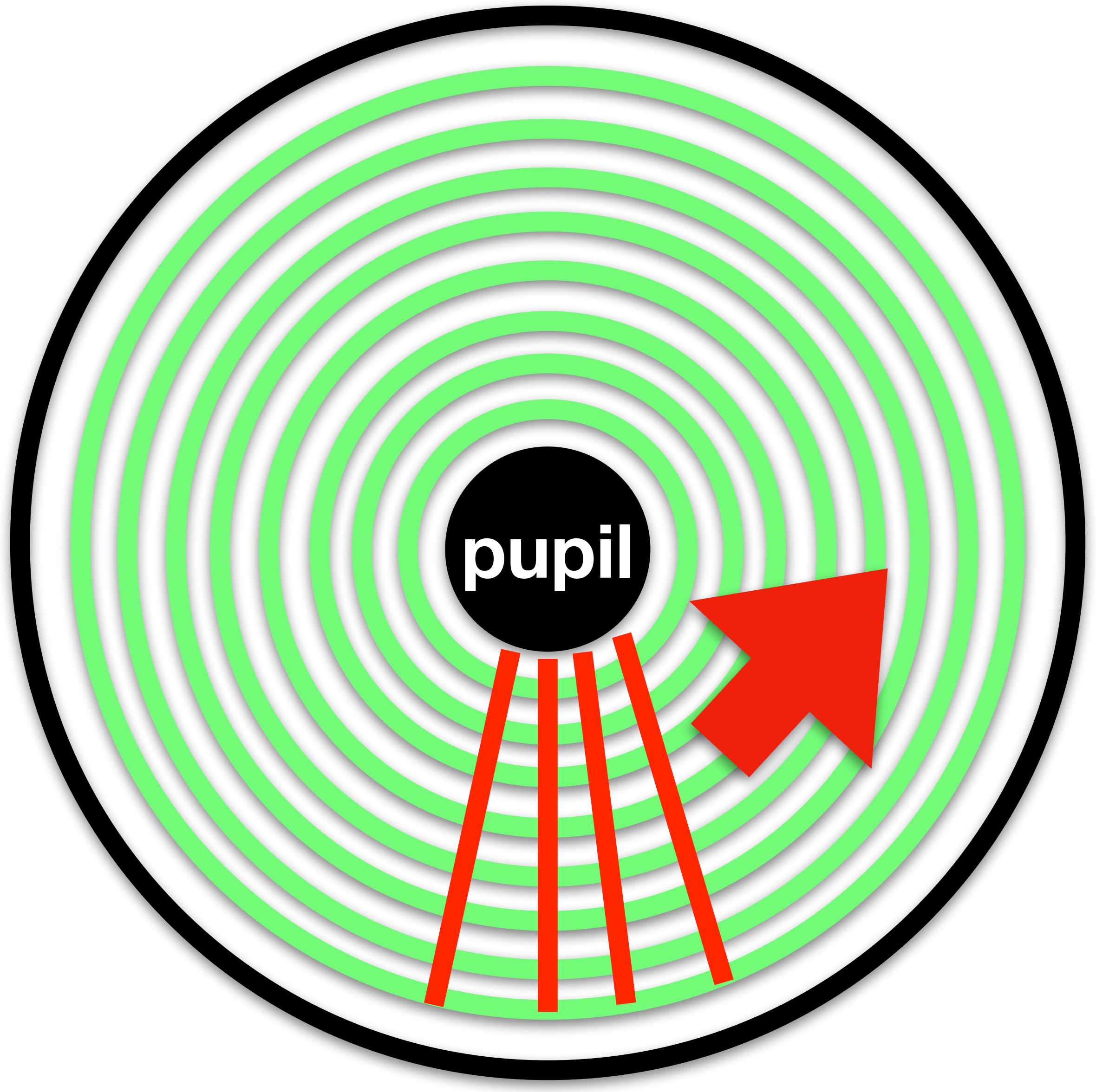


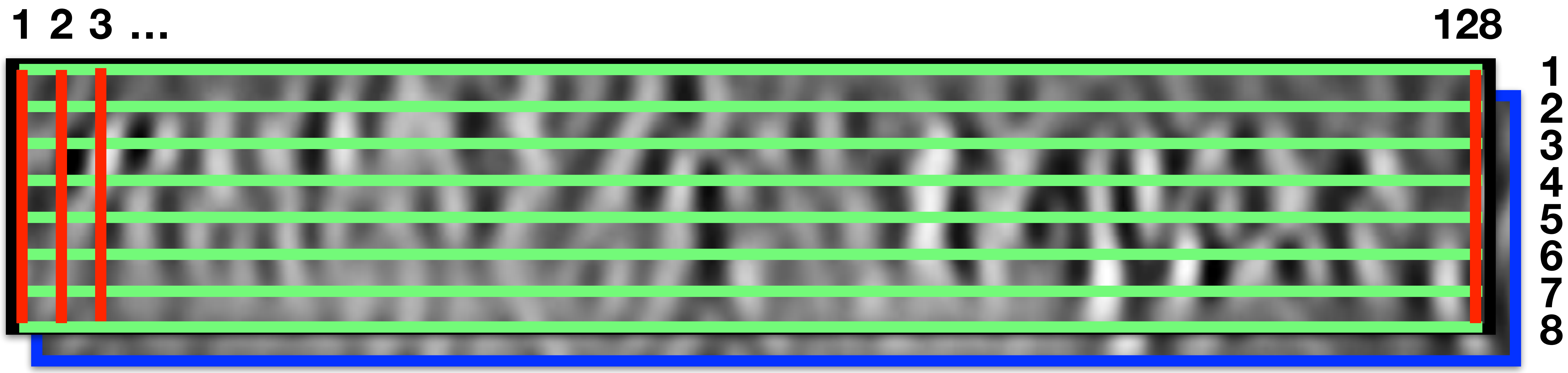




Number of cells: 8 x 128 = 1024

# Feature Extraction

**2D-Gabor Filtering Approach (2/3)**




Number of cells: 8 x 128 = 1024 **x 2 = 2048**



LOYOLA UNIVERSITY CHICAGO

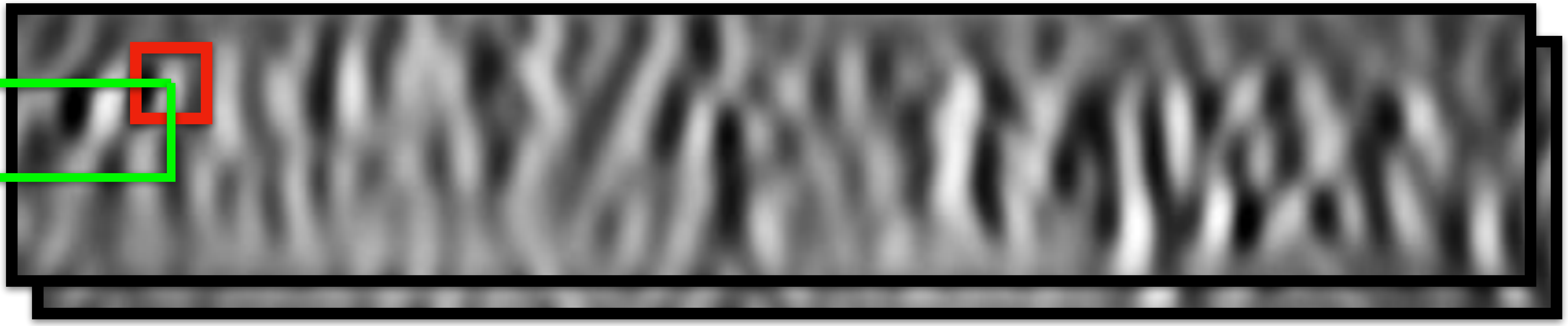
# Feature Extraction

**2D-Gabor Filtering Approach (2/3)**

Take one cell…

positive value: bit 1

negative value: bit 0

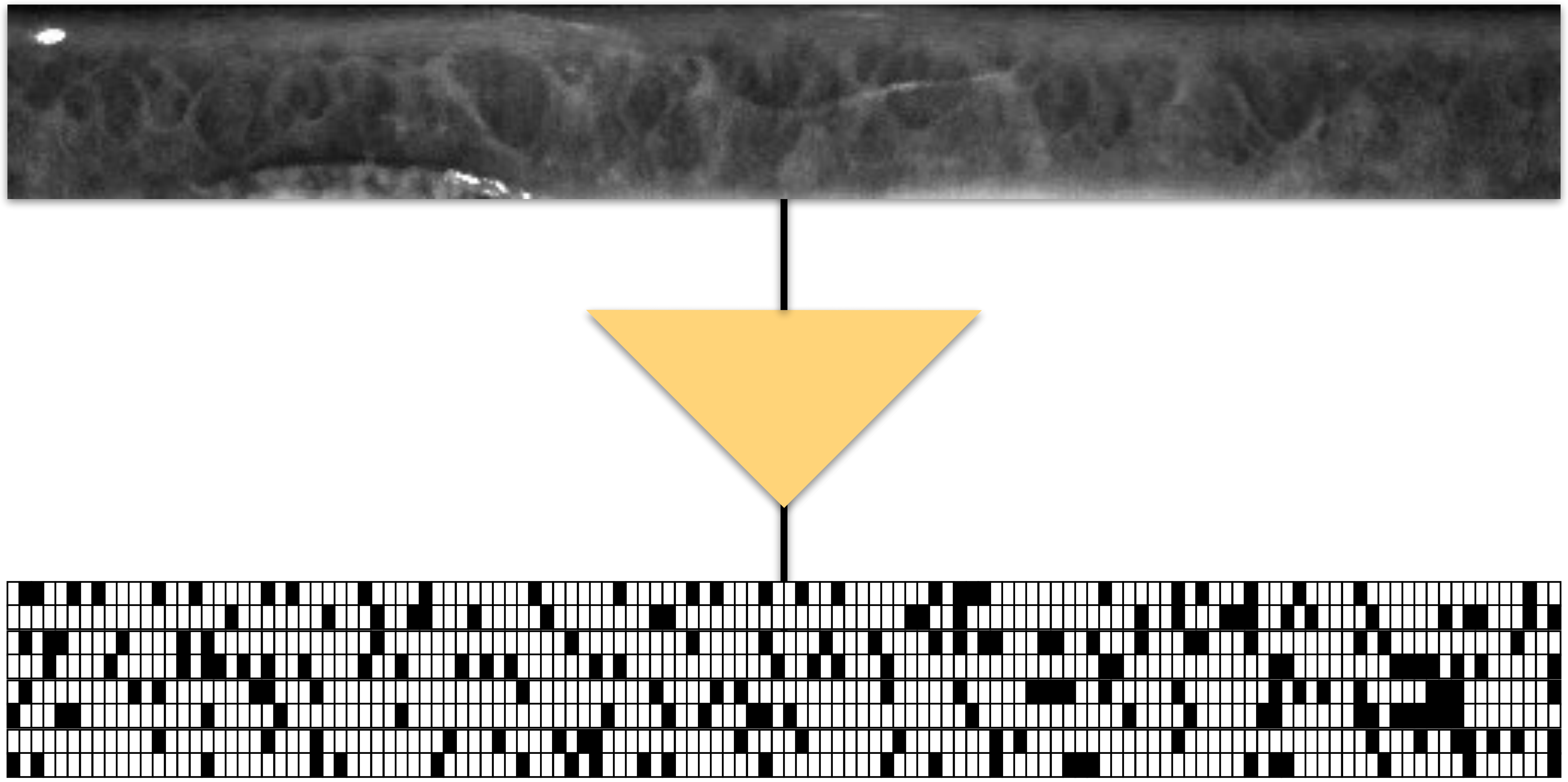


Number of cells: 8 x 128 = 1024 x 2 = 2048

2048 bits

# Feature Extraction

## 2D-Gabor Filtering Approach (2/3)



**2048 bits**
**IrisCode**

# Feature Extraction

**BSIF Approach (3/3)**

**Binarized Statistical Image Features (BSIF)**
General-purpose local image descriptors designed for texture encoding.

Kannala and Rahtu
*BSIF: Binarized Statistical Image Features*
ICPR 2012

Examples of textures that one might one to describe.



LOYOLA UNIVERSITY CHICAGO

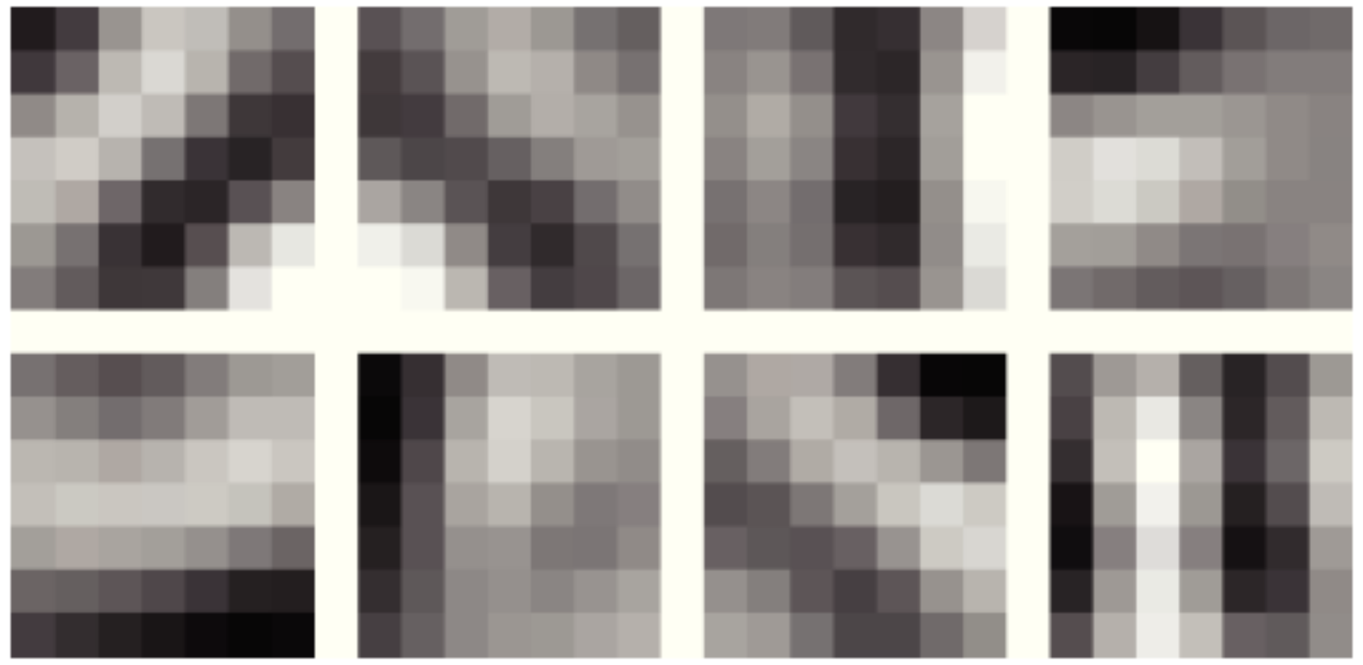
# Feature Extraction

## BSIF Approach (3/3)

**Binarized Statistical Image Features (BSIF)**
Subspaces of representative image patches (further used as filters) are learned from a set of example patches through *Independent Component Analysis* (ICA).

ICA: *N* filters of size *l x l* are estimated from examples by maximizing their mutual statistical independence.

