Iris Recognition III

COMP 388-002/488-002 Biometrics

Daniel Moreira

Fall 2025

LOYOLA
UNIVERSITY CHICAGO

Today we will…

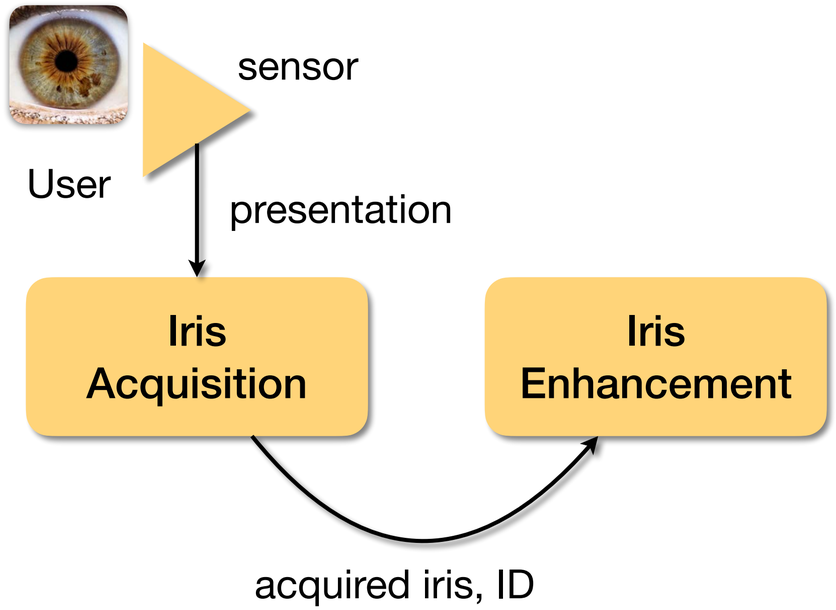
Get to know
Iris description and matching.

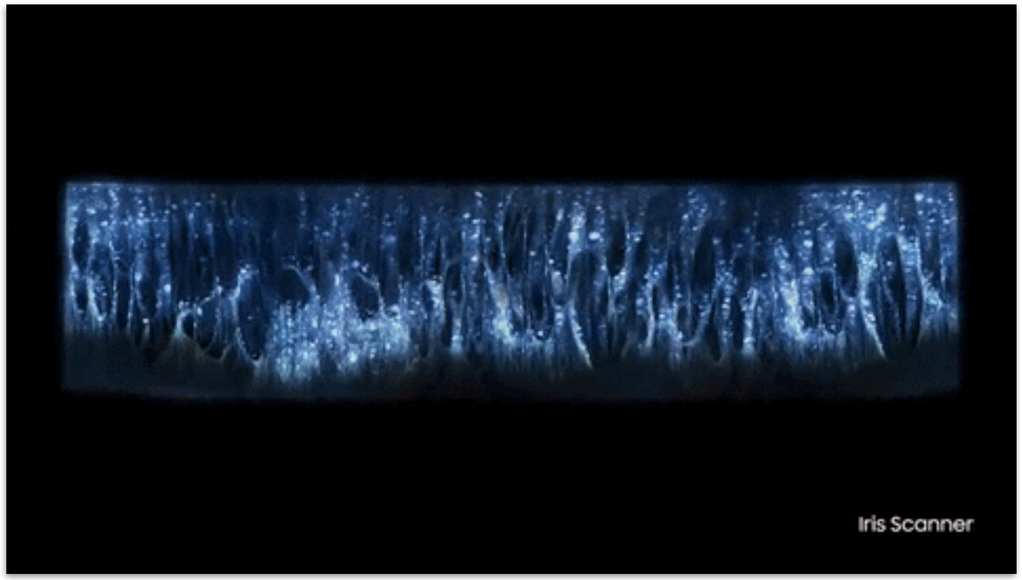
Today's Attendance

Please fill out the form

forms.gle/UY3Pxjt8JG99wotUA

Iris Recognition





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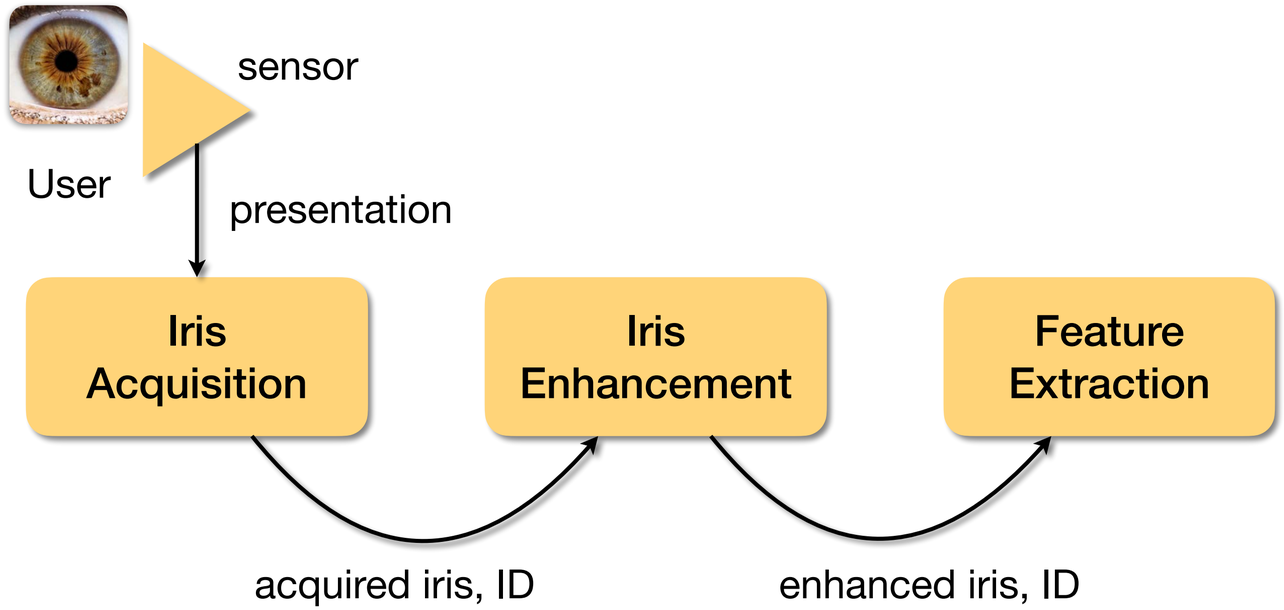
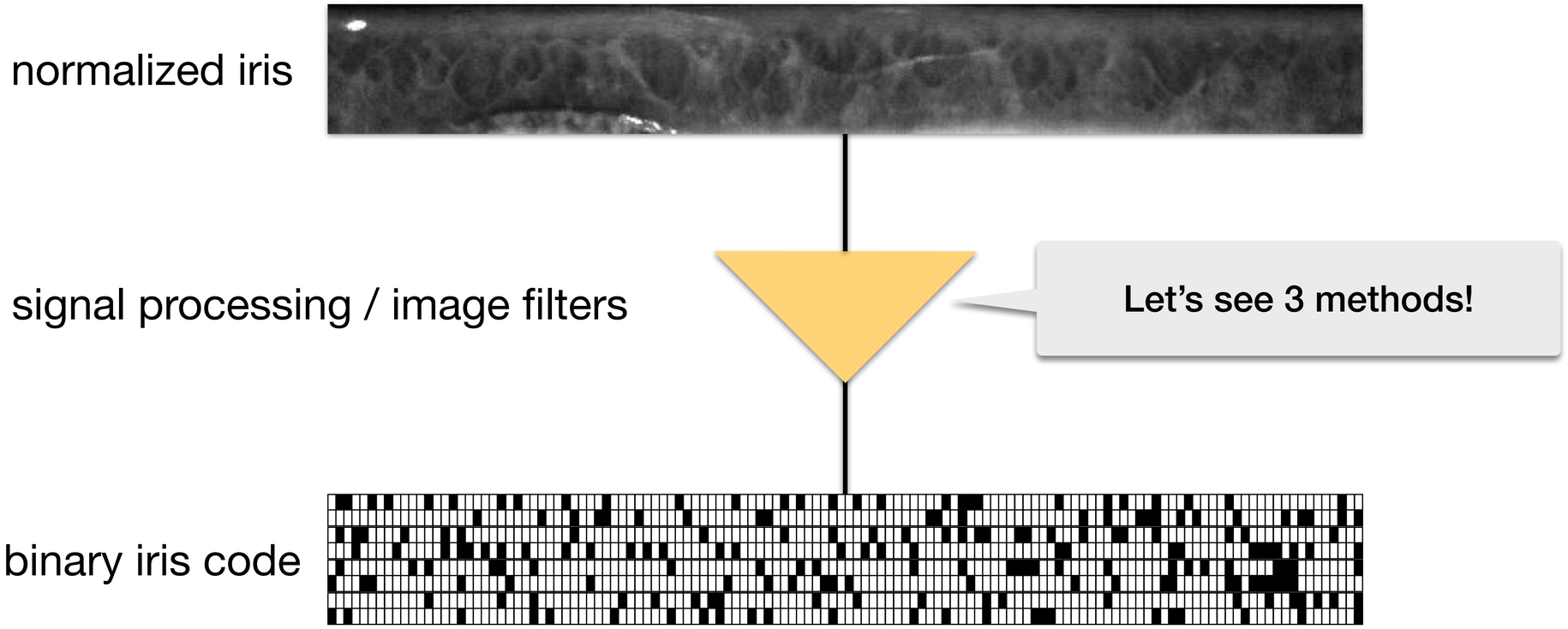


Feature Extraction

Typical Description Framework

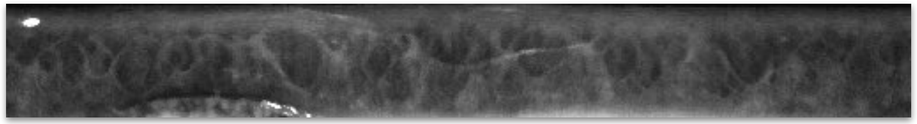


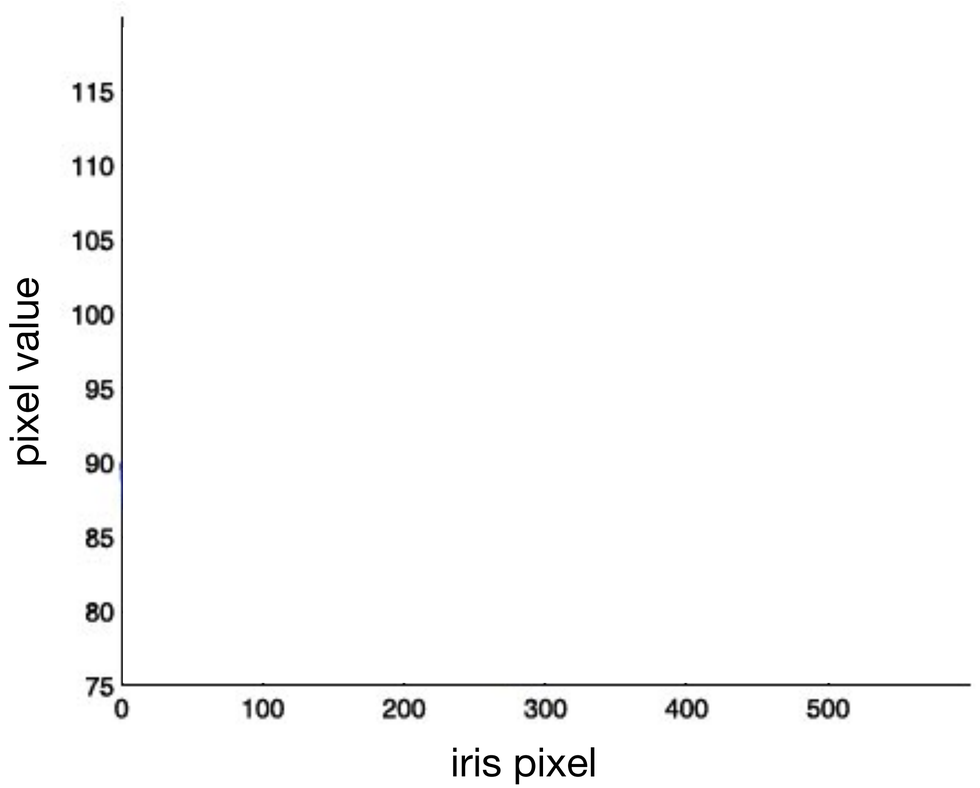
Feature Extraction

Zero-Crossing Approach (1/3)

Proposed by W. W. Boles.