Kannala and Rahtu
*BSIF: Binarized Statistical Image Features*
ICPR 2012



Eight filters of size 9x9 pixels that better represent patches of size 9x9. Computed with ICA.

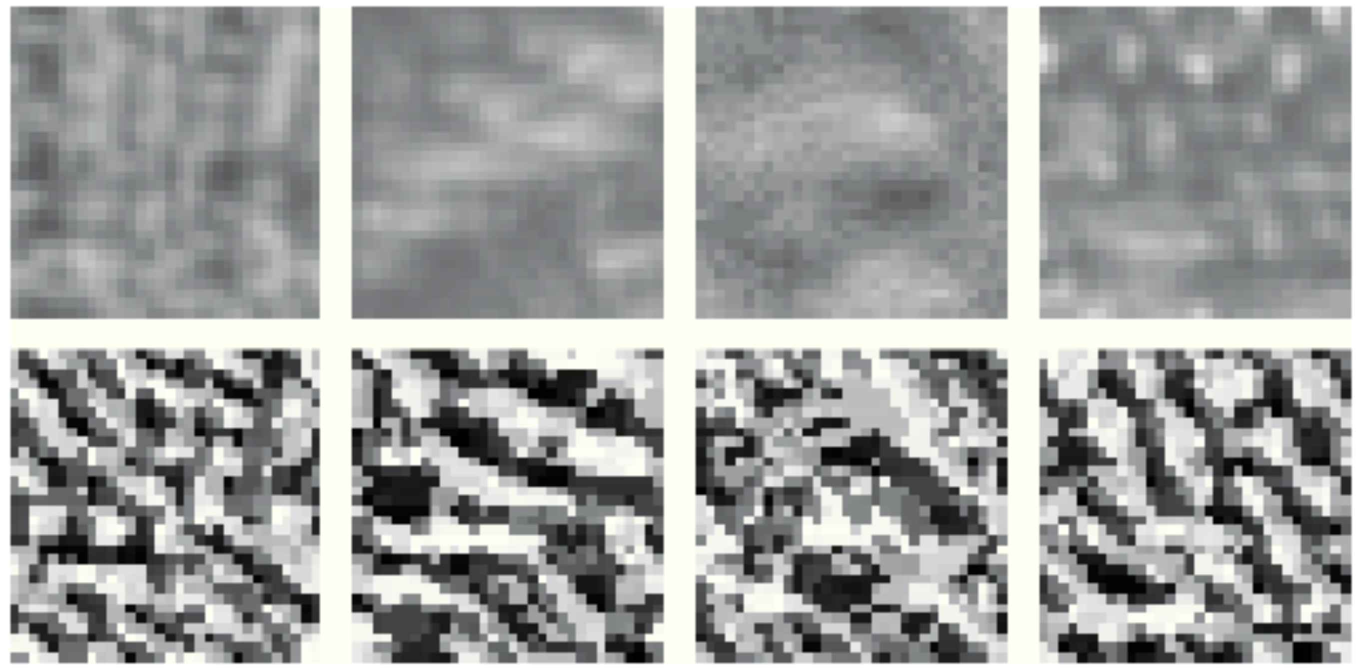
# Feature Extraction

## BSIF Approach (3/3)

**Binarized Statistical Image Features (BSIF)**
Images are convolved with each BSIF filter leading to various projections in the target subspace.

BSIF code: a threshold is used to make the image projections binary; anything above zero is ONE, everything else is ZERO.

Kannala and Rahtu
*BSIF: Binarized Statistical Image Features*
ICPR 2012



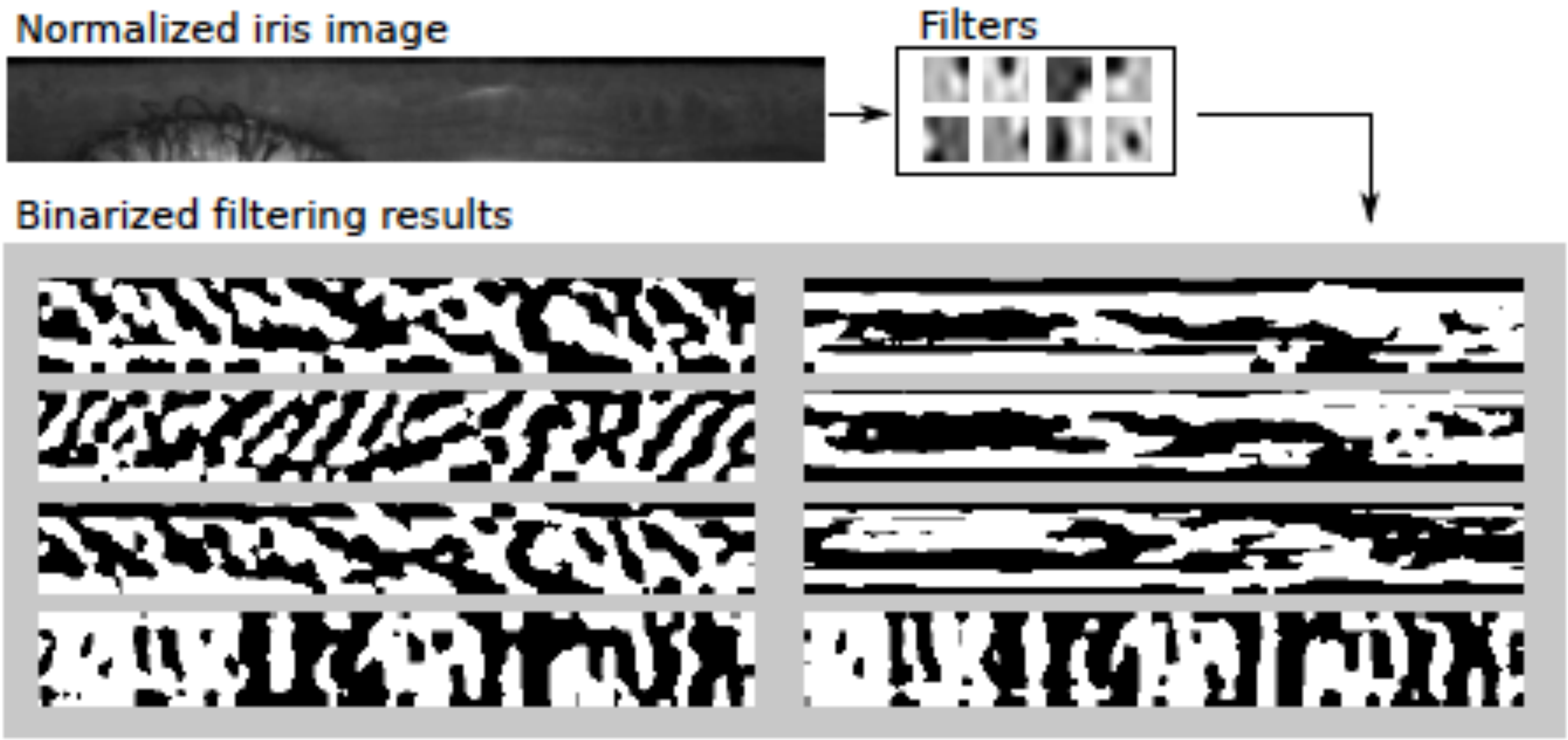
BSIF code examples

# Feature Extraction

**BSIF Approach (3/3)**
In the case of irises…

Solution's performance is on par with the Gabor-based one.

Czajka et al.
*Domain-Specific Human-Inspired Binarized Statistical Image Features for Iris Recognition*
WACV 2019