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





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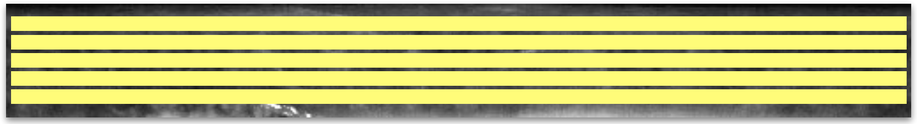
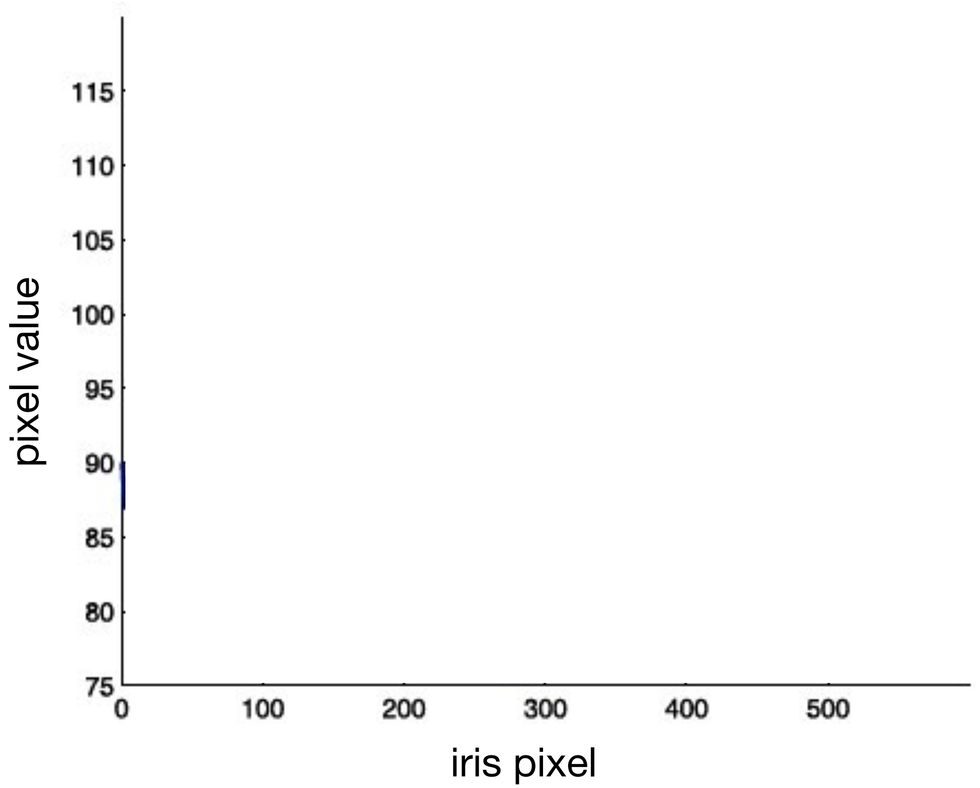


Dr. Adam Czajka



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Feature Extraction

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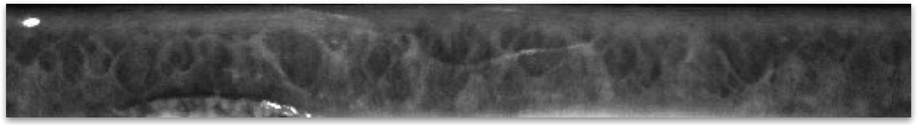
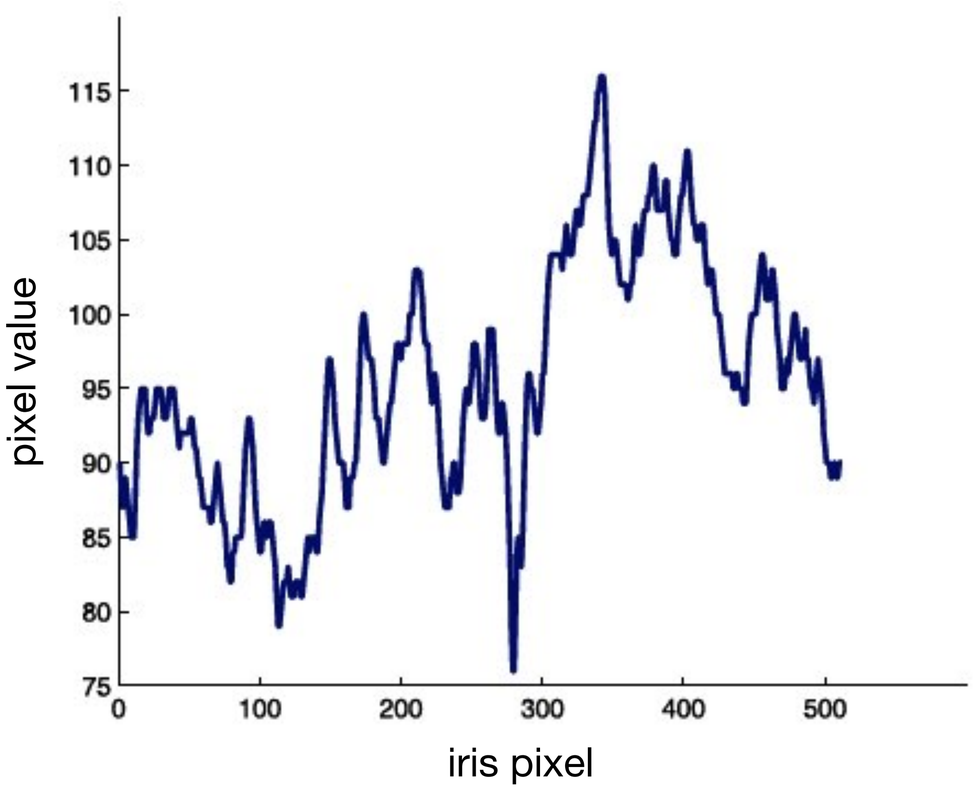


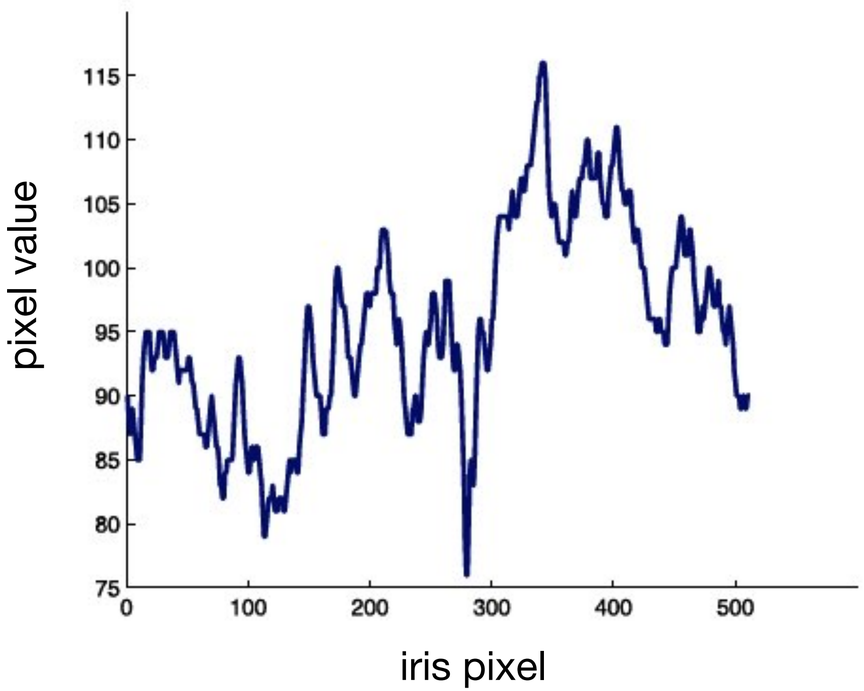
Dr. Adam Czajka



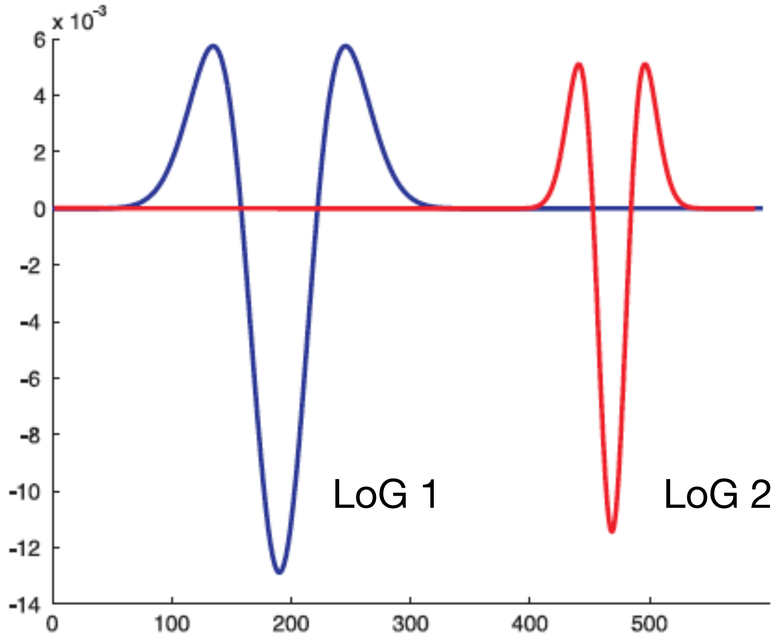
Feature Extraction

Zero-Crossing Approach (1/3)

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



Laplacians of Gaussians



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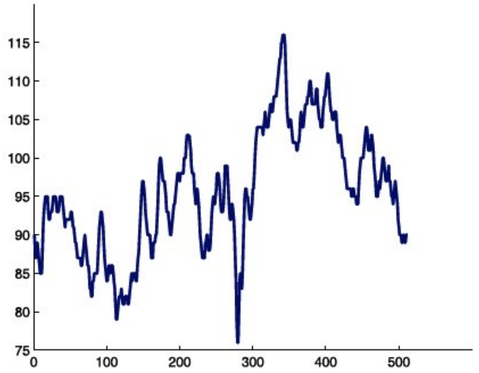
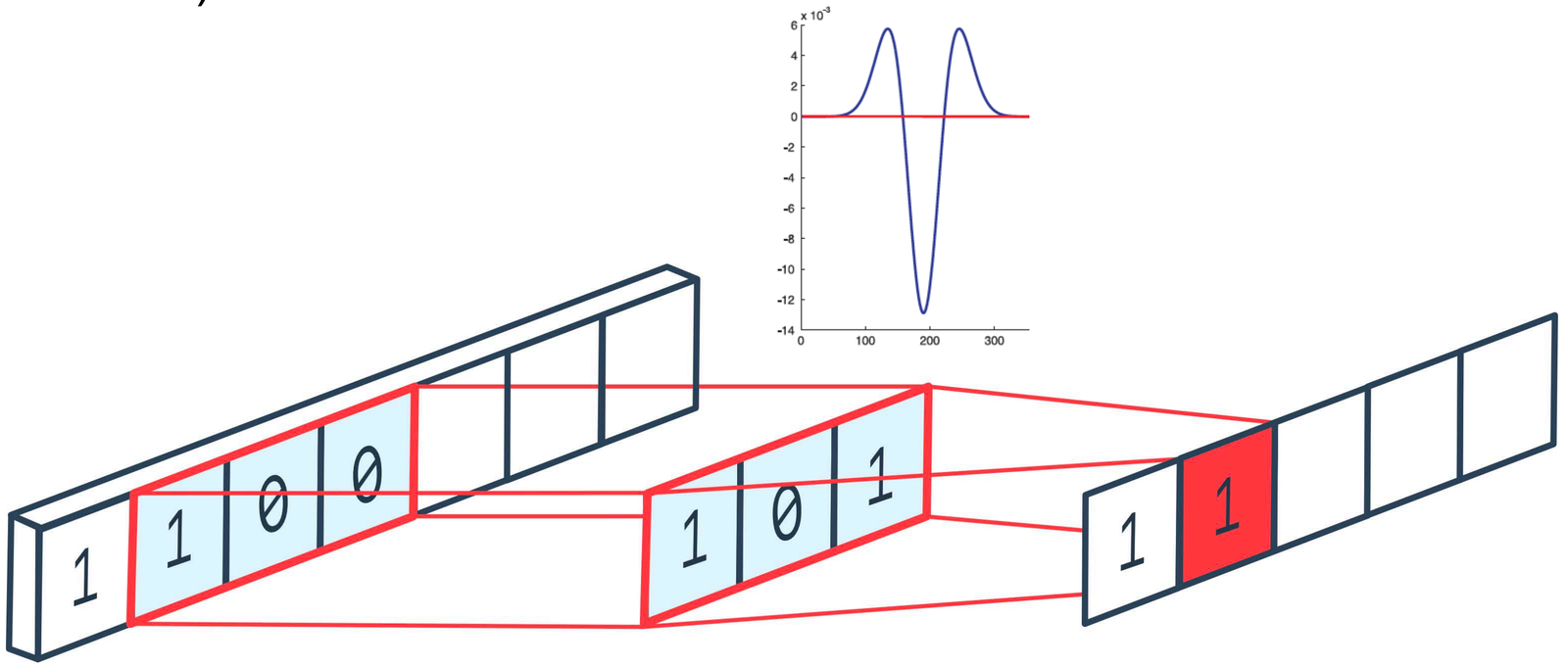
Feature Extraction

Zero-Crossing Approach (1/3)

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

1D Convolution





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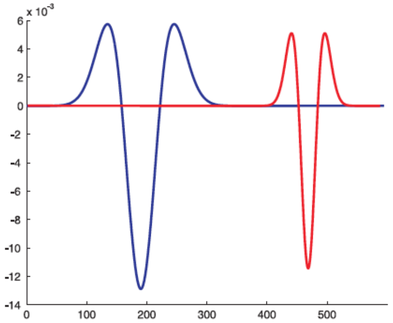
Feature Extraction

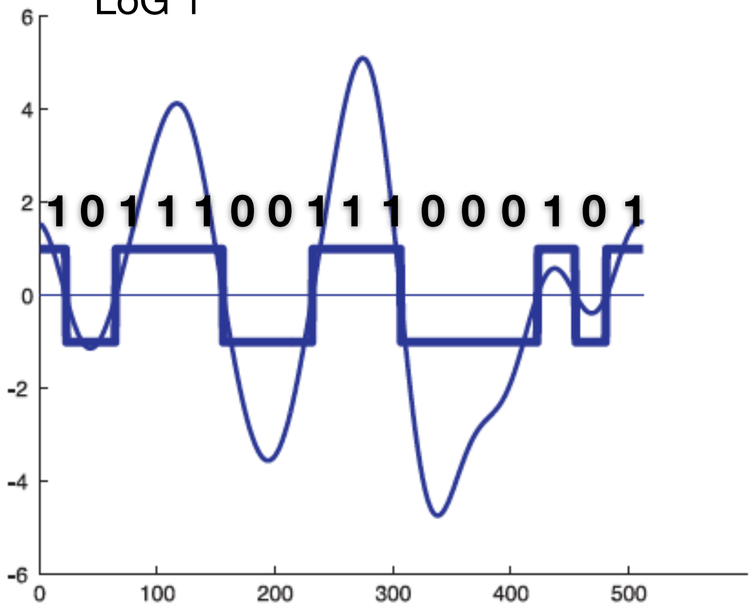
Zero-Crossing Approach (1/3)