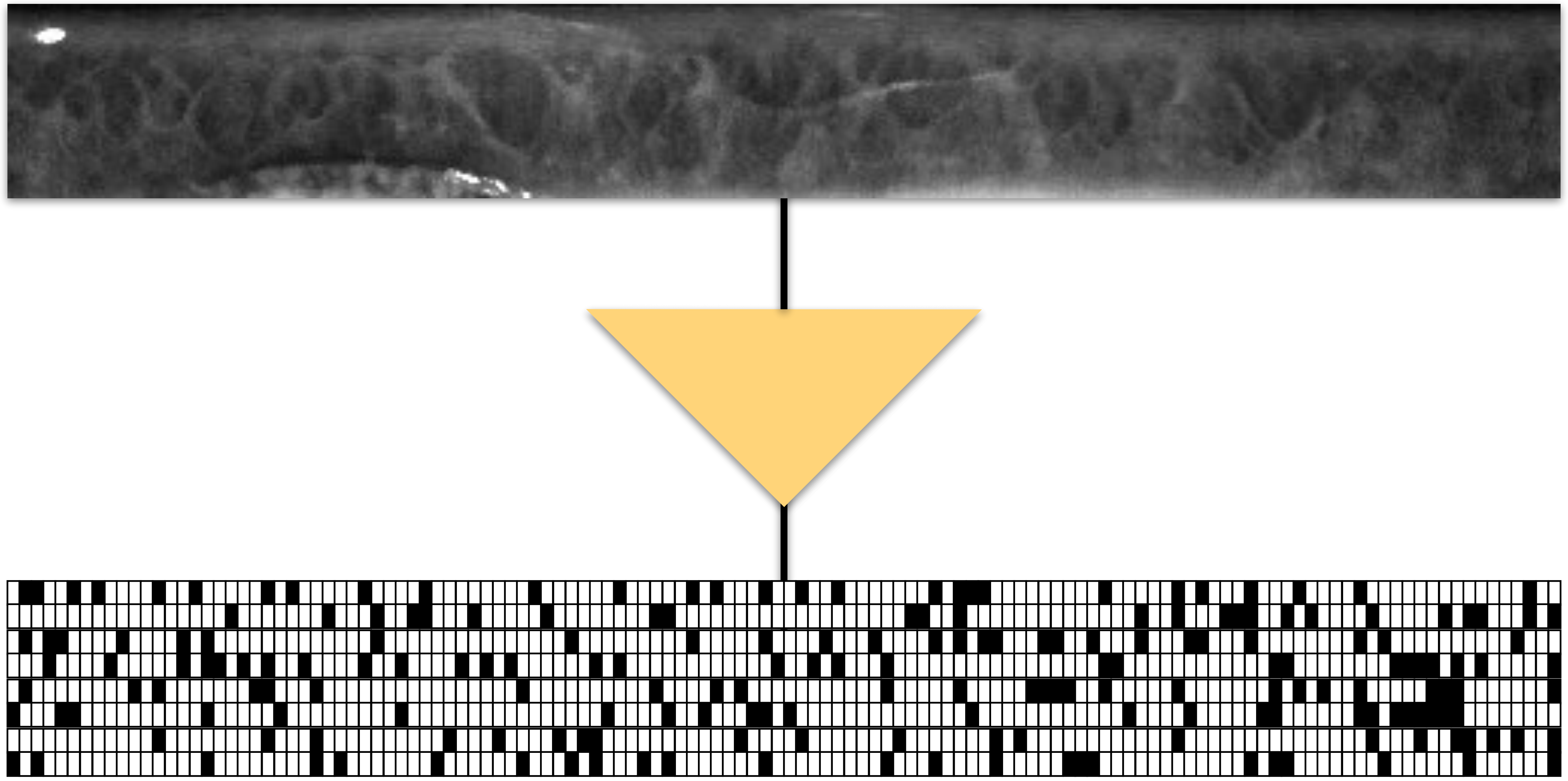



LOYOLA UNIVERSITY CHICAGO

# Feature Extraction

**BSIF Approach (3/3)**

In the case of irises…

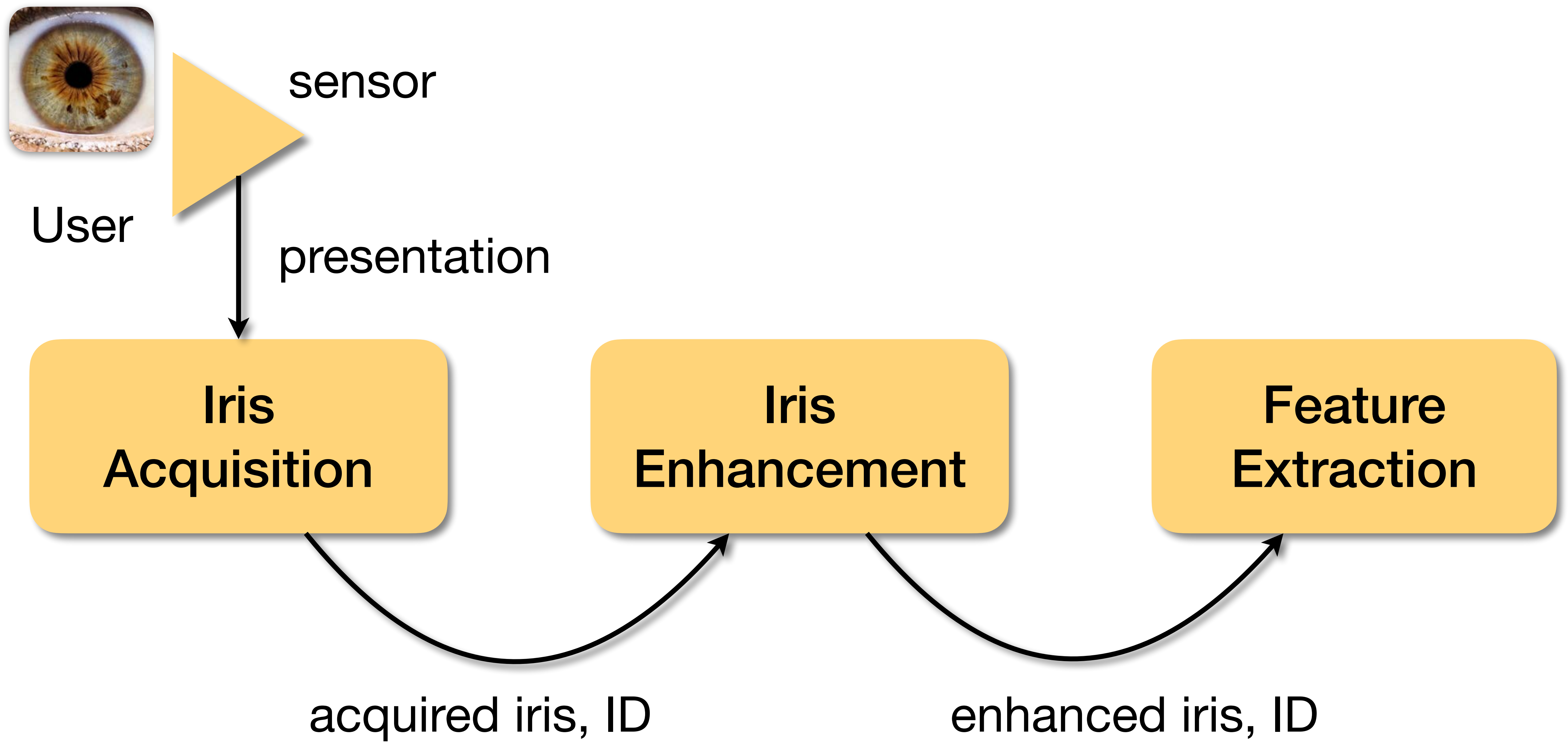


**BSIF Code**

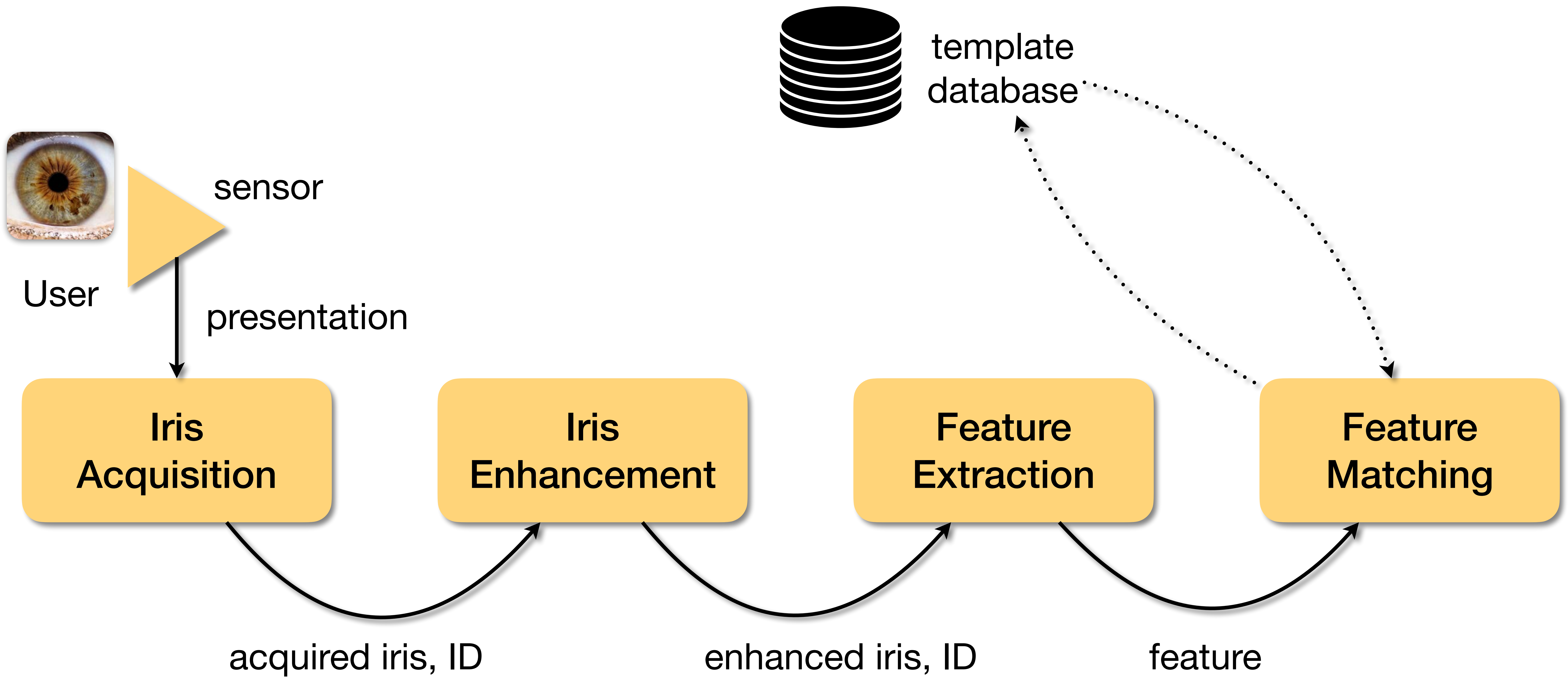


LOYOLA UNIVERSITY CHICAGO

# Iris Recognition



# Iris Recognition



# Feature Matching

**How to Compare Binary Codes?**

Use Hamming distance.

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| iris 1 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 1 |
| iris 2 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 0 |
| XOR | | | | | | | | | | | | | | | | |

Distance = sum( 1 0 0 0 1 0 0 0 1 0 0 1 1 0 0 1 ) = 6



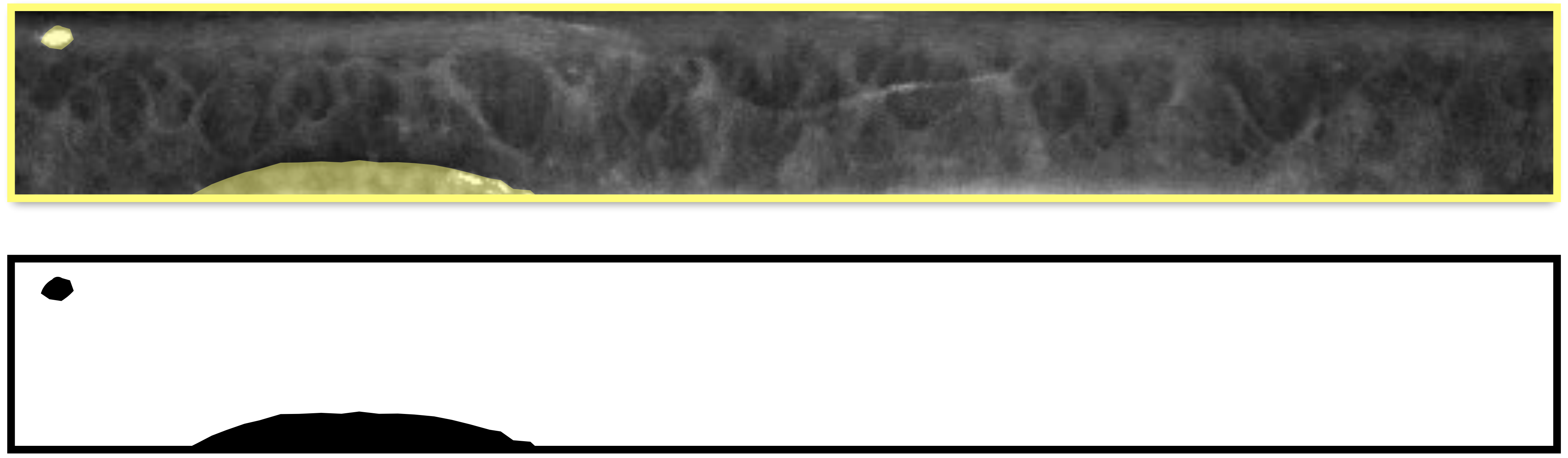
LOYOLA UNIVERSITY CHICAGO

# Feature Matching

**How to Compare Binary Codes?**

**Problems (1/2)**
How to consider iris masks?

Iris 1



Mask 1

Iris 2

Mask 2

# Feature Matching

**How to Compare Binary Codes?**

**Problems (1/2)**
How to consider iris masks?
Solution: Normalized Hamming Distance

$I_1$: cells from iris 1
$I_2$: cells from iris 2
$M_1$: cells from mask 1
$M_2$: cells from mask 2

$$dist = \frac{bitwise\_sum(I_1\ XOR\ I_2\ AND\ M_1\ AND\ M_2)}{bitwise\_sum(M_1\ AND\ M_2)}$$

Only cells considered by both masks are used.