LoG 1 LoG 2

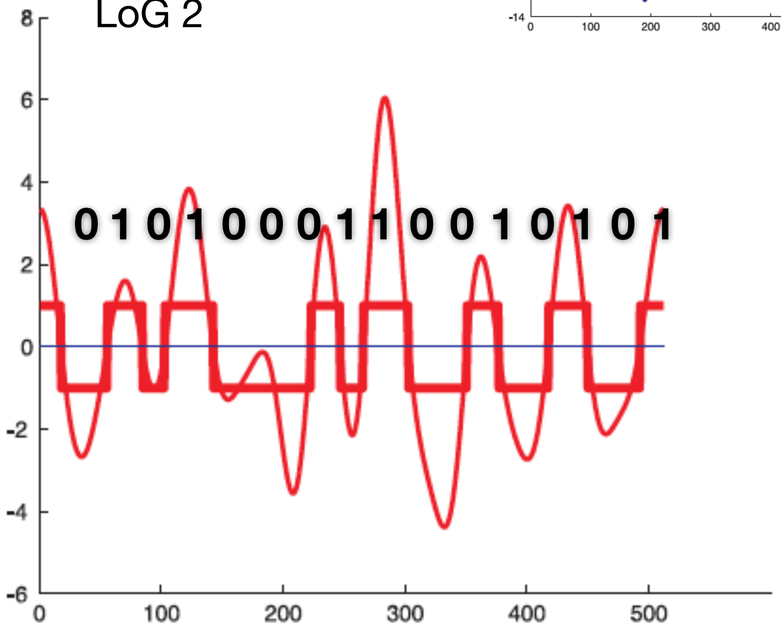


2. Zero-crossings lead to bits up; everything else is zero.

LoG 1



LoG 2



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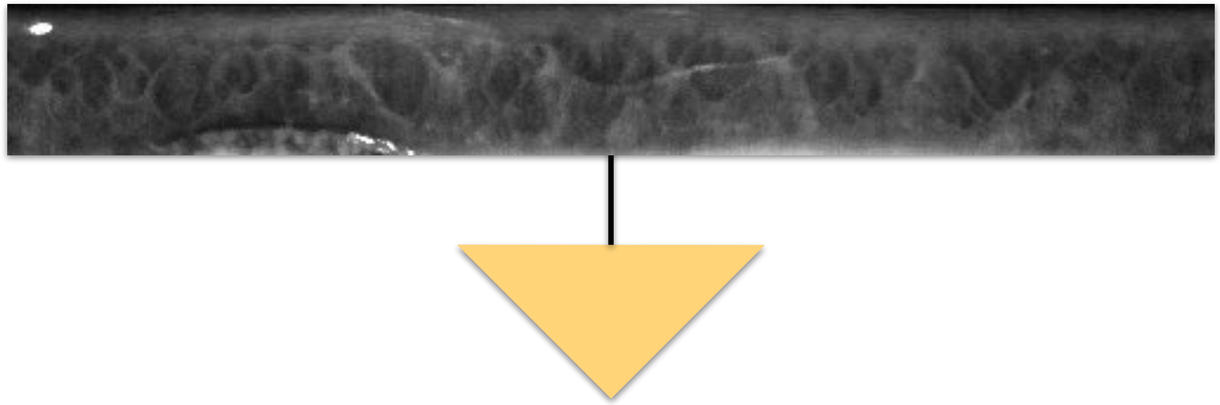
Feature Extraction

Zero-Crossing Approach (1/3)



LoG 1

1 0 1 1 1 1 0 0 1 1 1 0 0 0 1 0 1

LoG 2

0 1 0 1 0 0 0 1 1 0 0 1 0 1 0 1

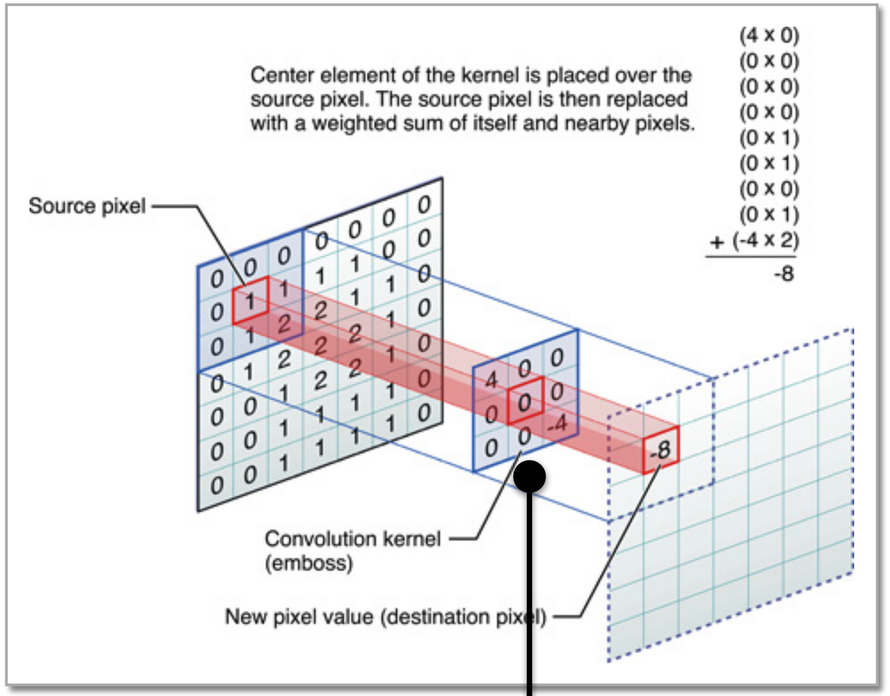
concatenation

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

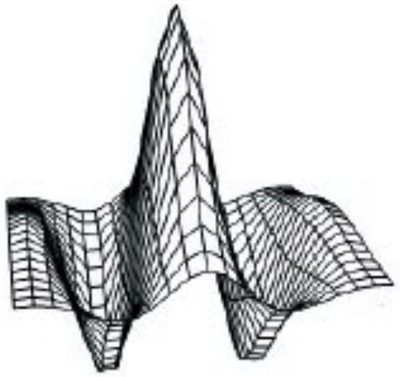
Feature Extraction

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

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

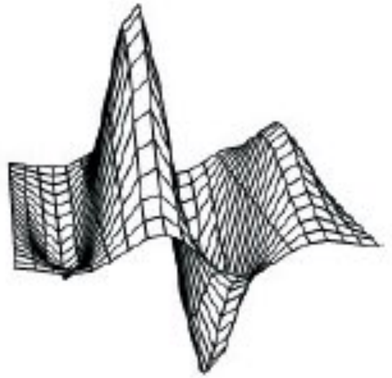
Gabor wavelets are a good model of neural receptive fields found in the visual cortex.

Filter 1



wavelet real component

Filter 2



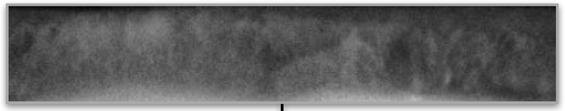
wavelet imaginary component

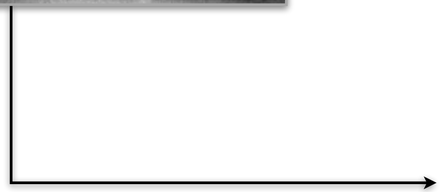
J. Daugman
Probing the Uniqueness and Randomness of IrisCodes: Results from 200 Billion Iris Pair Comparisons.
IEEE Proceedings, 2006

Feature Extraction

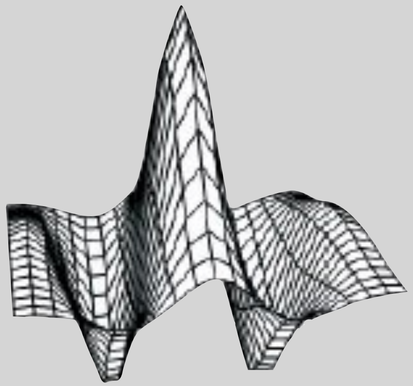
2D-Gabor Filtering Approach (2/3)

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



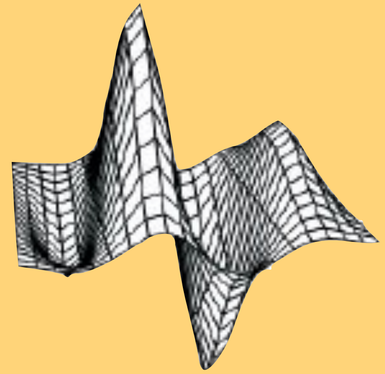


Filter 1



wavelet real component

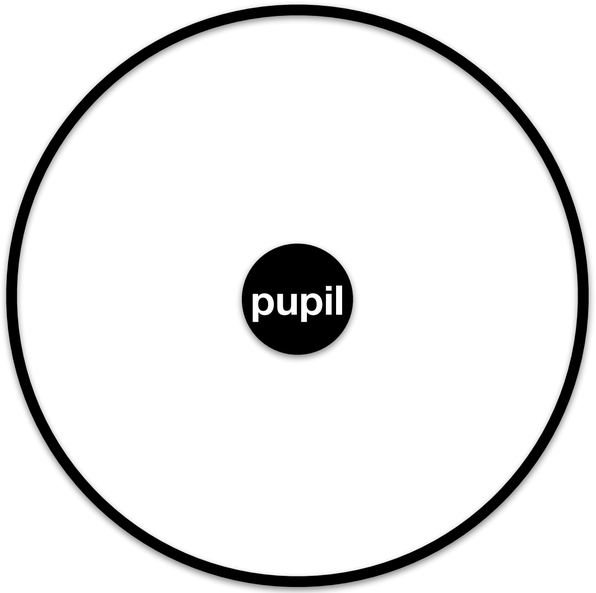
Filter 2

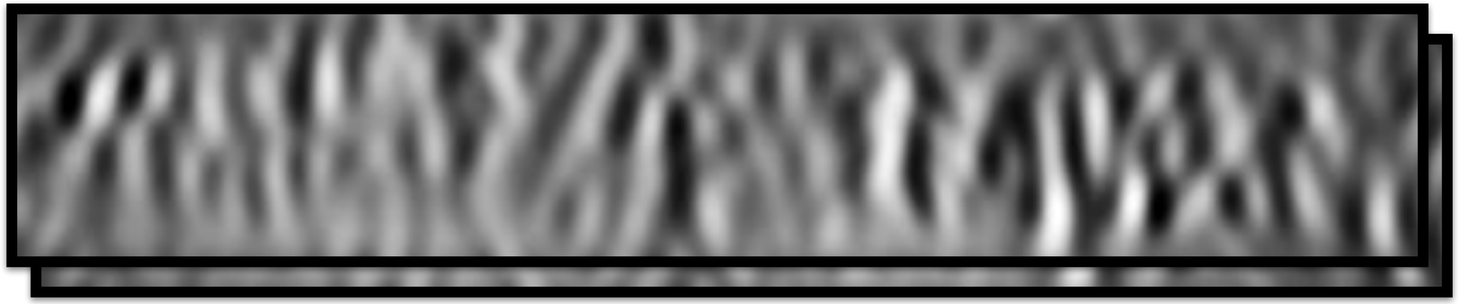


wavelet imaginary component

Feature Extraction

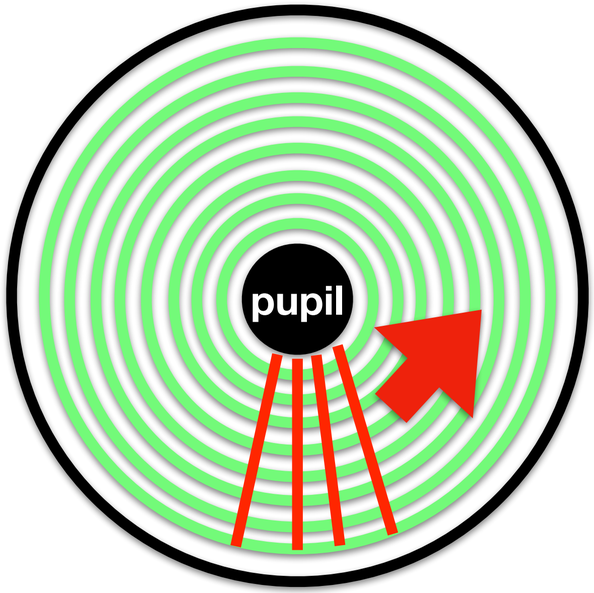
2D-Gabor Filtering Approach (2/3)

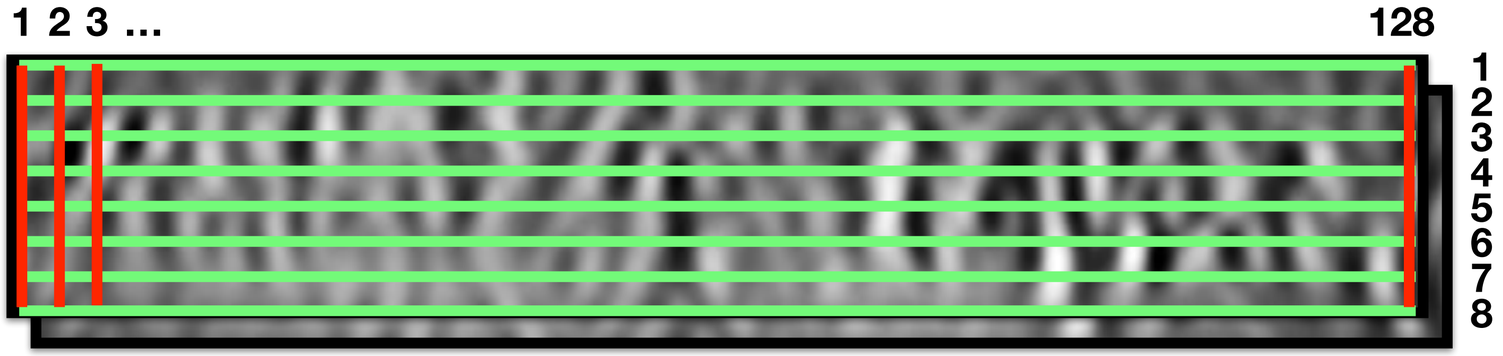




Feature Extraction

2D-Gabor Filtering Approach (2/3)