LOYOLA UNIVERSITY CHICAGO

# Feature Matching

**How to Compare Binary Codes?**

**Problems (2/2)**
How to deal with iris rotations?
They happen when heads are tilted…



LOYOLA UNIVERSITY CHICAGO

# Feature Matching

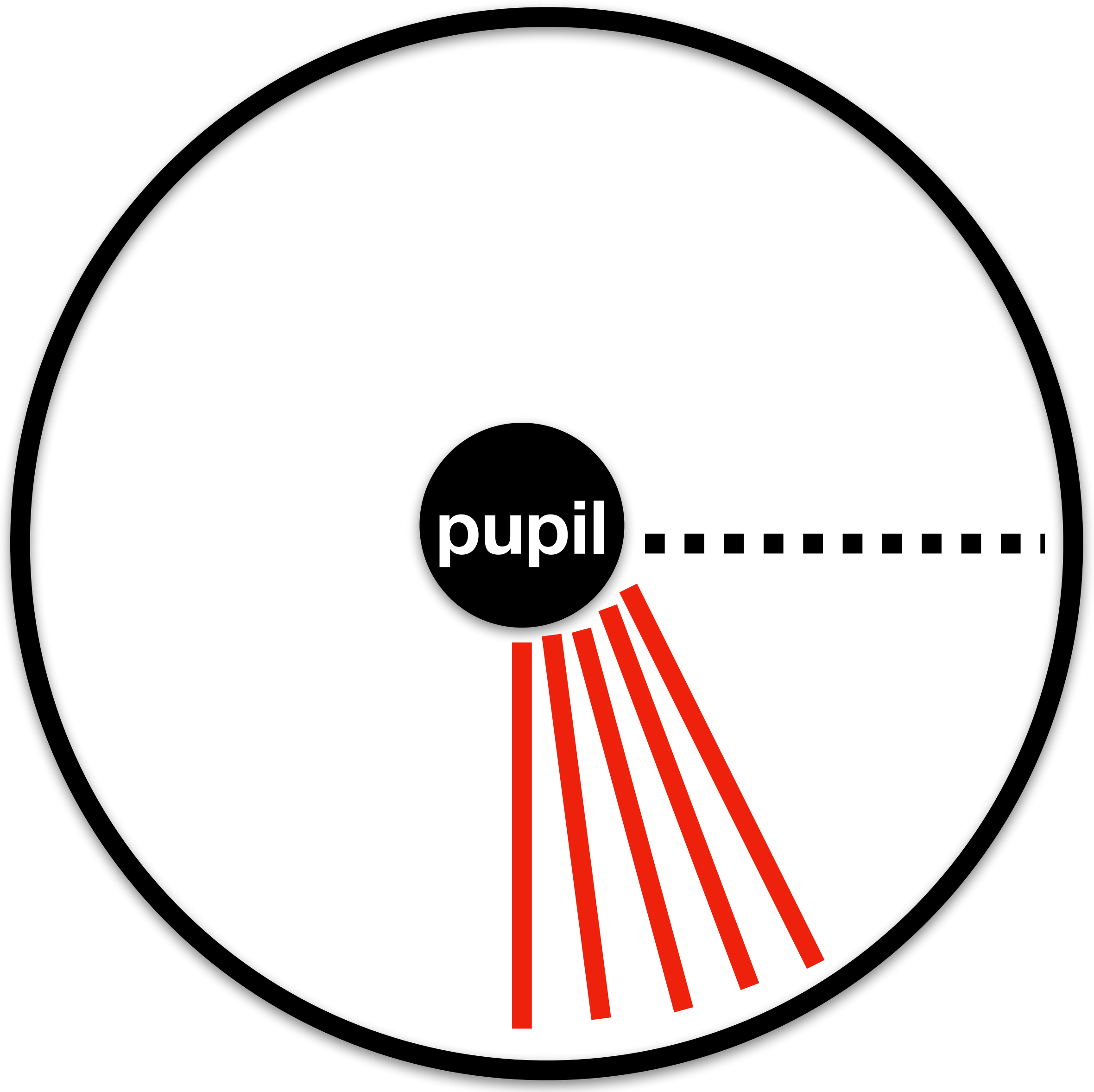
**How to match with iris rotations?**

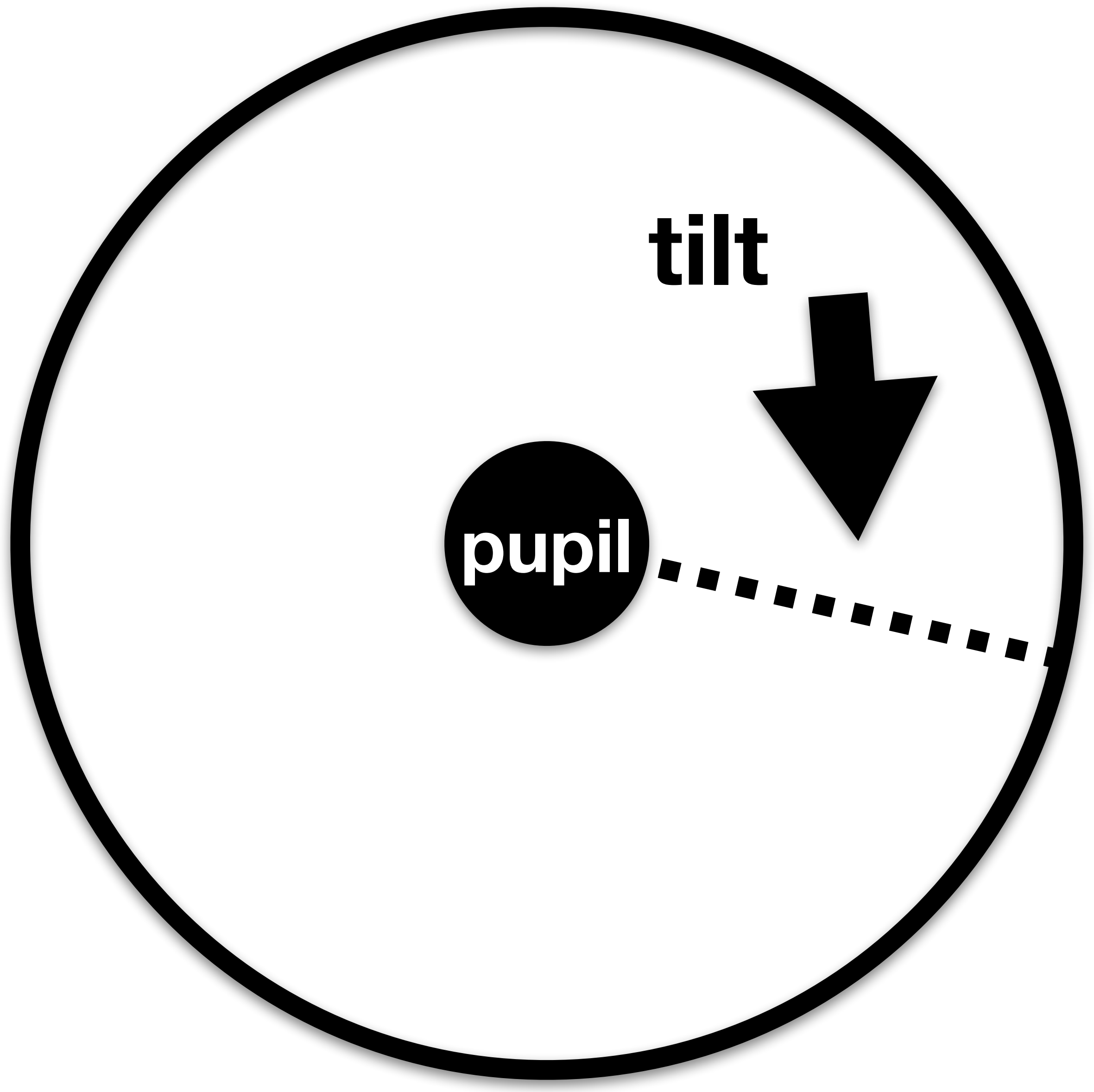



LOYOLA UNIVERSITY CHICAGO

# Feature Matching

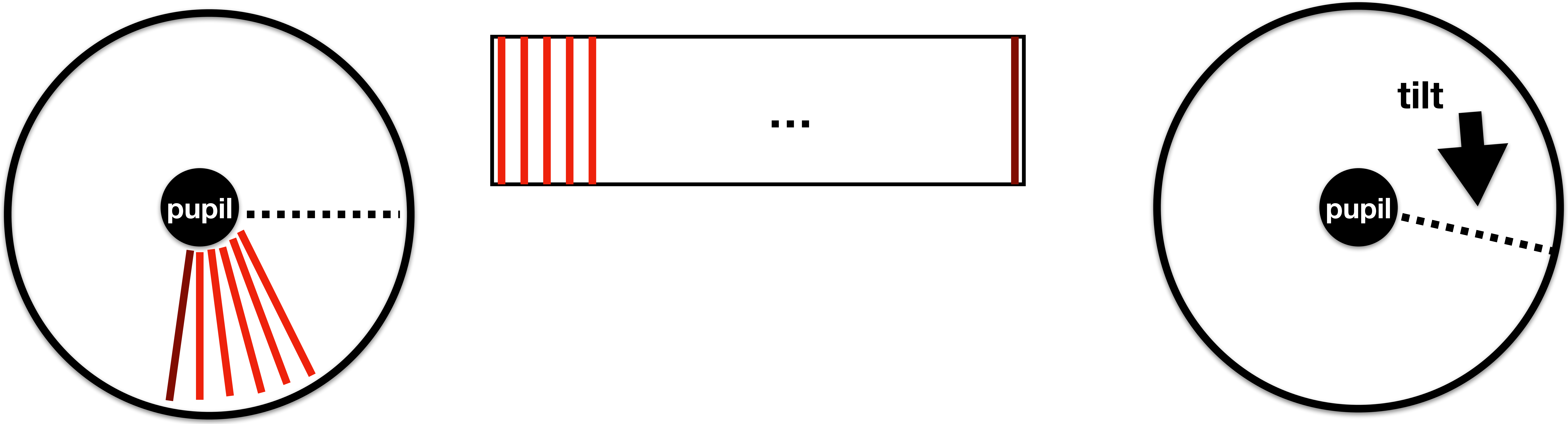
**How to match with iris rotations?**



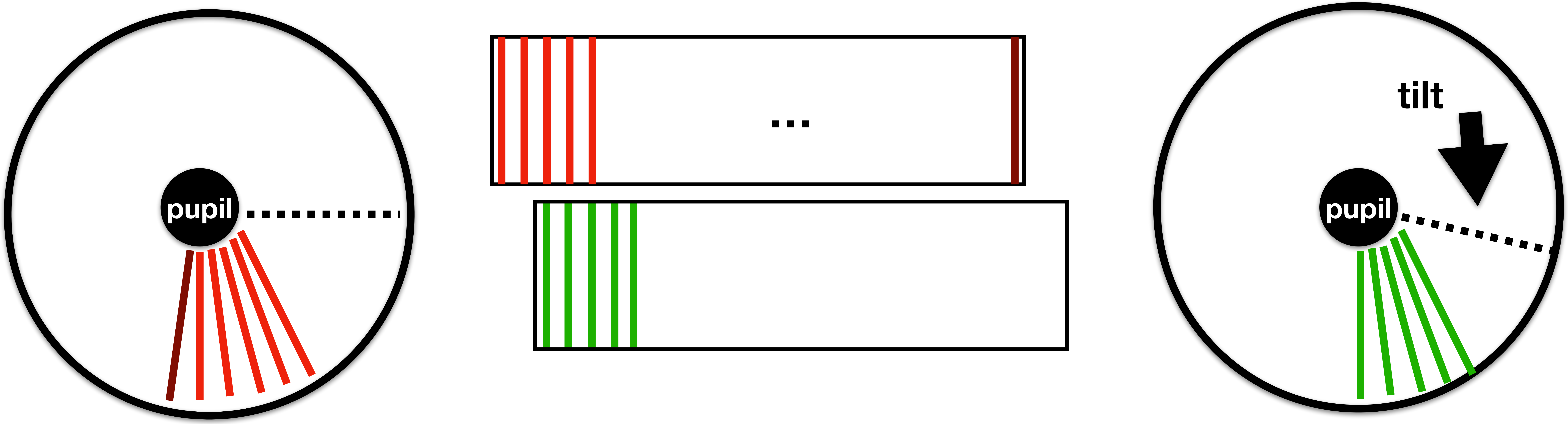
# Feature Matching

**How to match with iris rotations?**



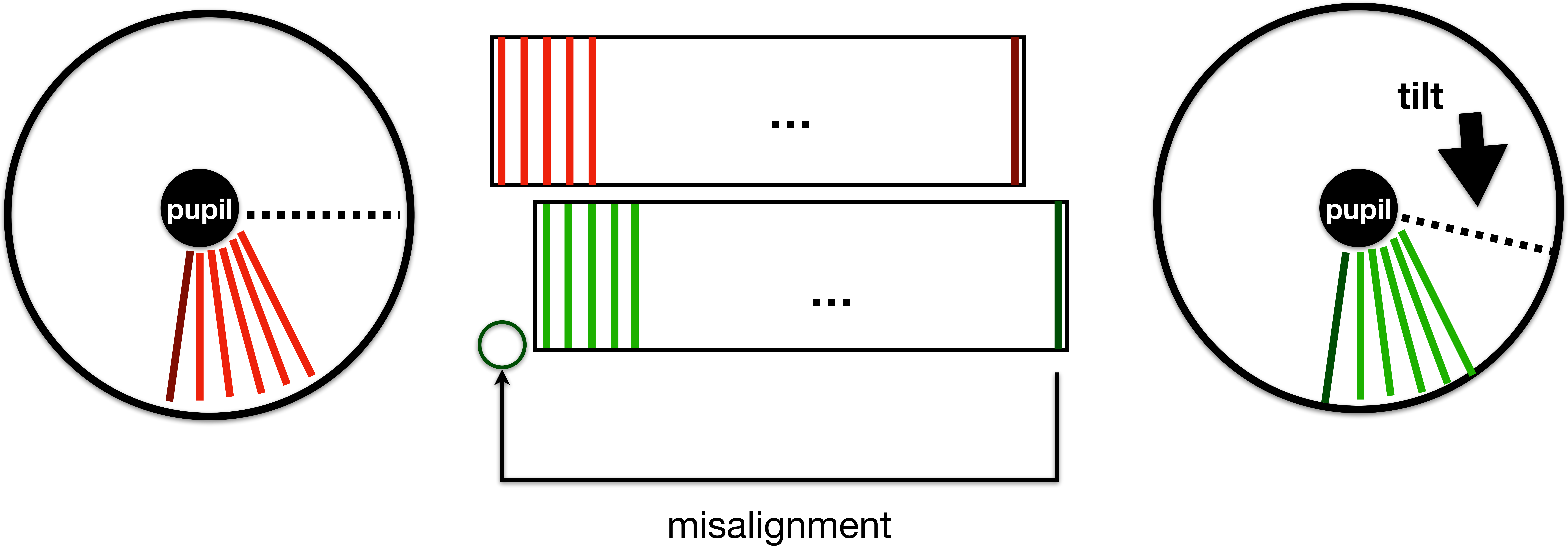
# Feature Matching

**How to match with iris rotations?**



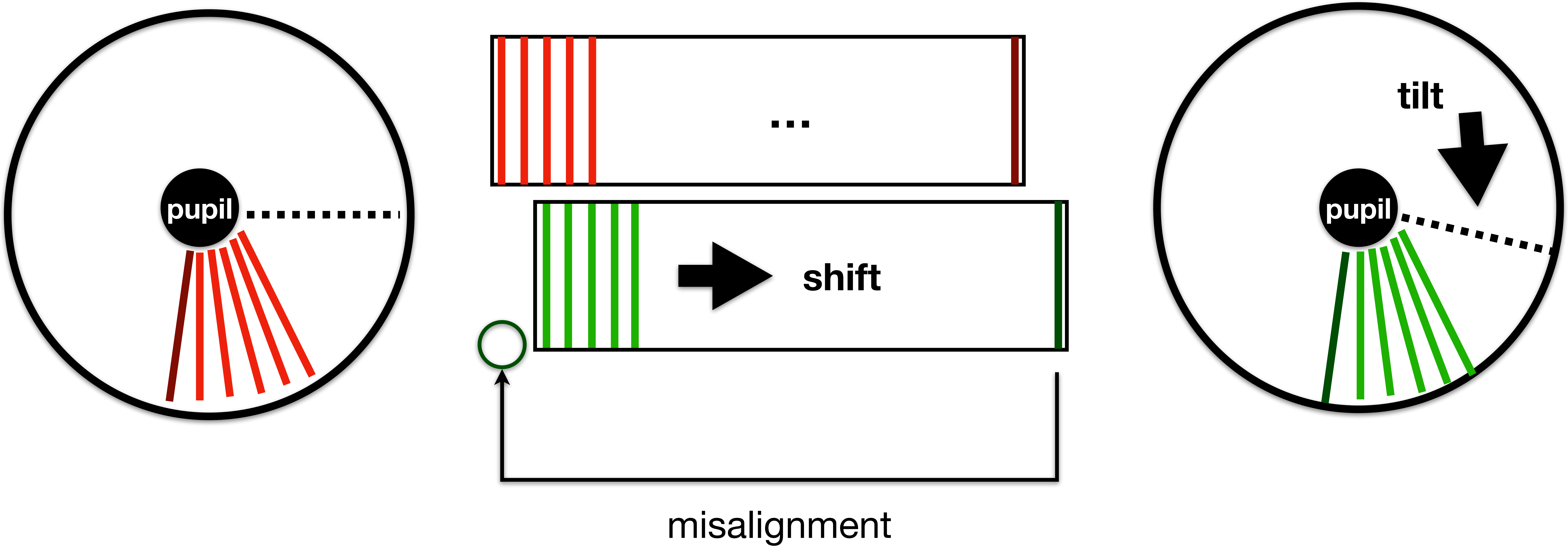
# Feature Matching

**How to match with iris rotations?**



# Feature Matching

**How to match with iris rotations?**






LOYOLA UNIVERSITY CHICAGO

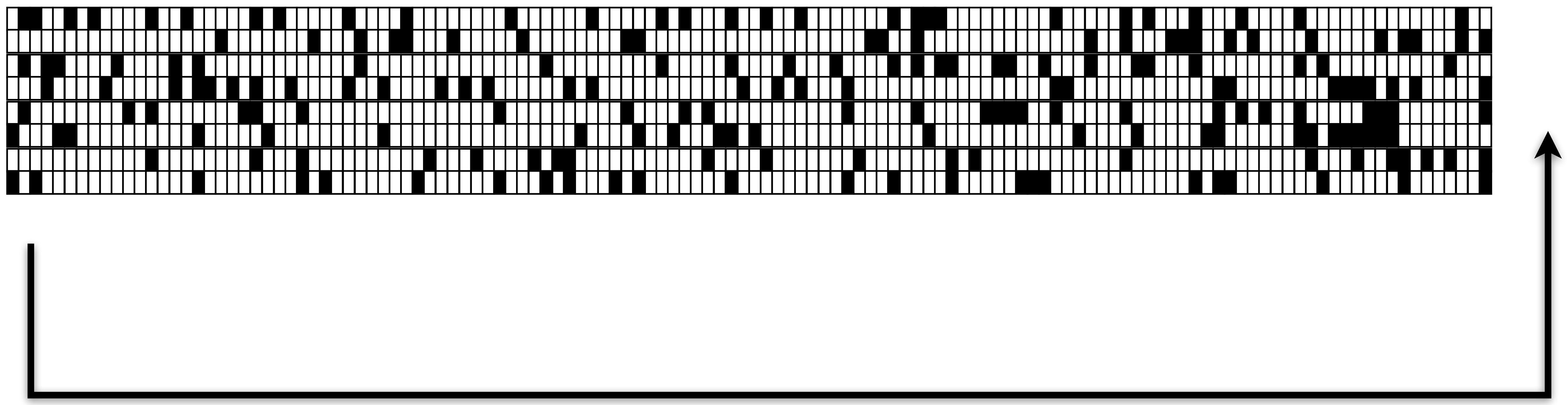
# Feature Matching

**How to Compare Binary Codes?**

**Problems (2/2)**

How to deal with iris rotations?

Solution: provide different shifts for one of the iris codes.





LOYOLA UNIVERSITY CHICAGO

# Feature Matching

**How to Compare Binary Codes?**

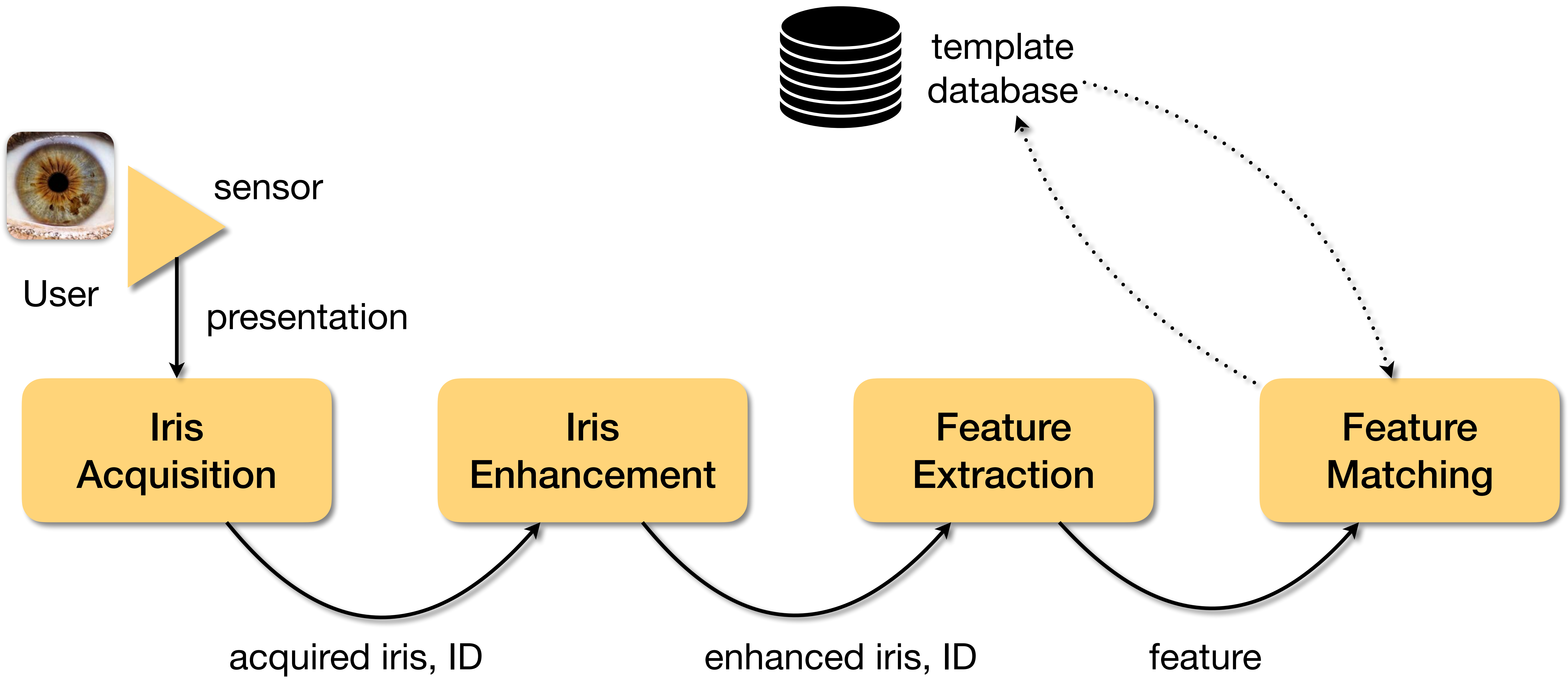
**Problems (2/2)**
How to deal with iris rotations?
Solution: provide different shifts
for one of the iris codes.
Compute various normalized
Hamming distances (one for each shift).

Take the smallest distance as the score.

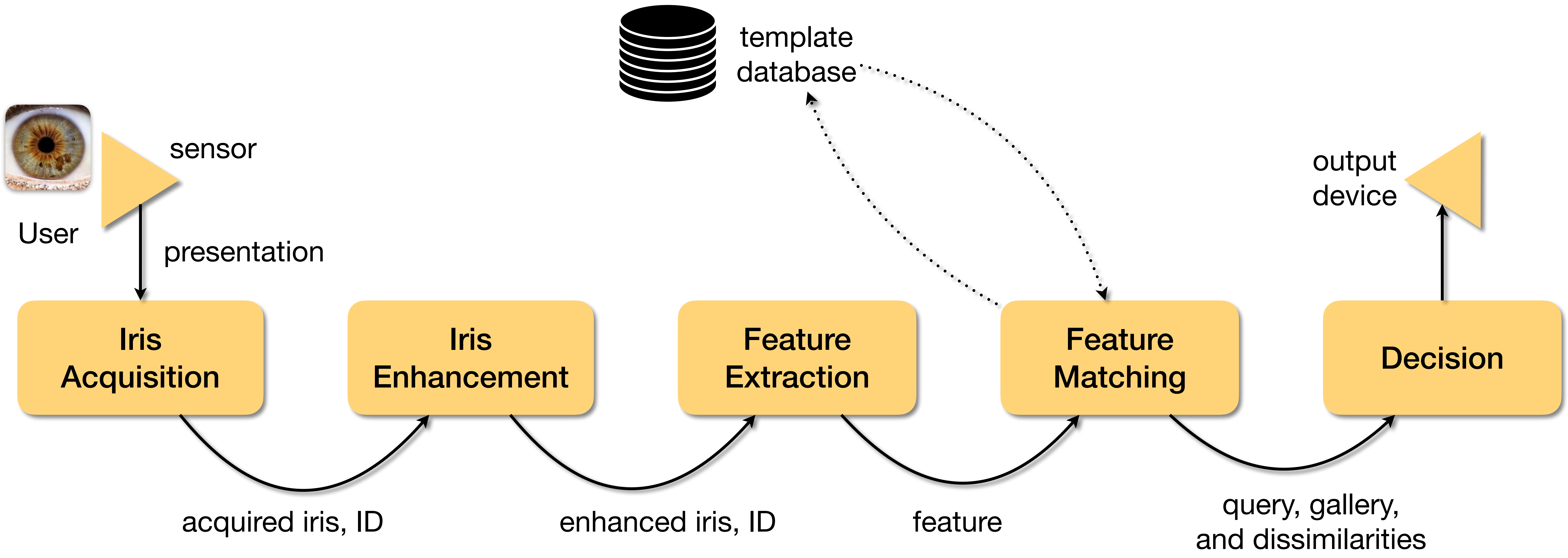



LOYOLA
UNIVERSITY CHICAGO

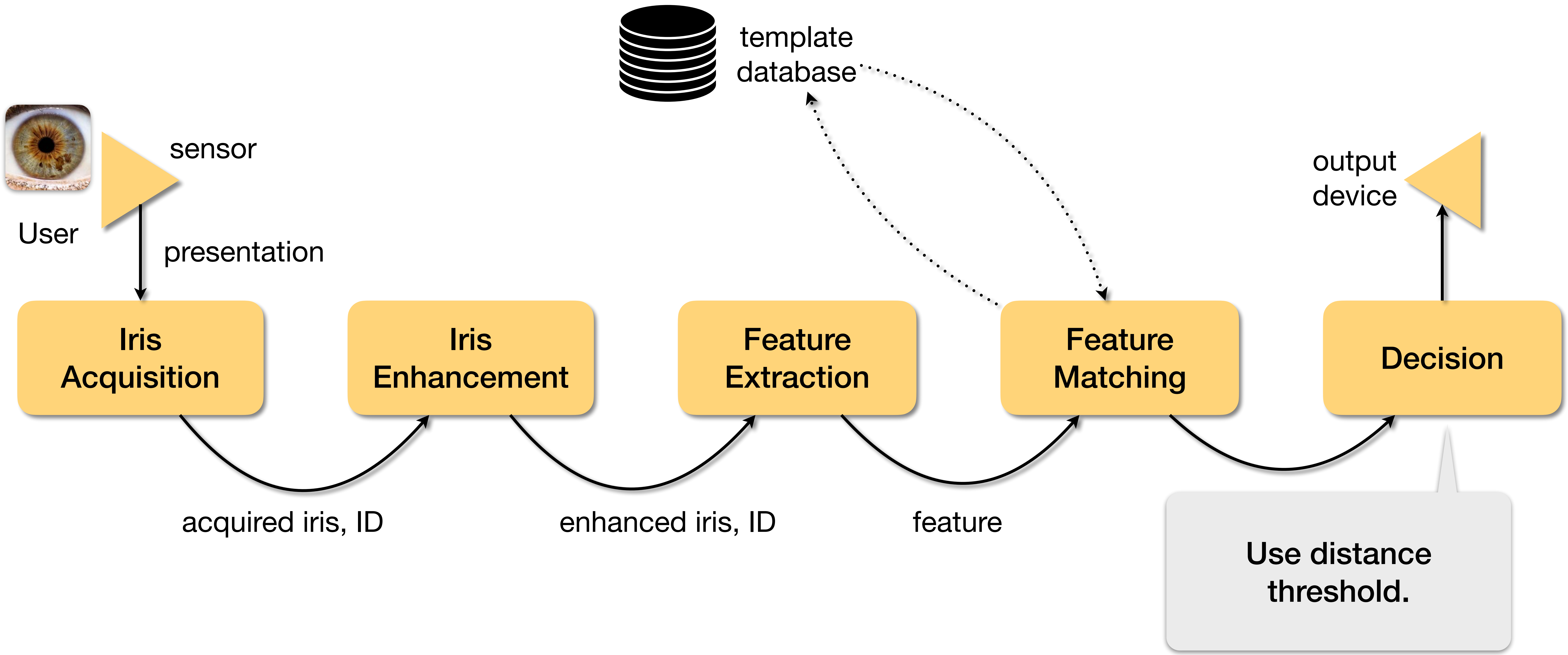
# Iris Recognition



# Iris Recognition

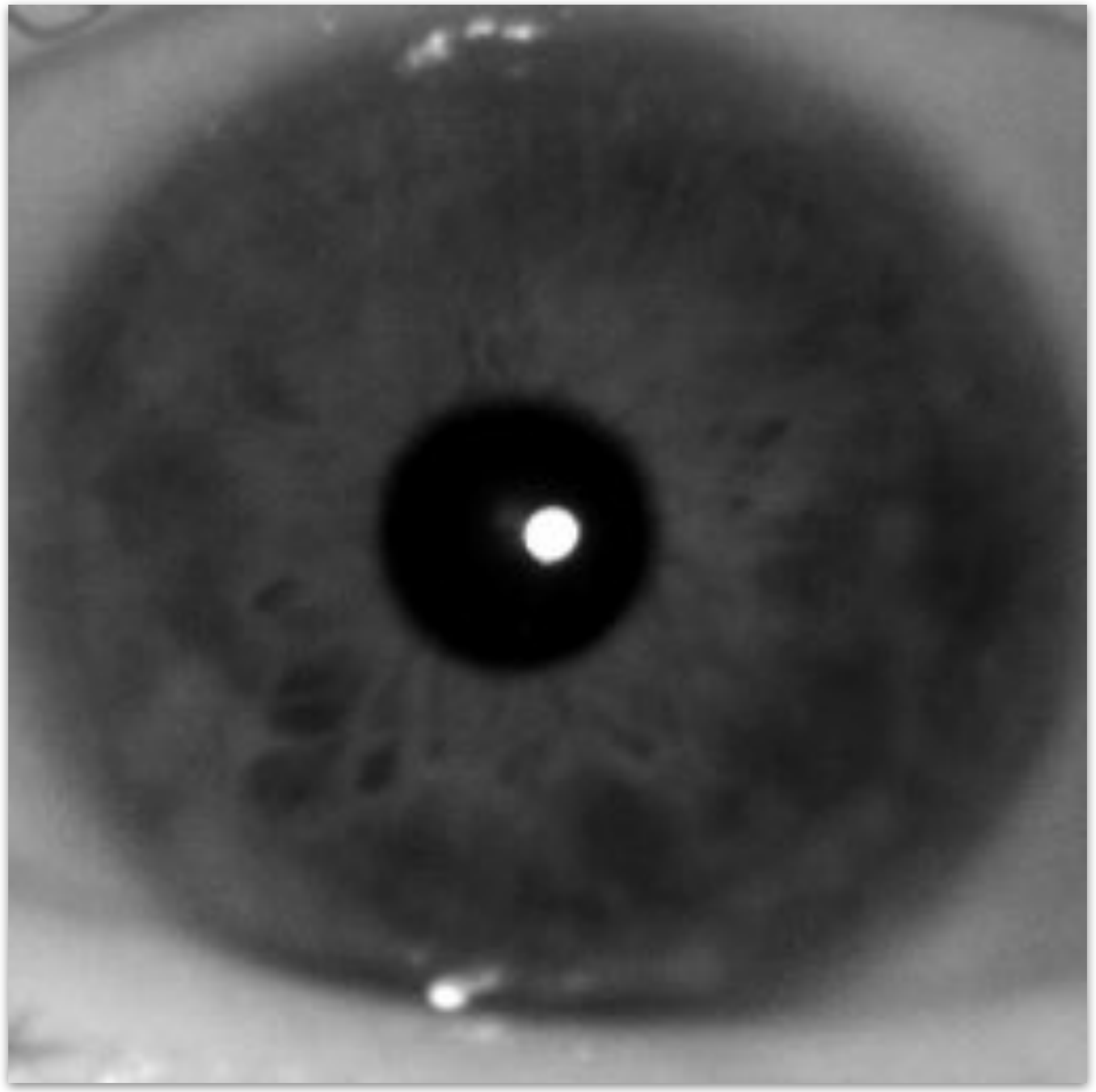


# Iris Recognition




LOYOLA UNIVERSITY CHICAGO

# Domain-Specific BSIF Codes



Original BSIF:
Natural images to learn filters.

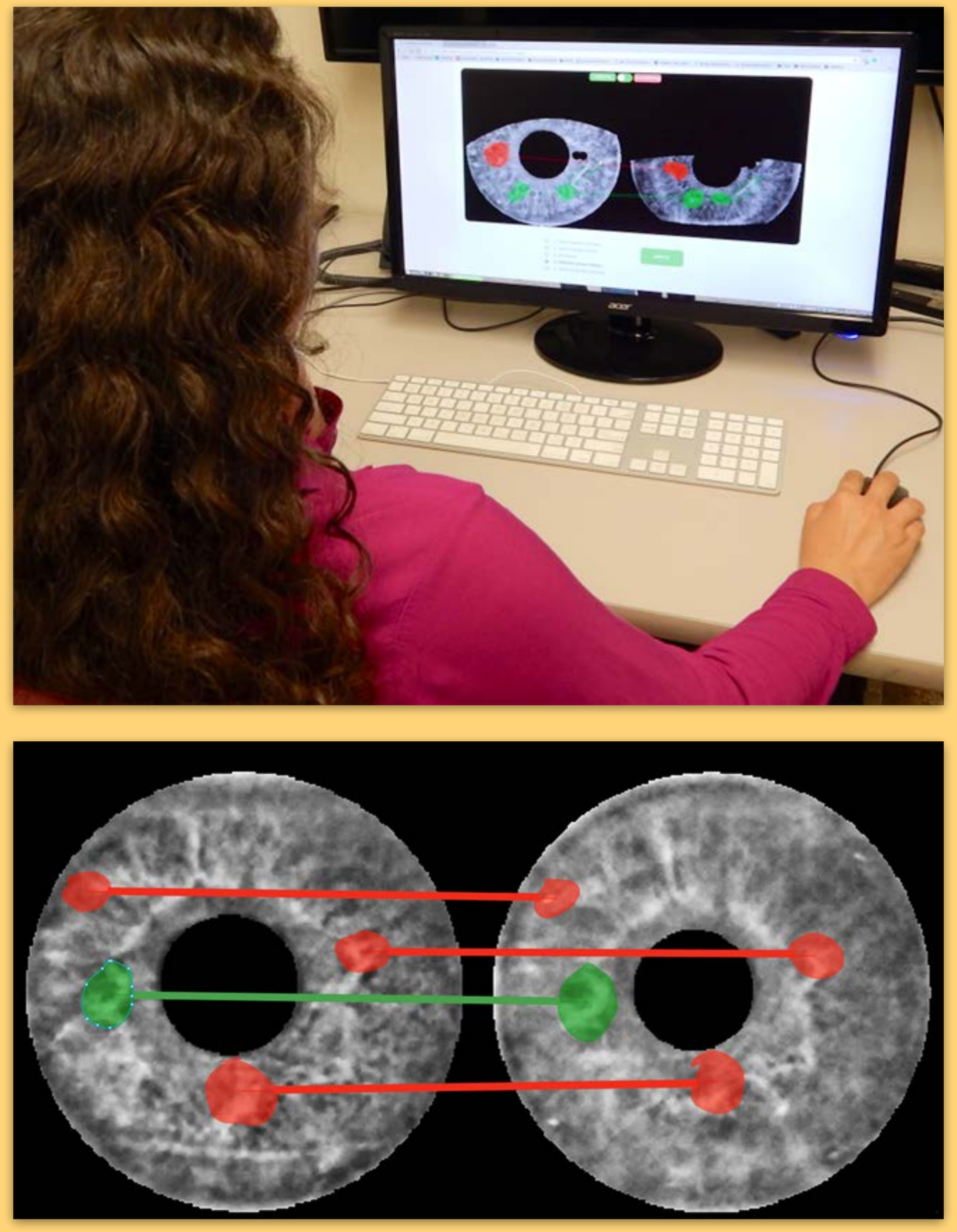
**What is the gain of learning from irises?**