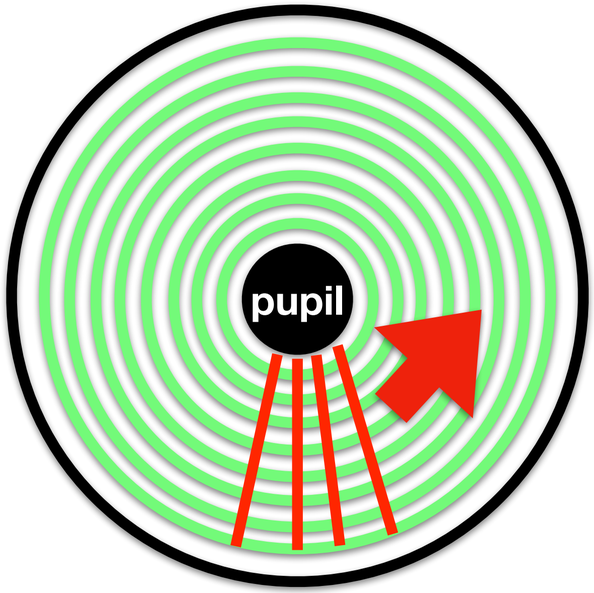


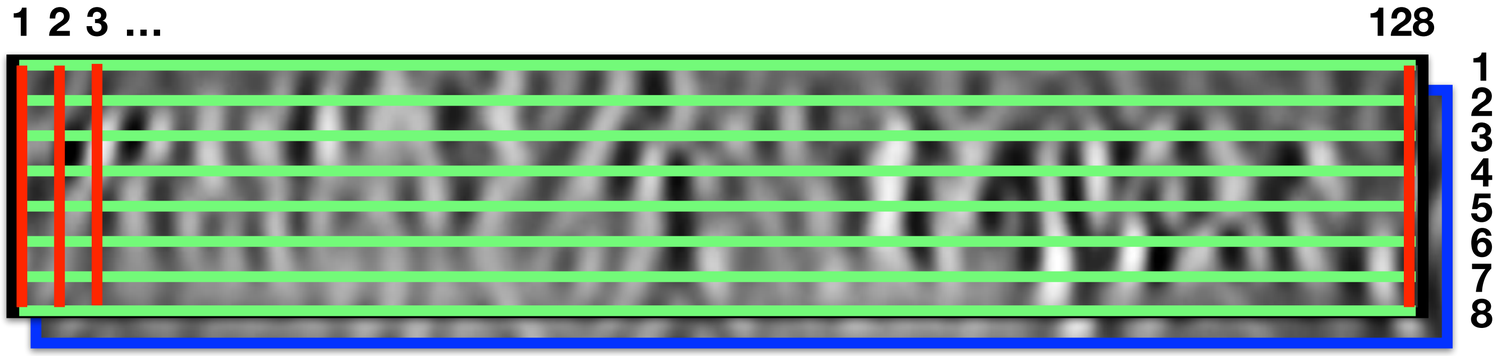


Number of cells: 8 x 128 = 1024

Feature Extraction

2D-Gabor Filtering Approach (2/3)



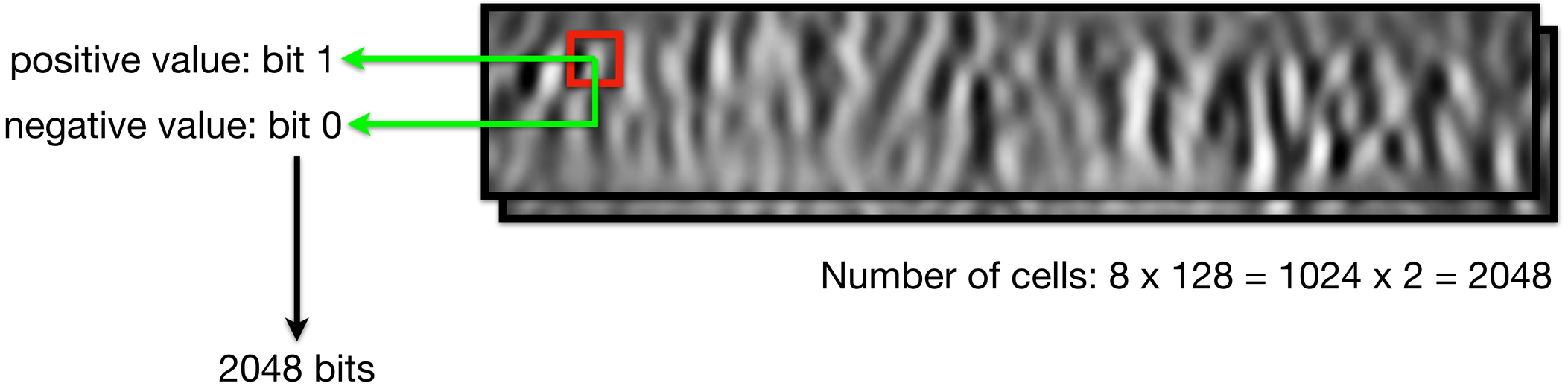


Number of cells: 8 x 128 = 1024 **x 2 = 2048**

Feature Extraction

2D-Gabor Filtering Approach (2/3)

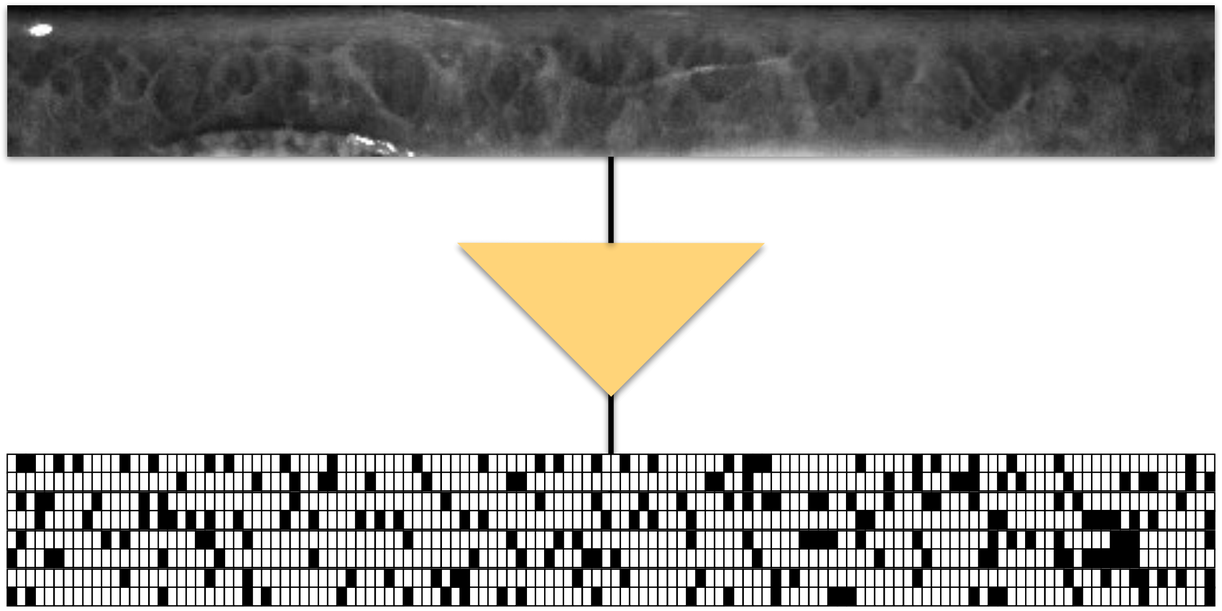
Take one cell…



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

Feature Extraction

2D-Gabor Filtering Approach (2/3)



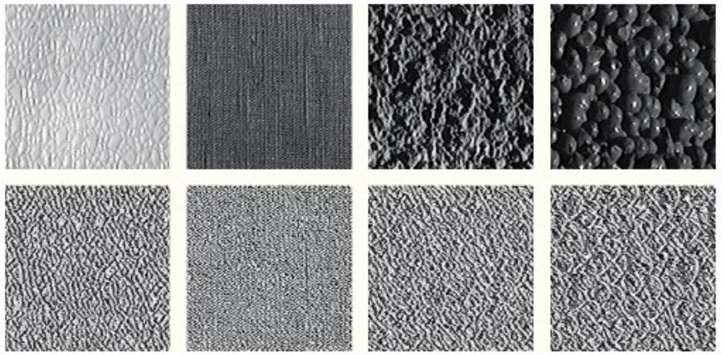
2048 bits
IrisCode

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.

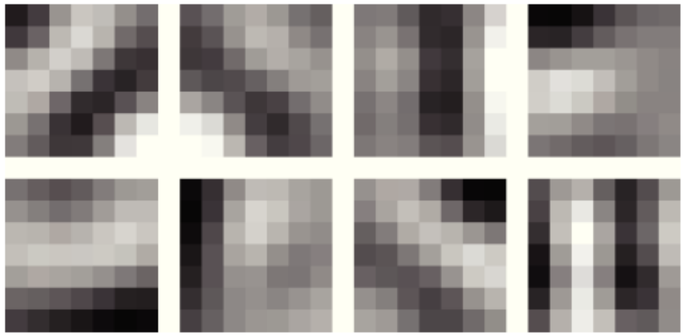
Feature Extraction

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.

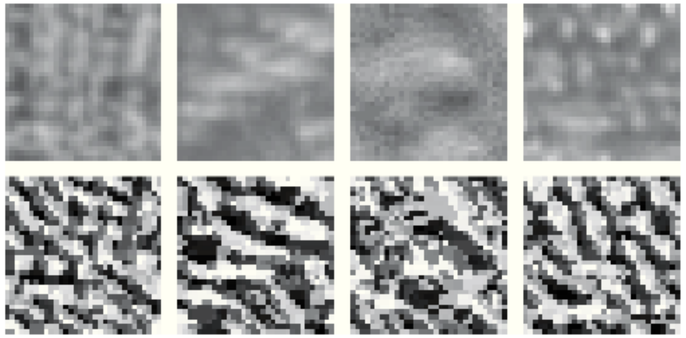
Feature Extraction

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



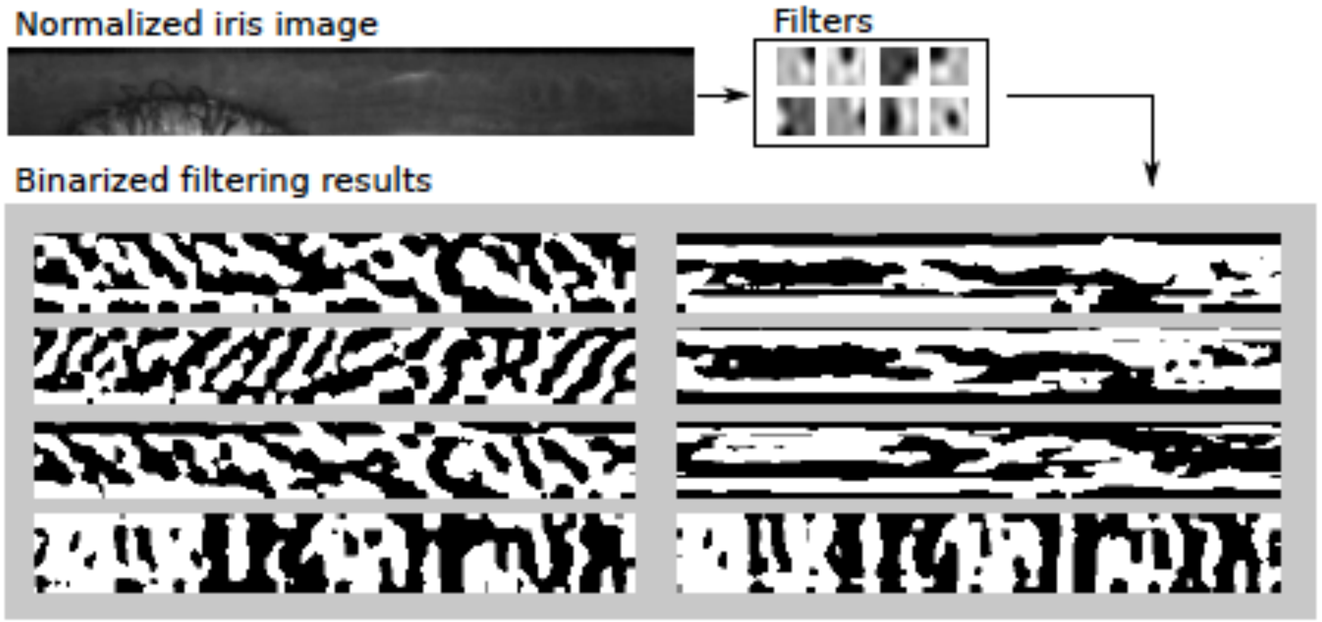
BSIF code examples

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



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Feature Extraction

BSIF Approach (3/3)

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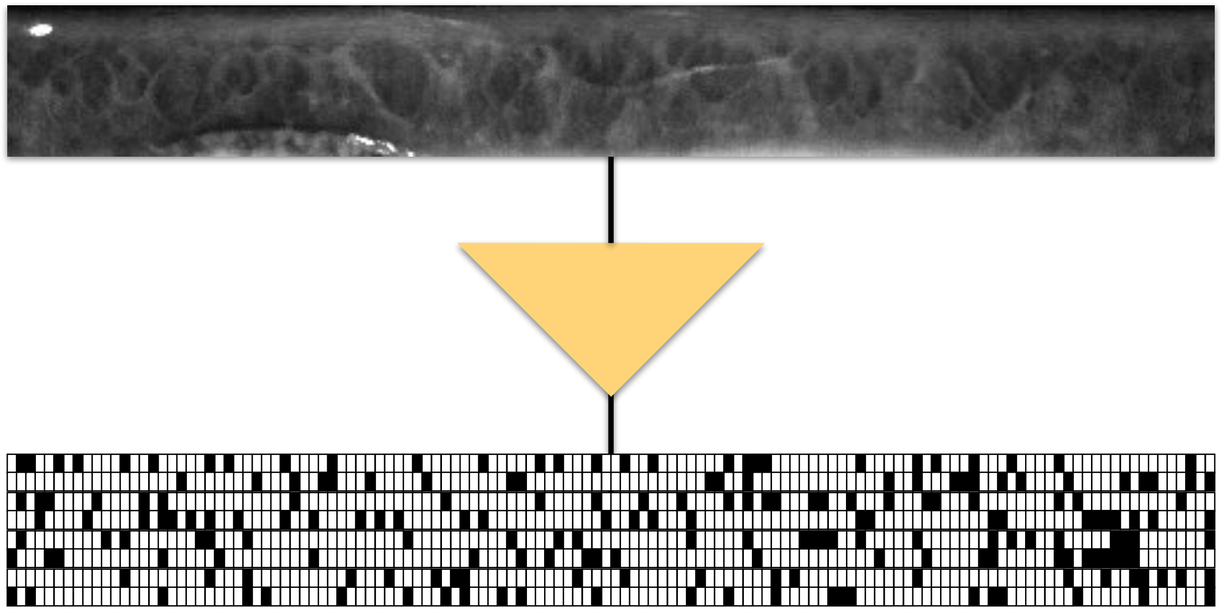
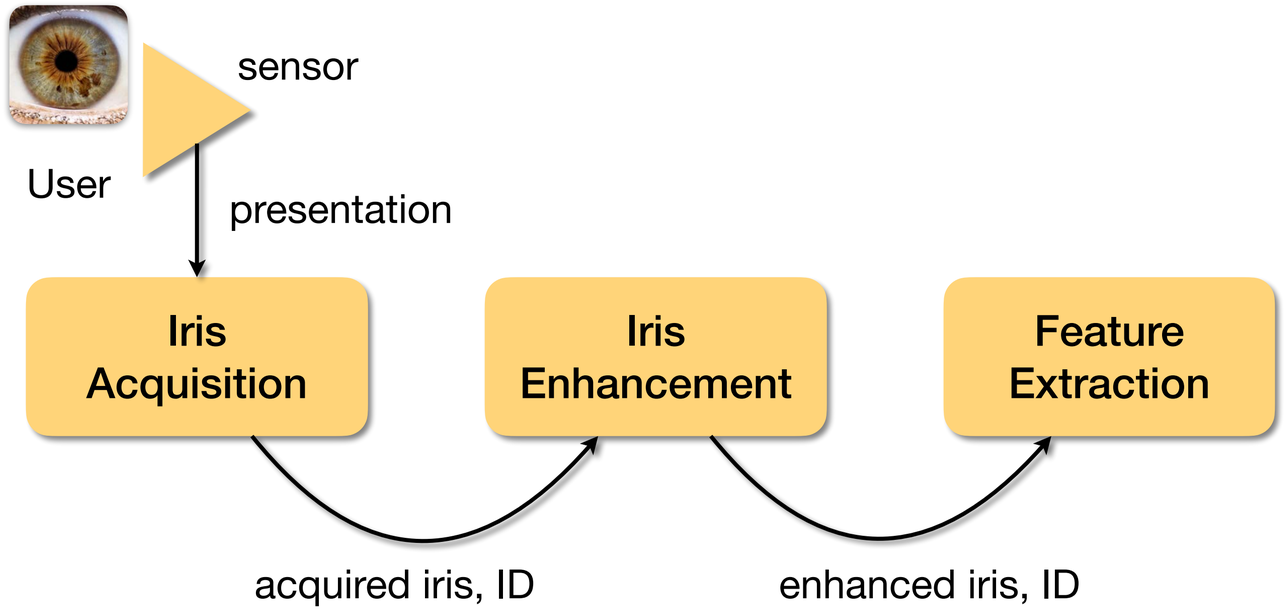
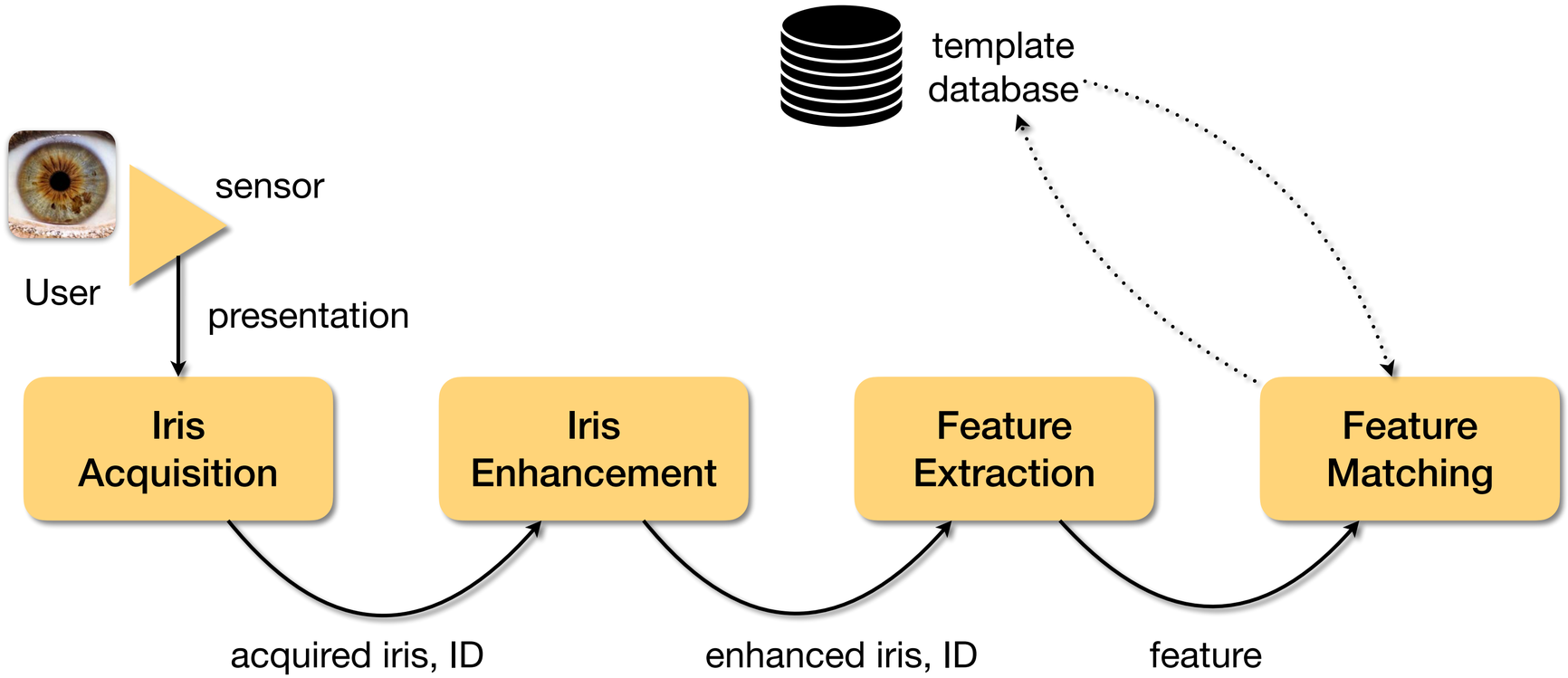


BSIF Code

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

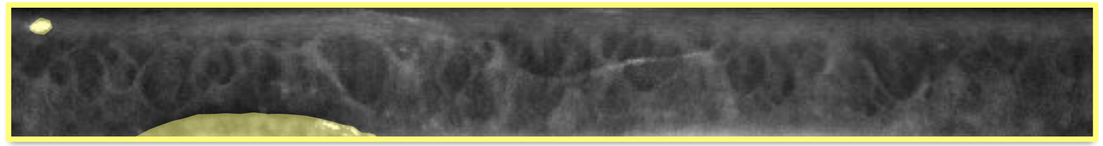
Distance = sum(**1 0 0 0 1 0 0 0 1 0 0 1 1 0 0 1**) = 6

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.

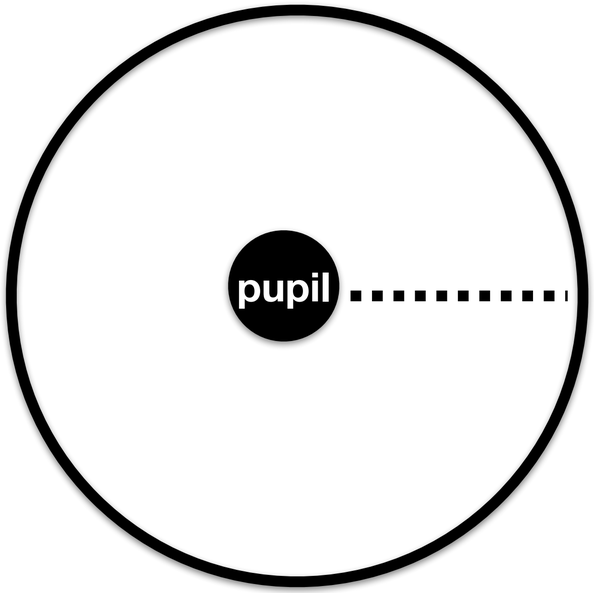
Feature Matching

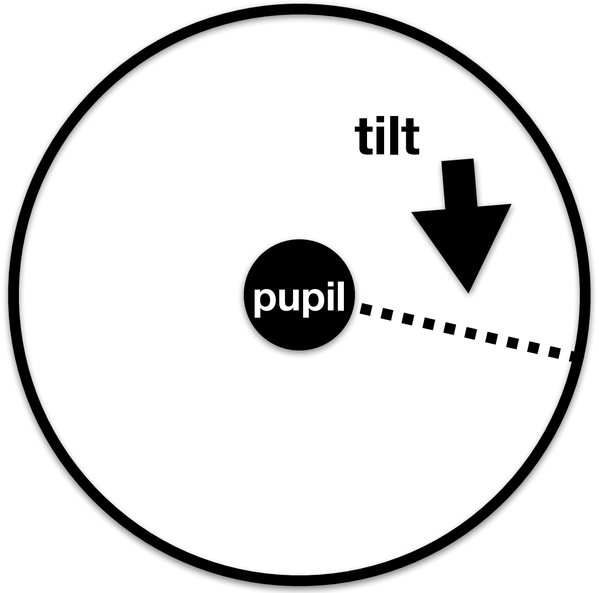
How to Compare Binary Codes?

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

Feature Matching

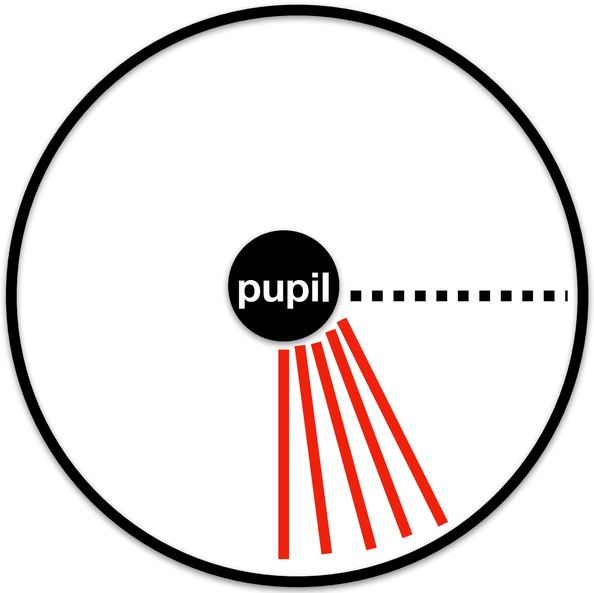
How to match with iris rotations?

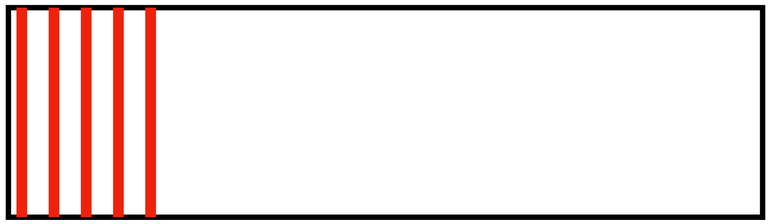


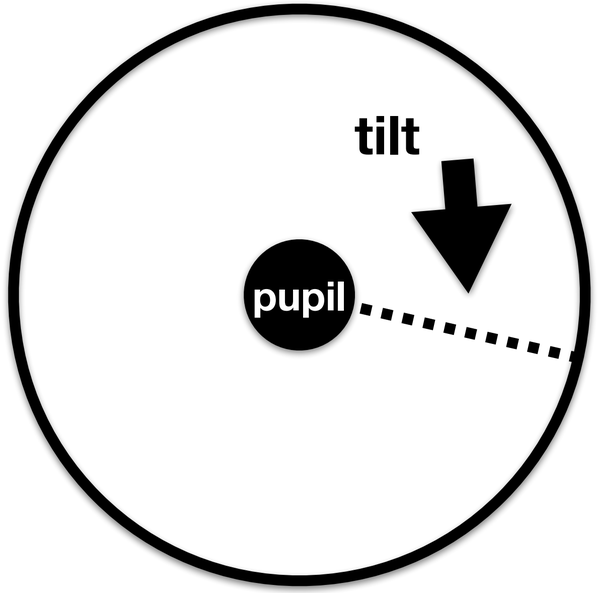


Feature Matching

How to match with iris rotations?

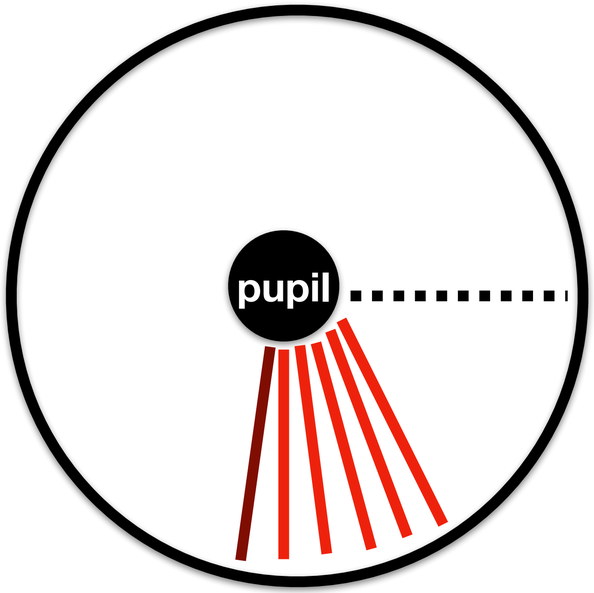


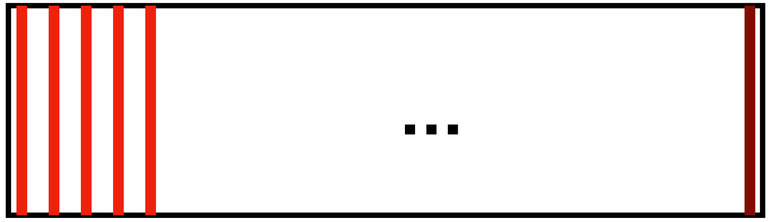


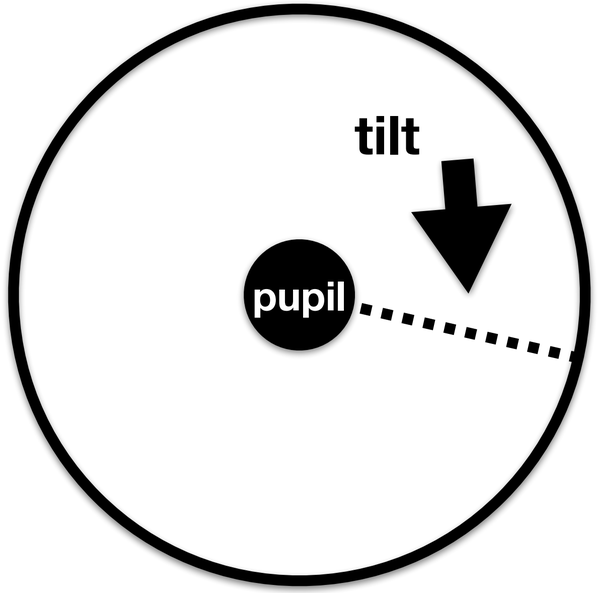


Feature Matching

How to match with iris rotations?