LOYOLA UNIVERSITY CHICAGO

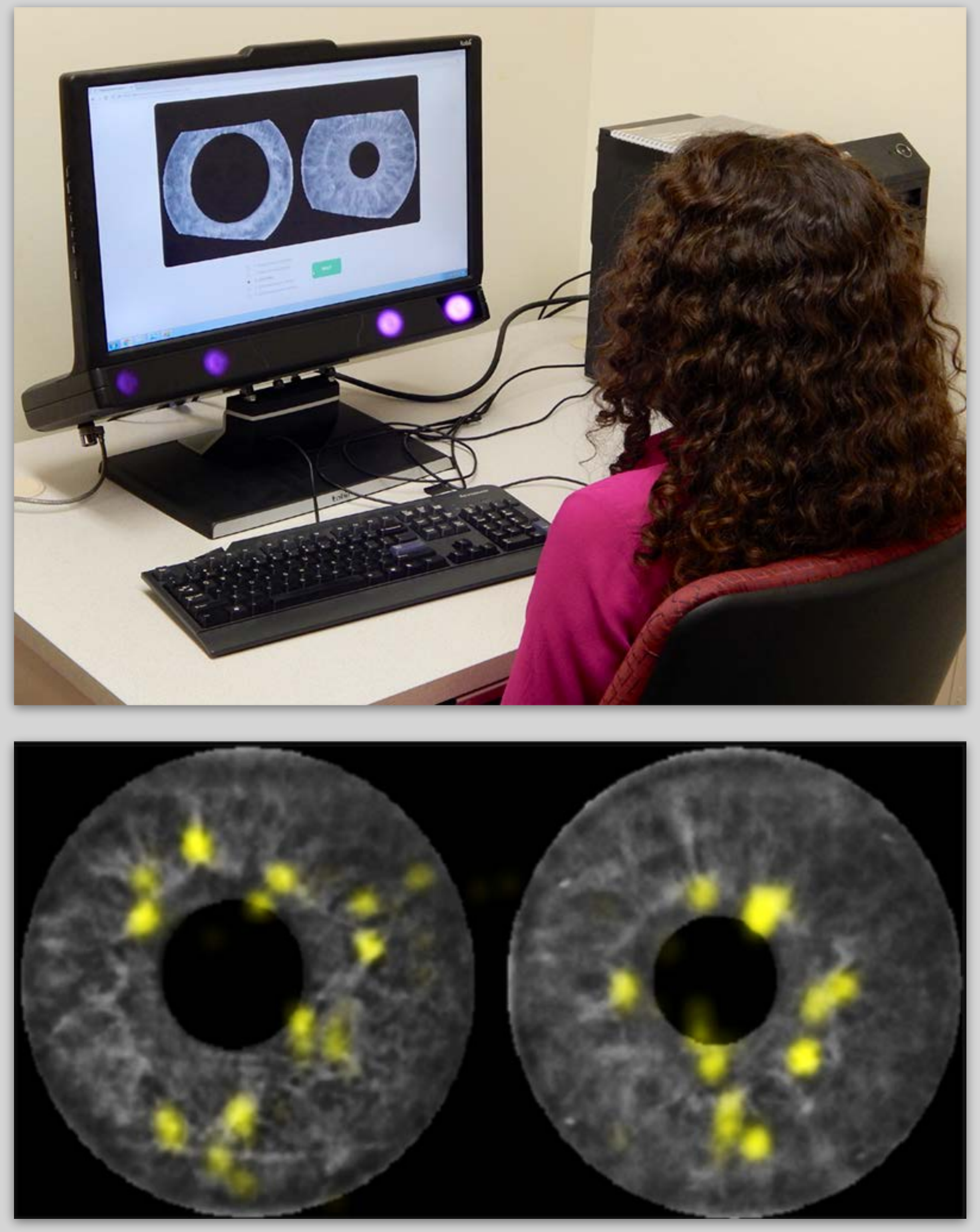
# Domain-Specific BSIF Codes

**How to Select Iris Patches?**

Manual Annotation



Eye-Tracker Data





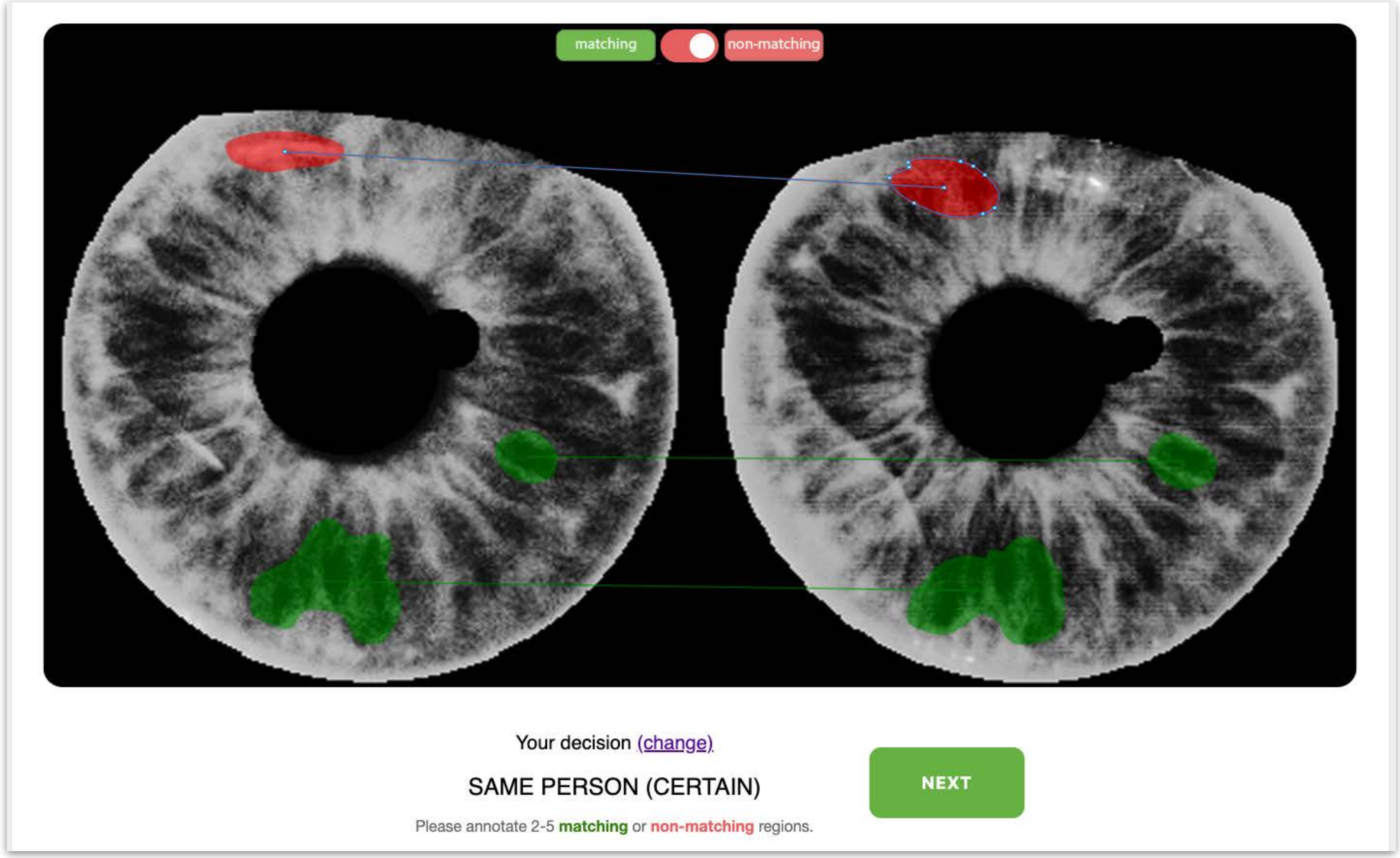
LOYOLA UNIVERSITY CHICAGO

# Domain-Specific BSIF Codes

## Annotation Tool

Available at
https://github.com/
danielmoreira/iris-examination

Paper.js
Web-browser drawing library.

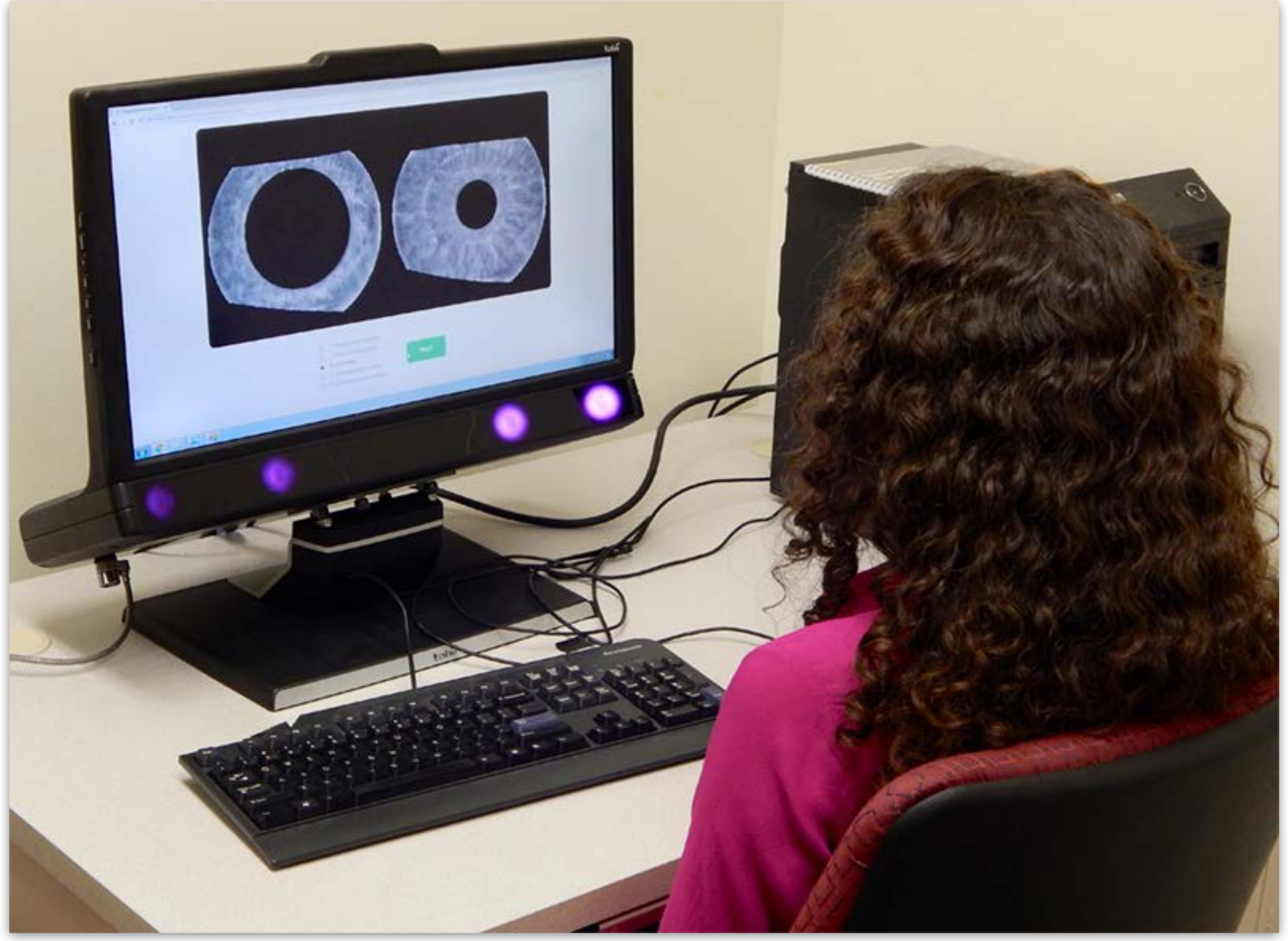





LOYOLA
UNIVERSITY CHICAGO

# Domain-Specific BSIF Codes

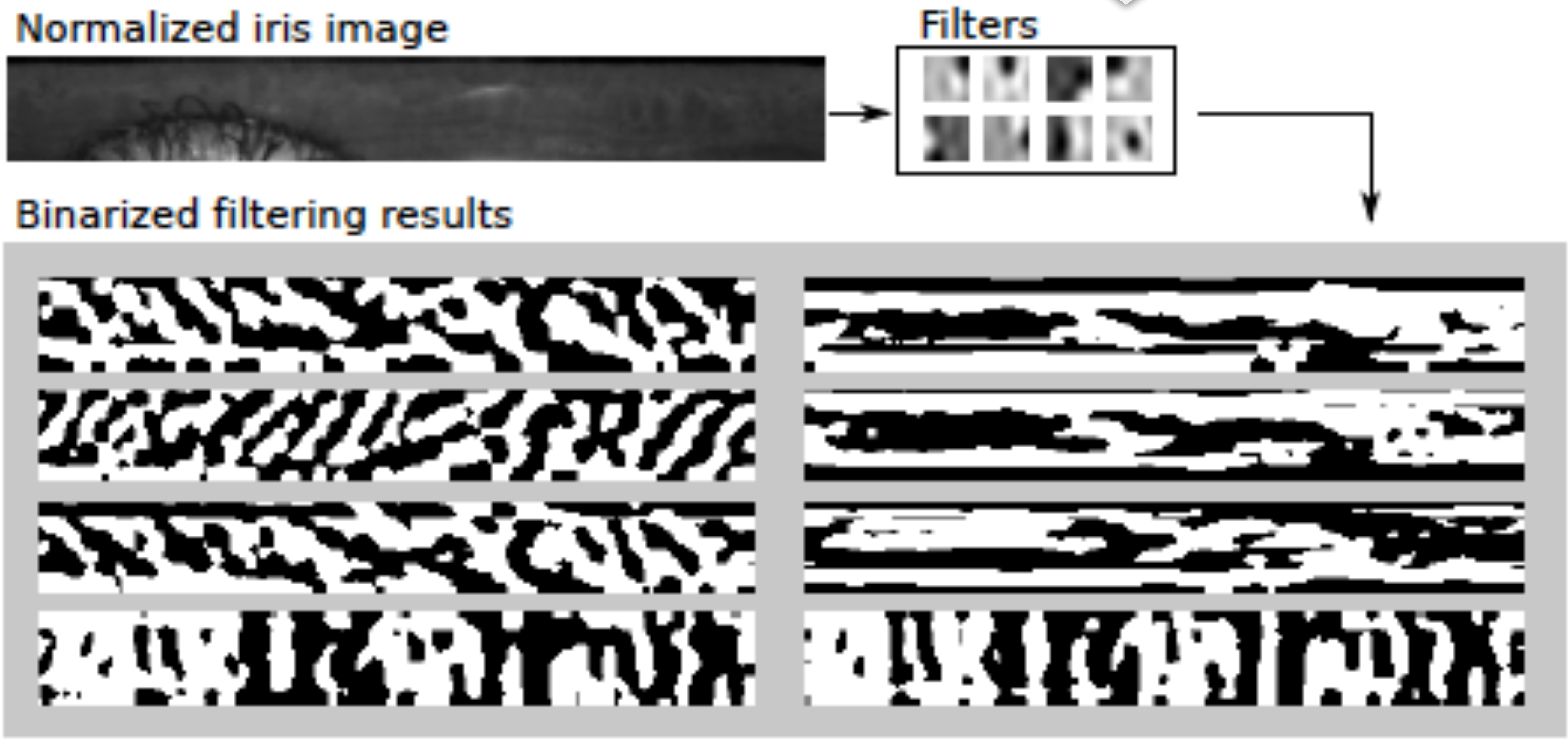
## Eye Tracker



# Domain-Specific BSIF Codes

## Application

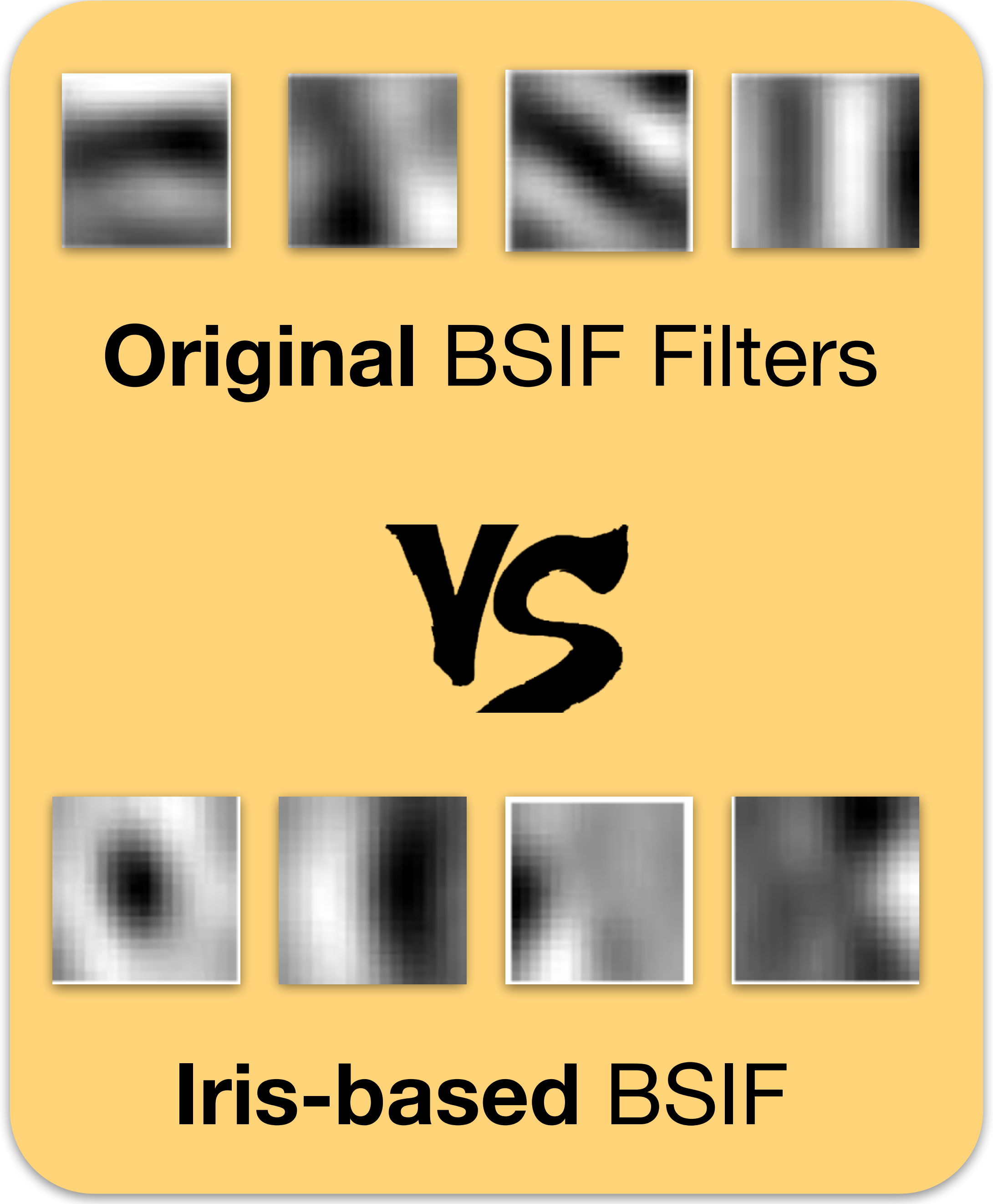
Either original or domain specific.