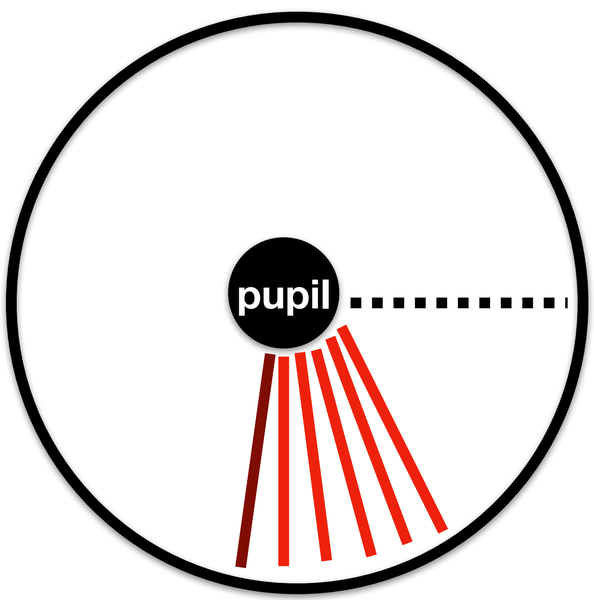


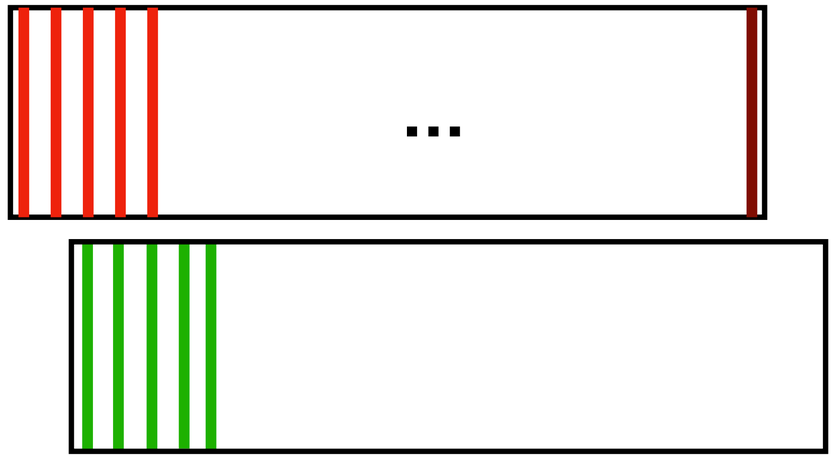


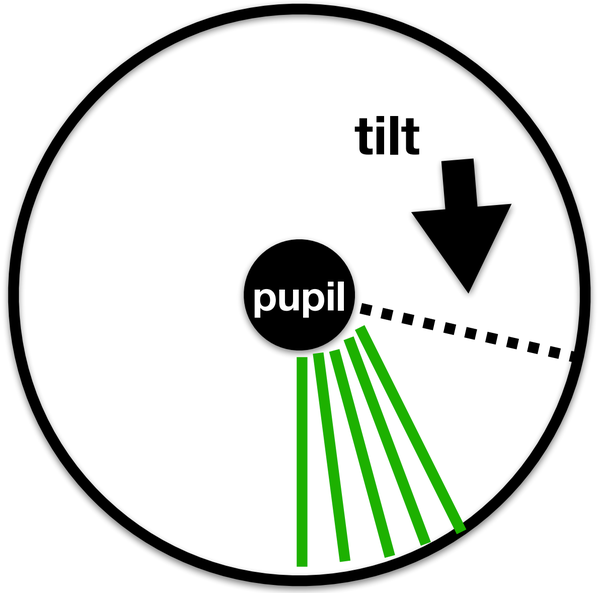


Feature Matching

How to match with iris rotations?

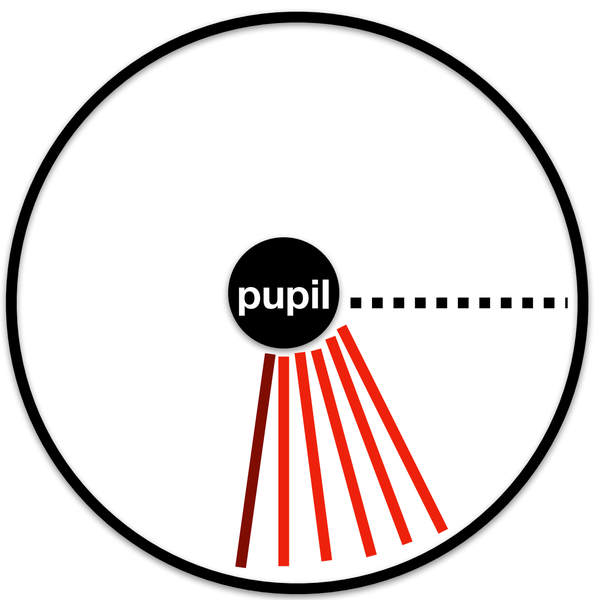


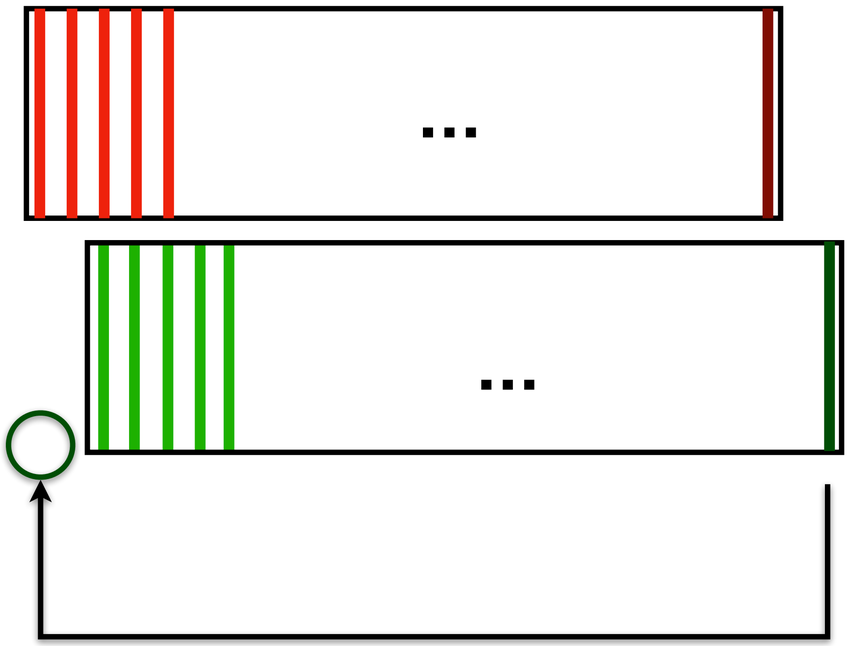




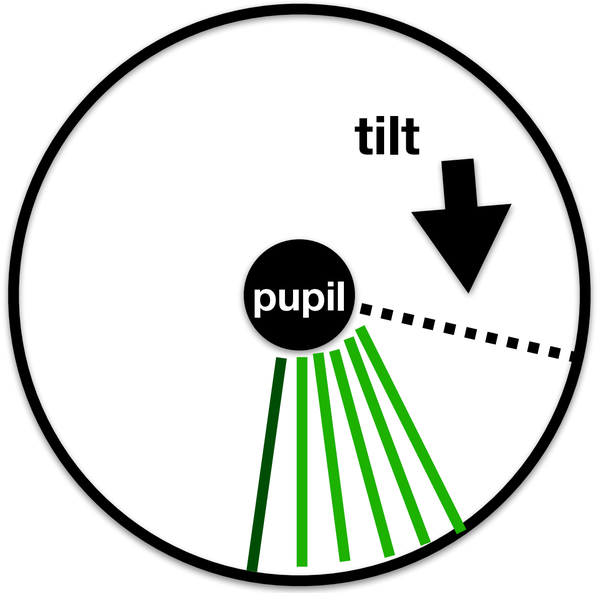
Feature Matching

How to match with iris rotations?



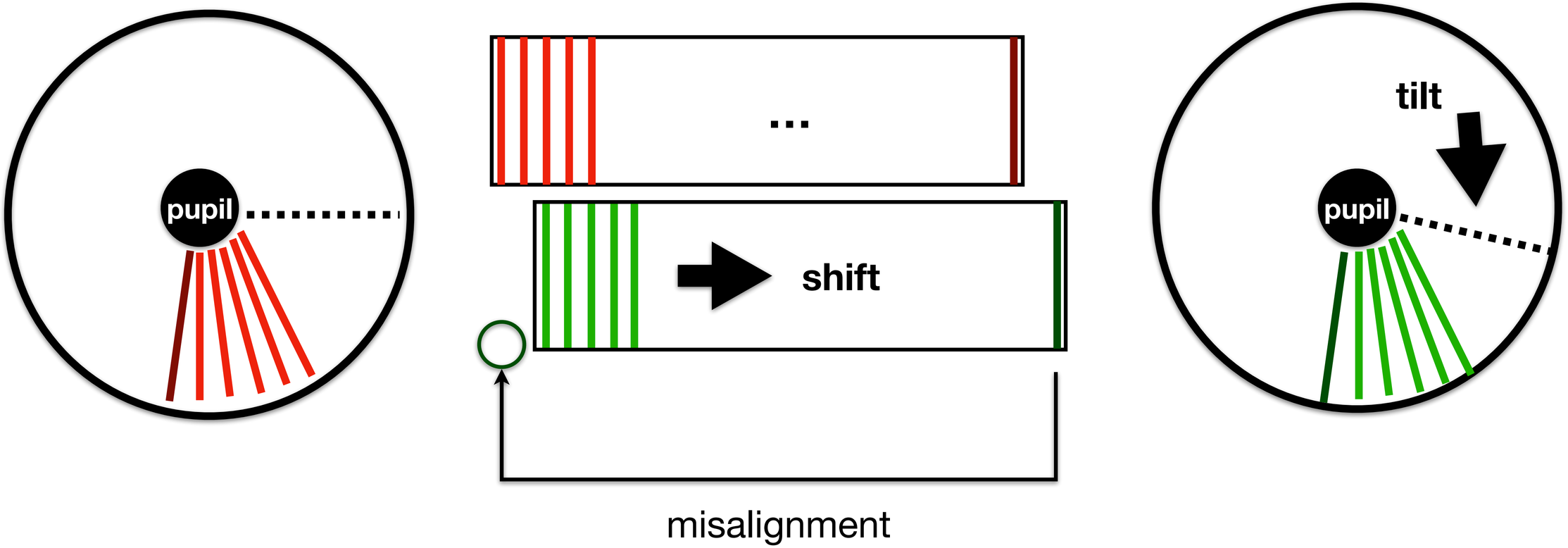


misalignment



Feature Matching

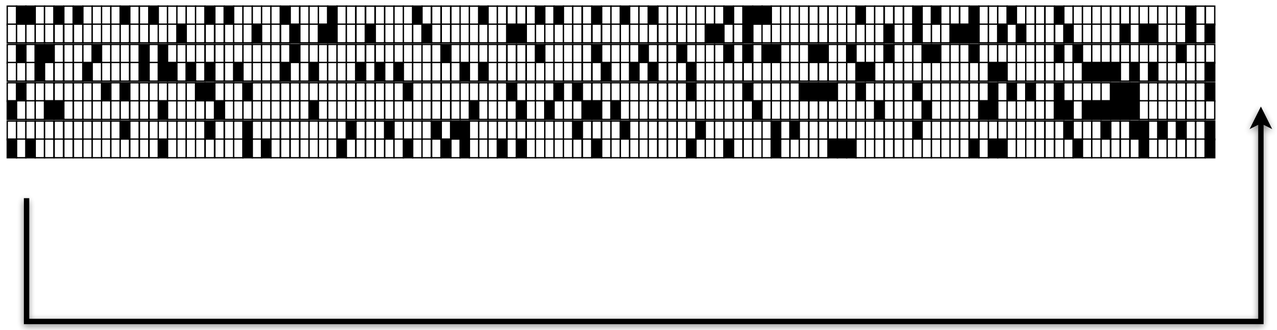
How to match with iris rotations?



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.



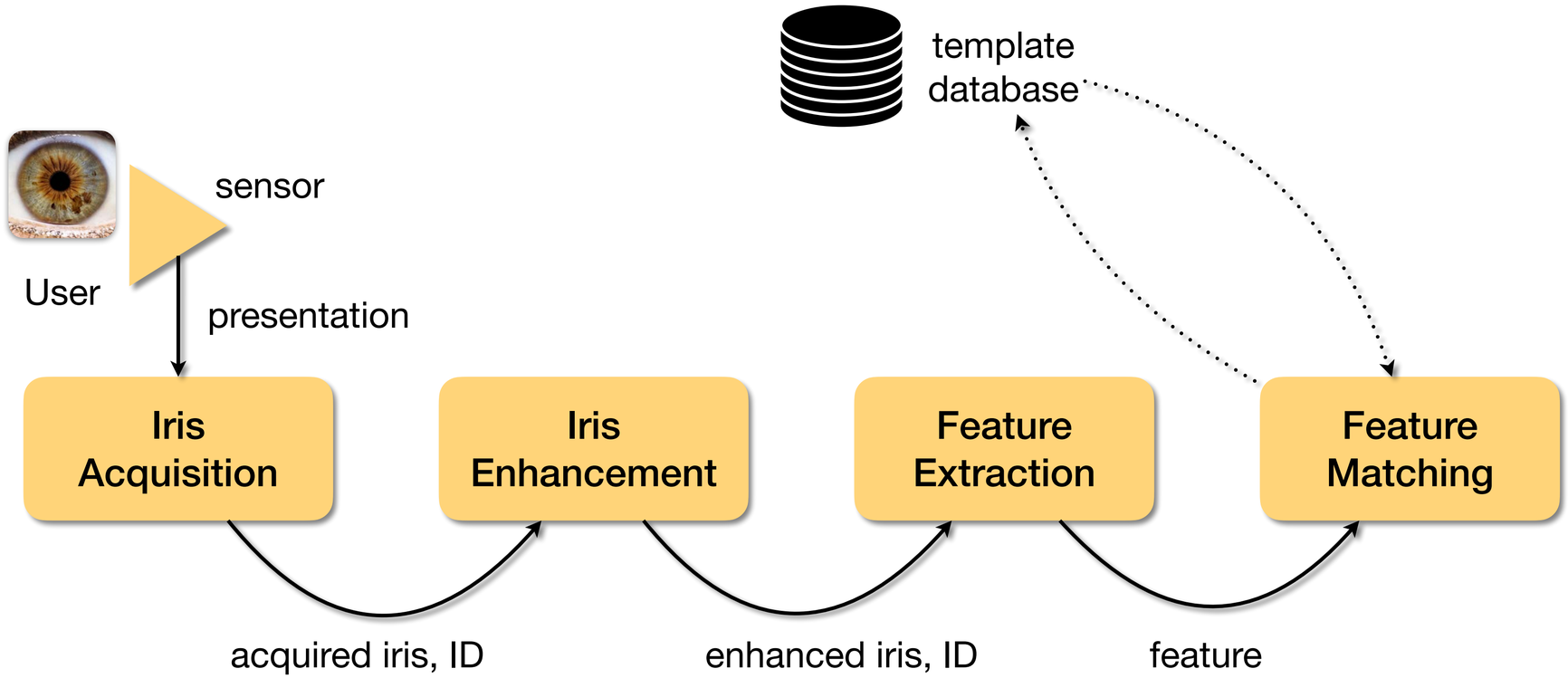
Feature Matching

How to Compare Binary Codes?

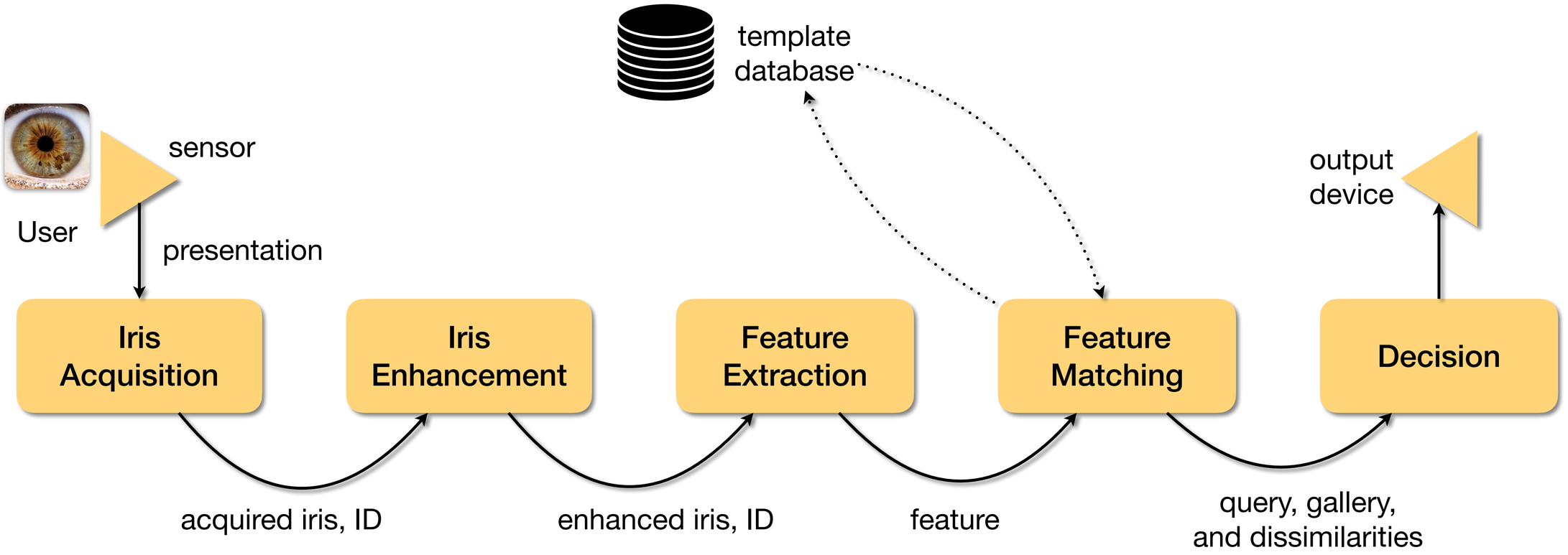
Problems (2/2)
How to deal with iris rotations?
Solution: provide different shifts
for one of the iris codes.
Compute various normalized
Hamming distances (one for each shift).

Take the smallest distance as the score.

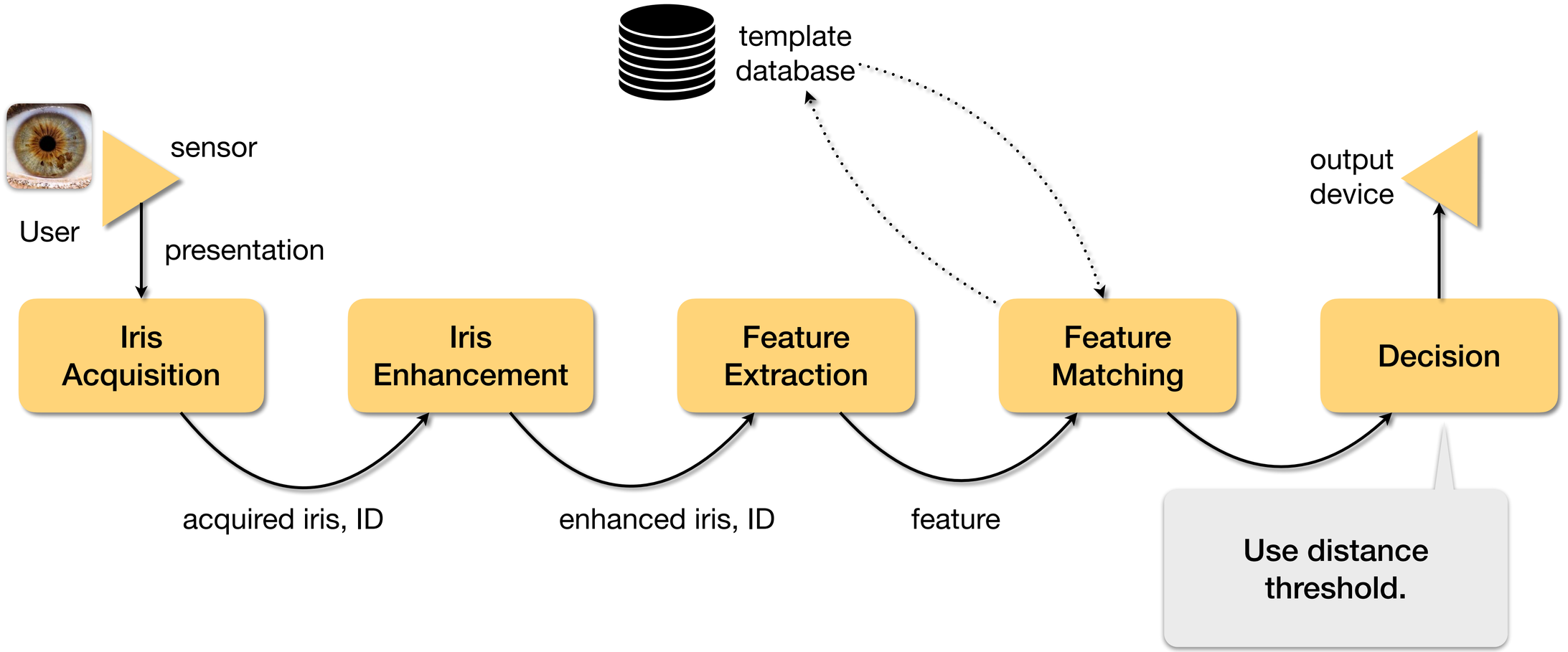
Iris Recognition



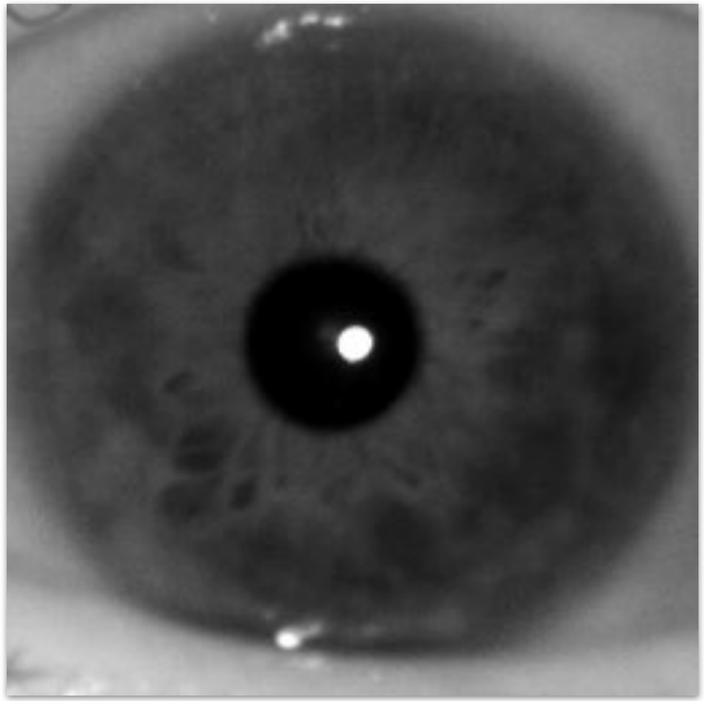
Iris Recognition



Iris Recognition



Domain-Specific BSIF Codes



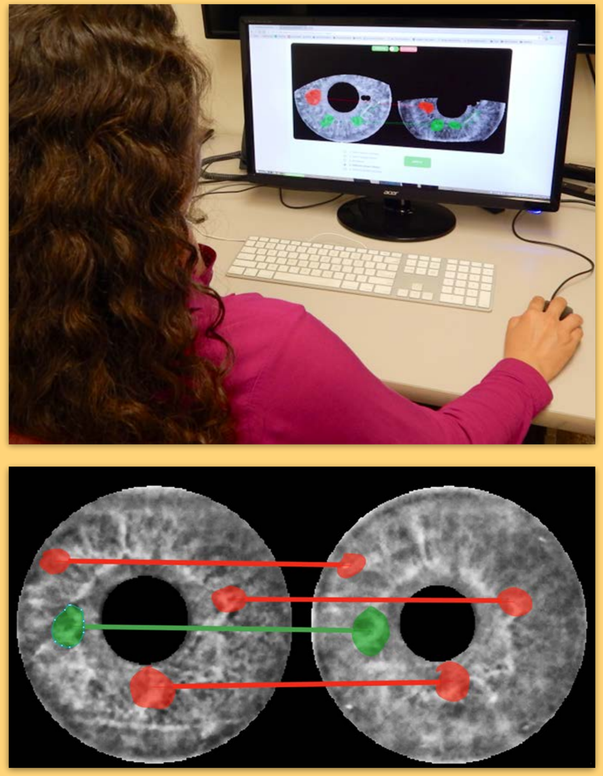
Original BSIF:
Natural images to learn filters.

What is the gain of learning from irises?

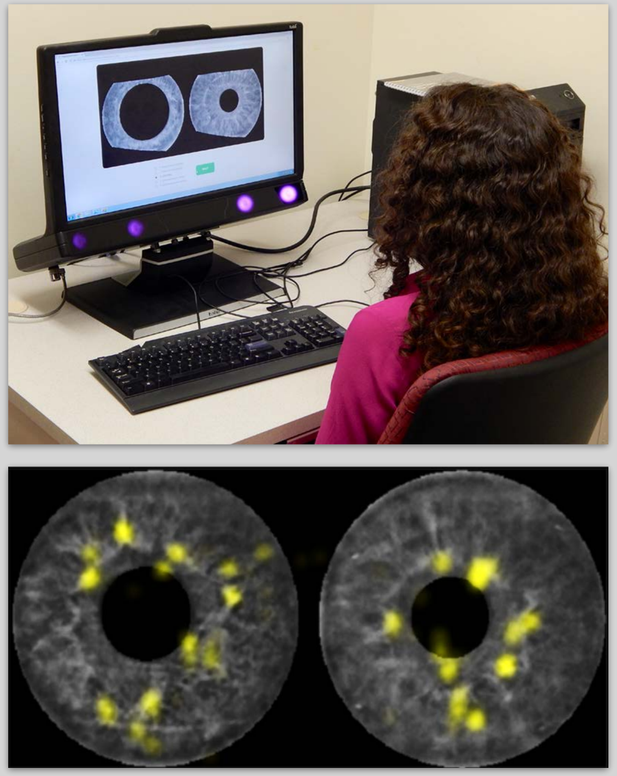
Domain-Specific BSIF Codes

How to Select Iris Patches?