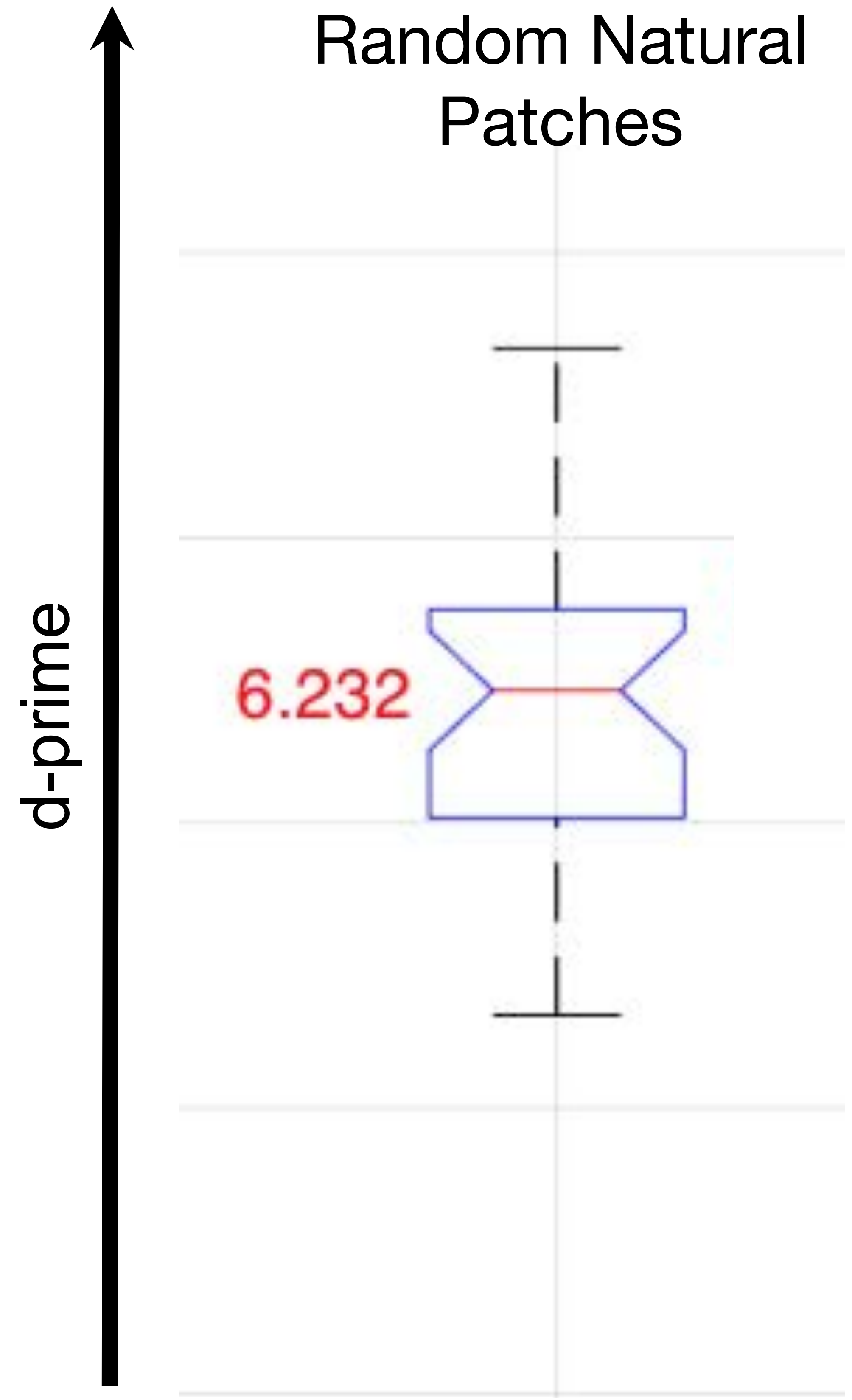



Czajka et al.
*Domain-Specific Human-Inspired Binarized Statistical Image Features for Iris Recognition*
WACV 2019

# Domain-Specific BSIF Codes

## Results

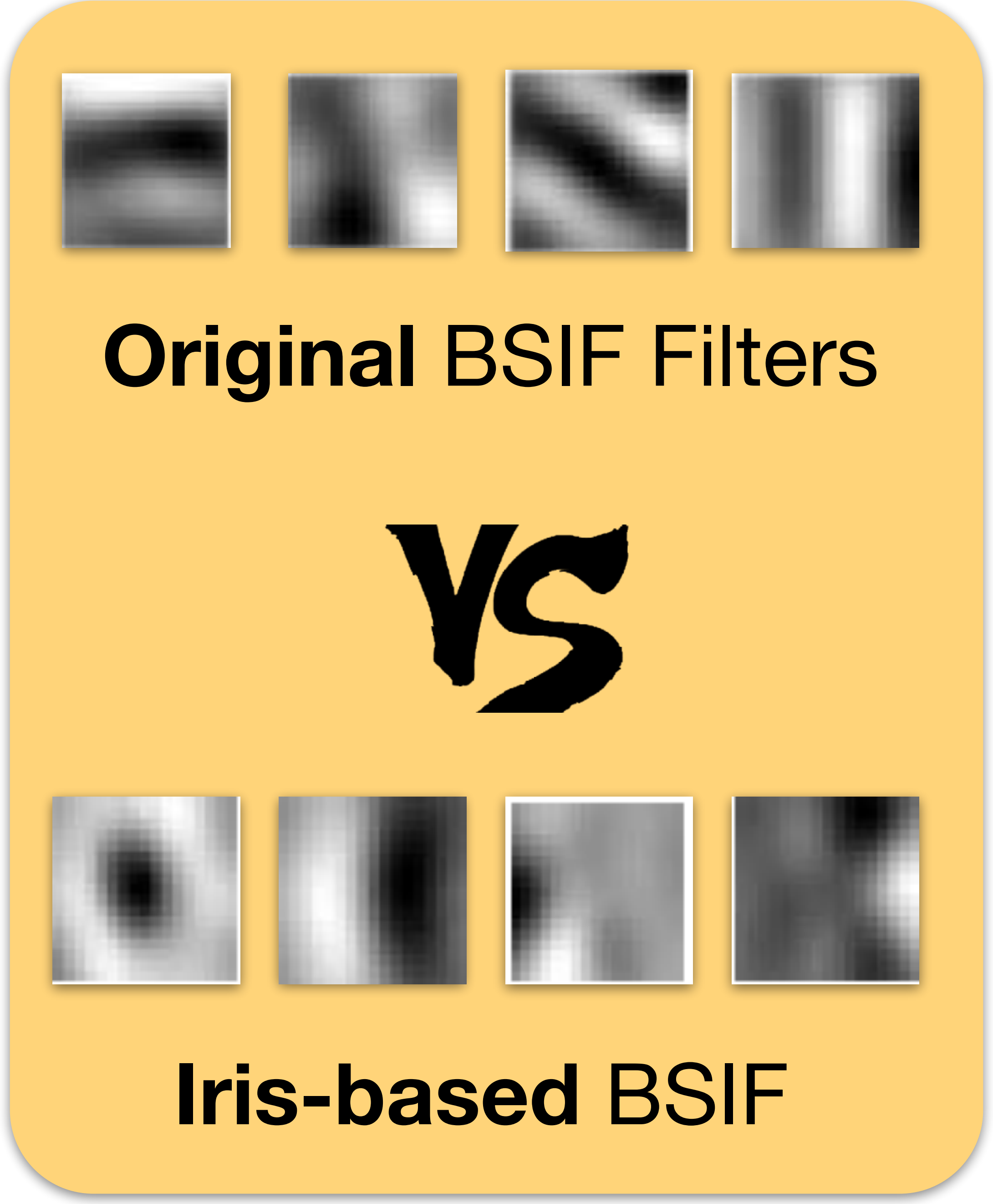


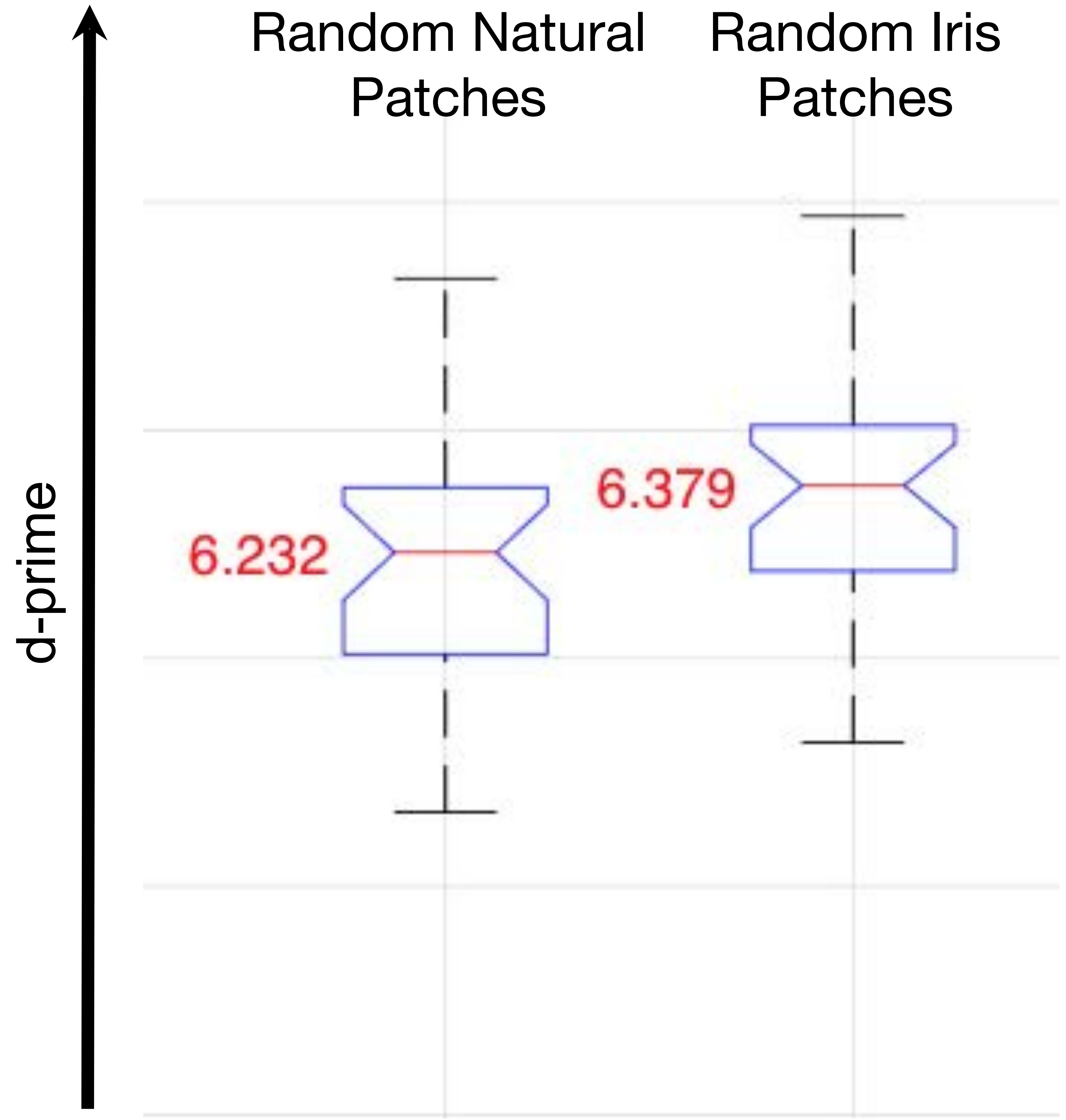




Czajka et al.
*Domain-Specific Human-Inspired Binarized Statistical Image Features for Iris Recognition*
WACV 2019

# Domain-Specific BSIF Codes

## Results




Czajka et al.
*Domain-Specific Human-Inspired Binarized Statistical Image Features for Iris Recognition*
WACV 2019

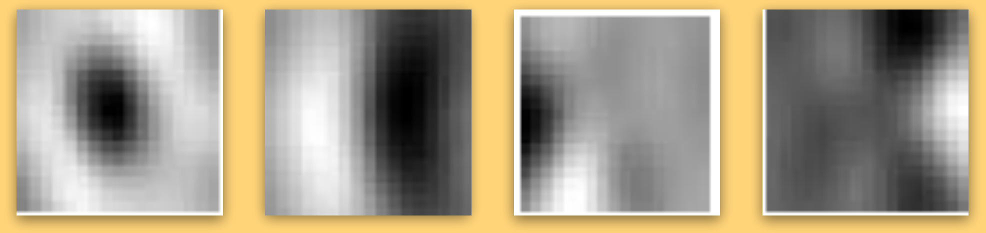
LOYOLA UNIVERSITY CHICAGO

# Domain-Specific BSIF Codes

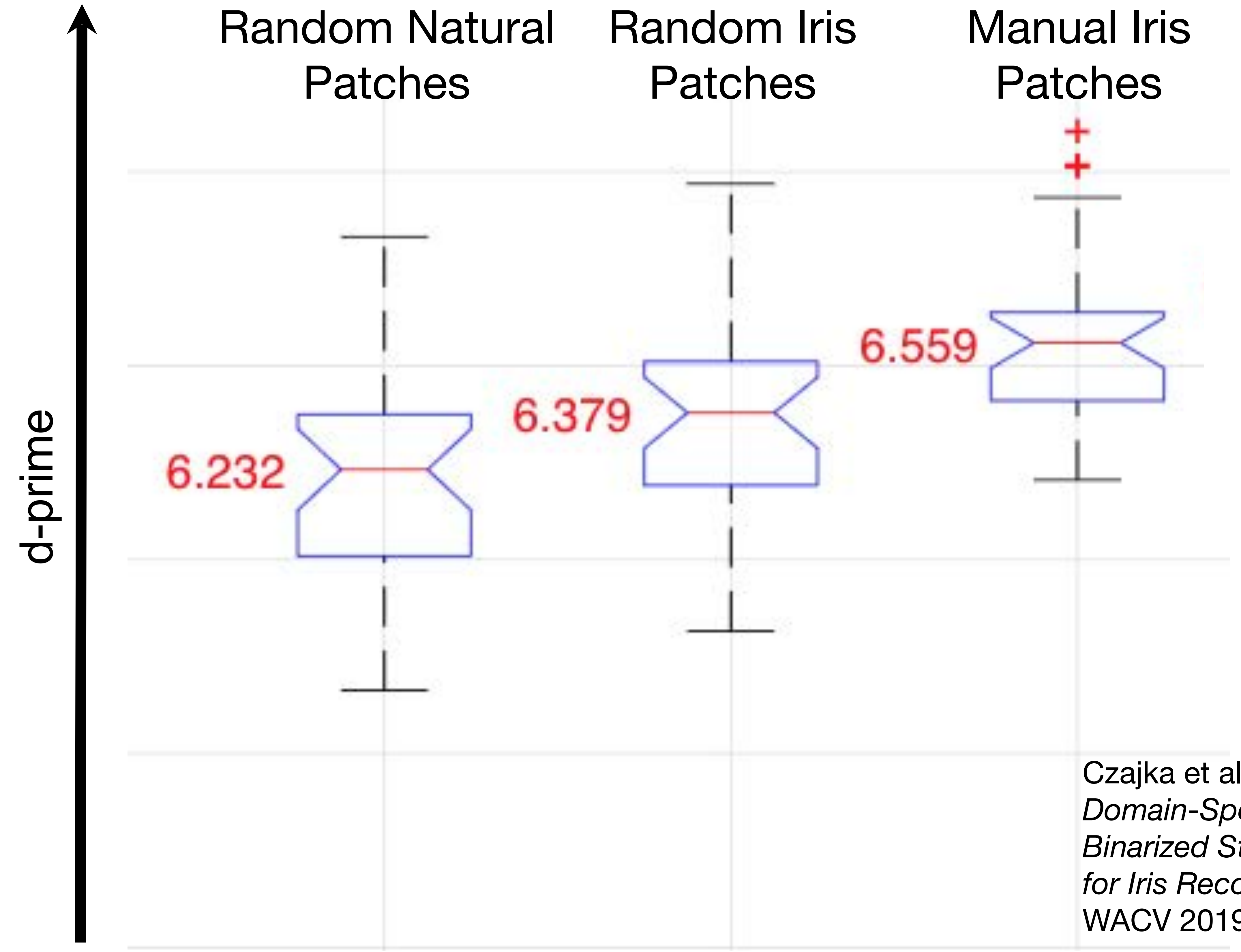
## Results

**Original** BSIF Filters

VS



**Iris-based** BSIF

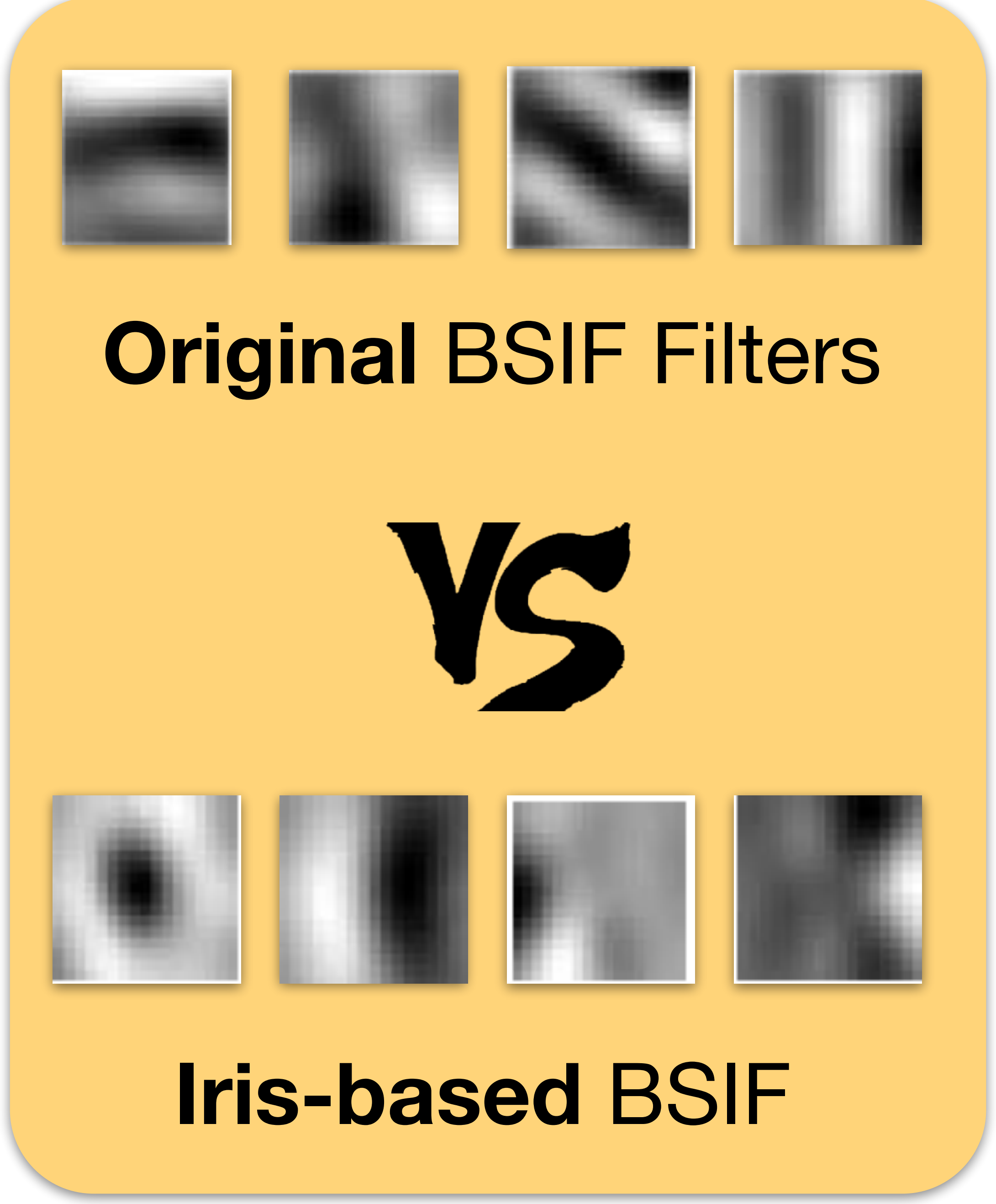


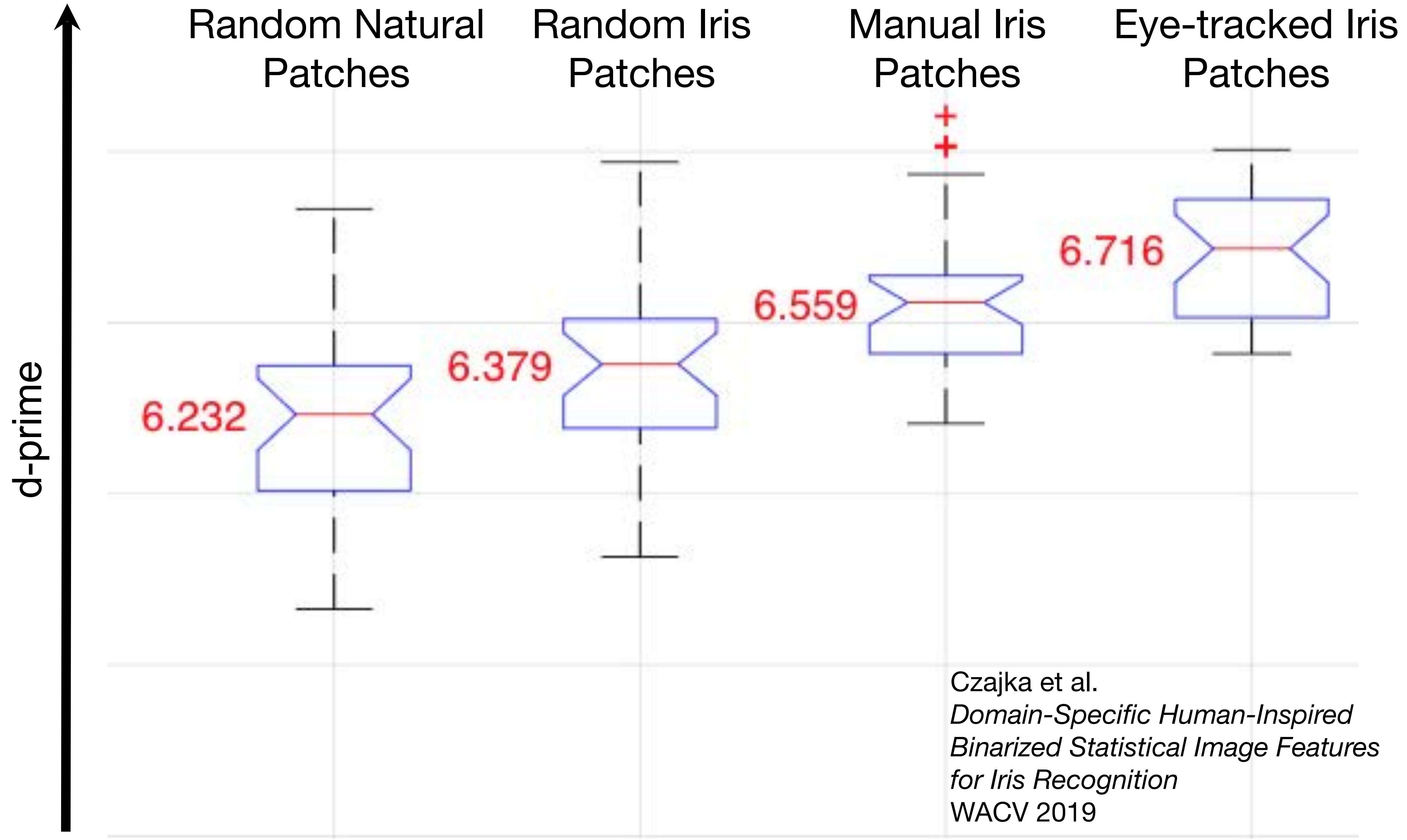

Czajka et al.
*Domain-Specific Human-Inspired Binarized Statistical Image Features for Iris Recognition*
WACV 2019

LOYOLA UNIVERSITY CHICAGO

# Domain-Specific BSIF Codes

## Results



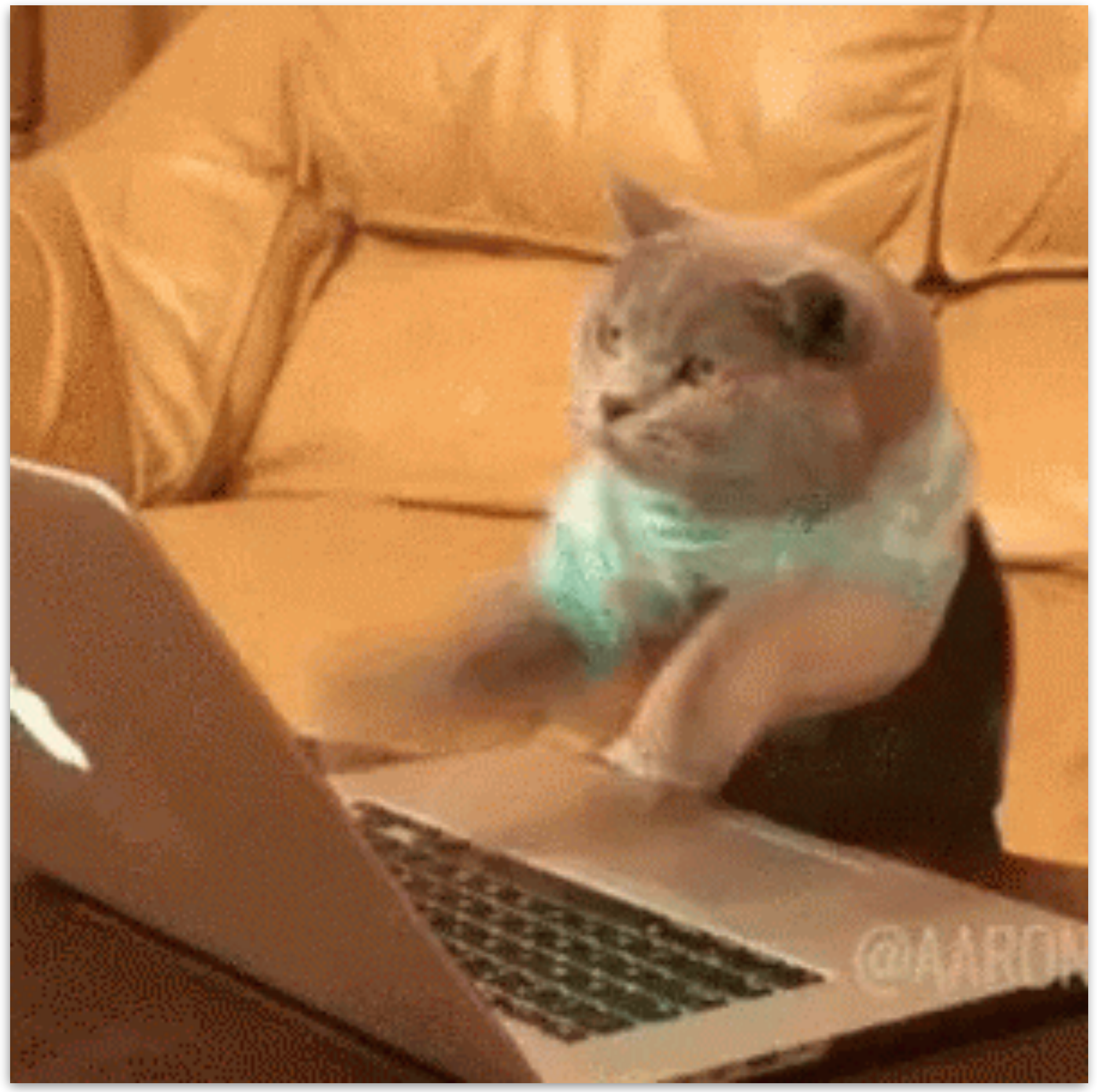

Czajka et al.
*Domain-Specific Human-Inspired Binarized Statistical Image Features for Iris Recognition*
WACV 2019

LOYOLA UNIVERSITY CHICAGO

# What’s Next?

**Fingerprint Recognition Coding Class.**

**Fill out your**
***Today-I-missed*** **Statement**
Please visit
https://sakai.luc.edu/x/HAZC1P.




LOYOLA UNIVERSITY CHICAGO