Manual Annotation



Eye-Tracker Data

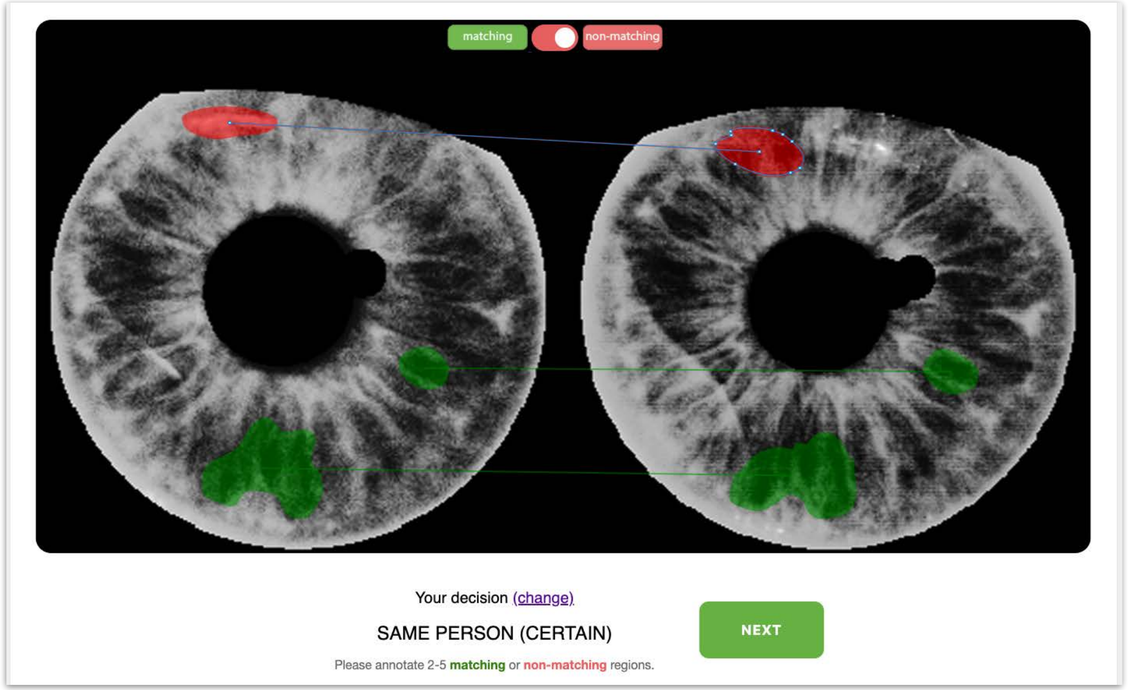


Domain-Specific BSIF Codes

Annotation Tool

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

Paper.js
Web-browser drawing library.



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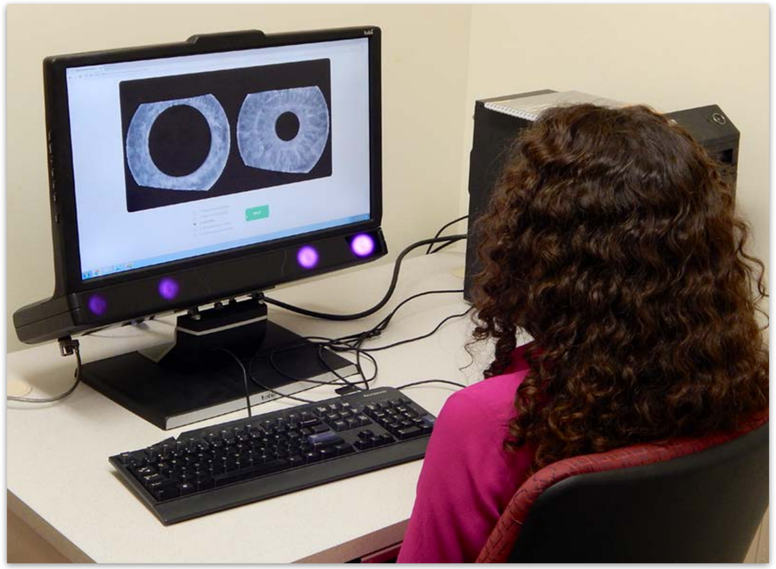
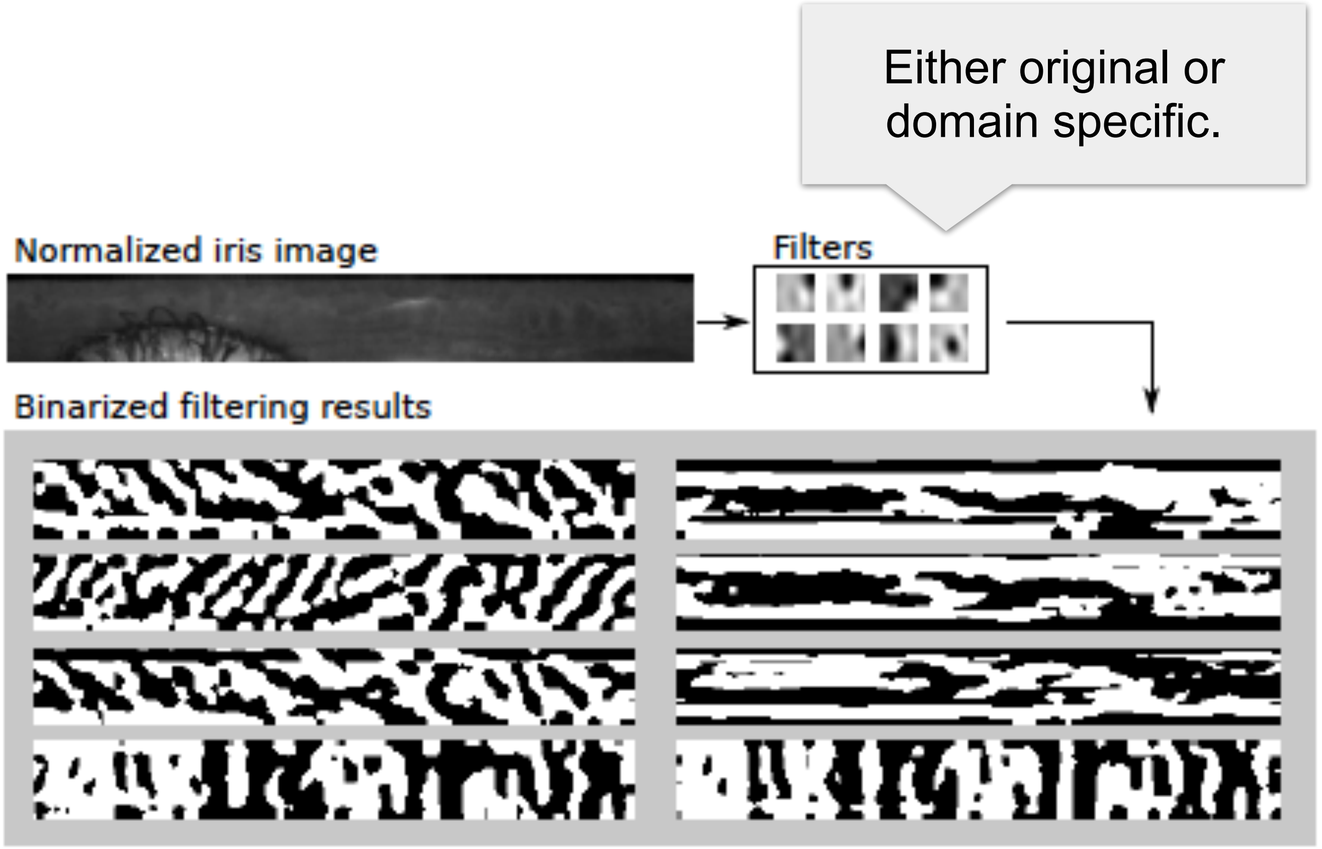
Domain-Specific BSIF Codes

Eye Tracker



Domain-Specific BSIF Codes

Application



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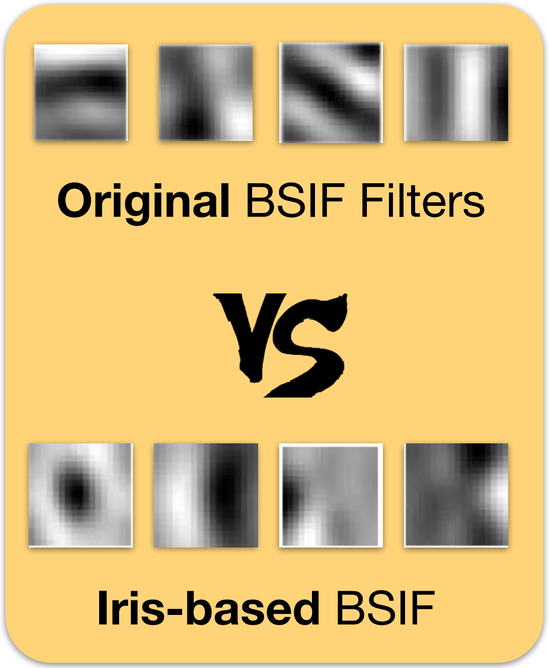
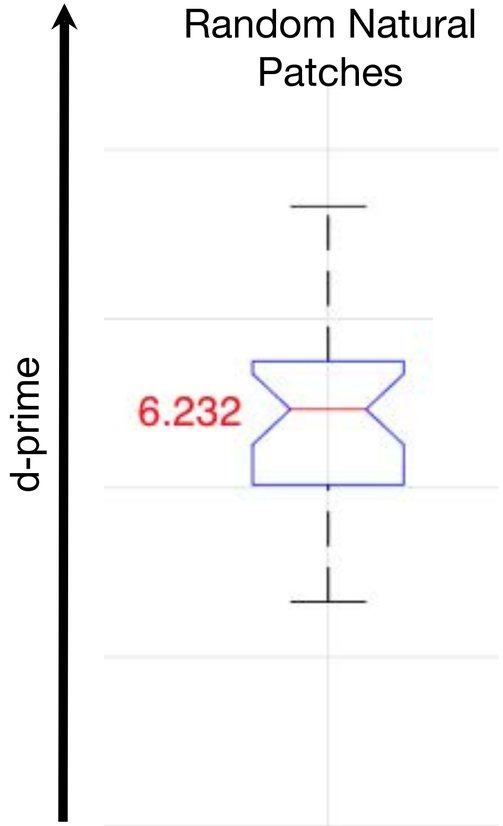
WACV 2019

Domain-Specific BSIF Codes

Results





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Domain-Specific BSIF Codes

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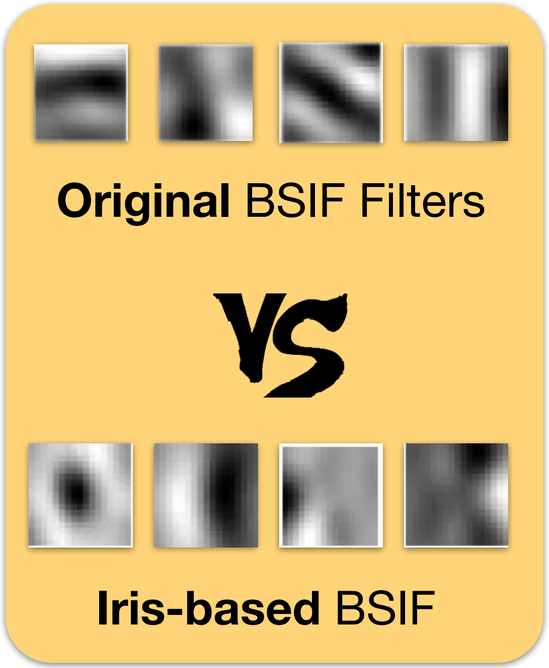

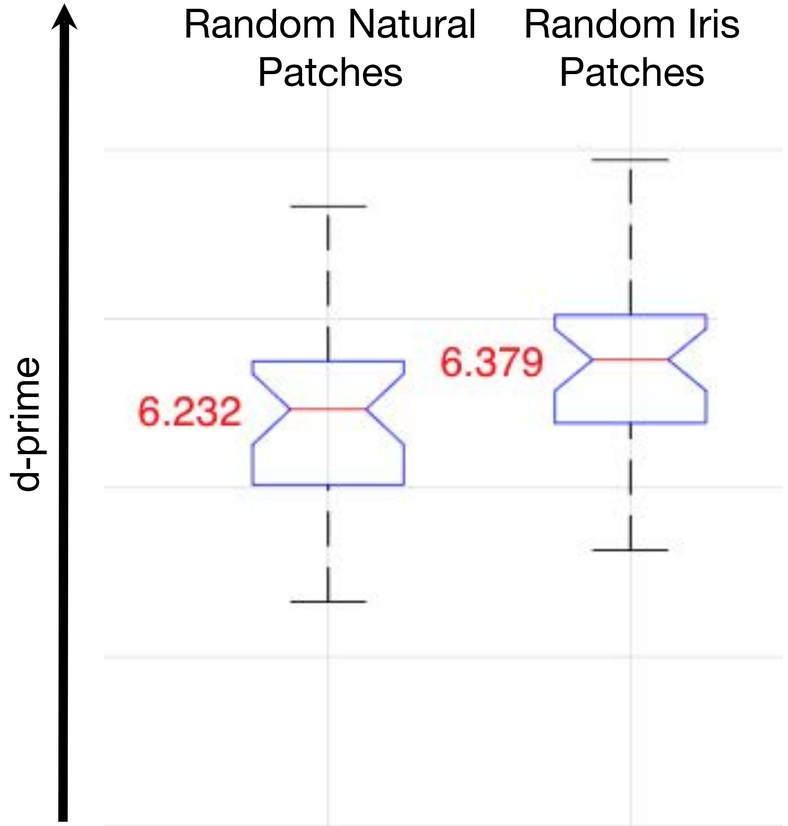

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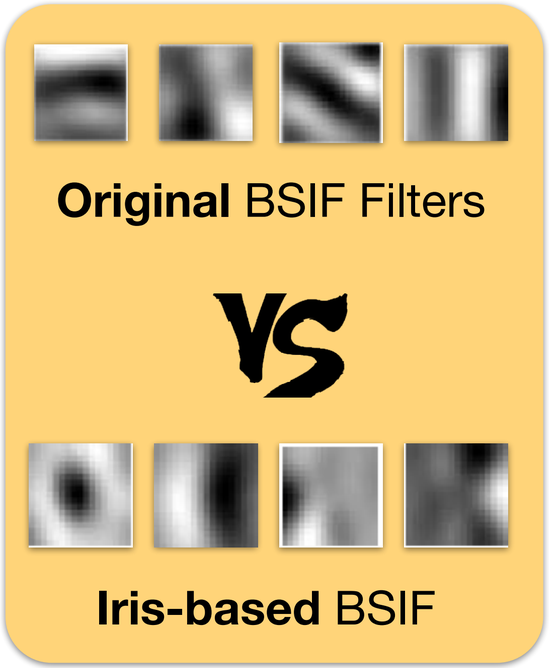

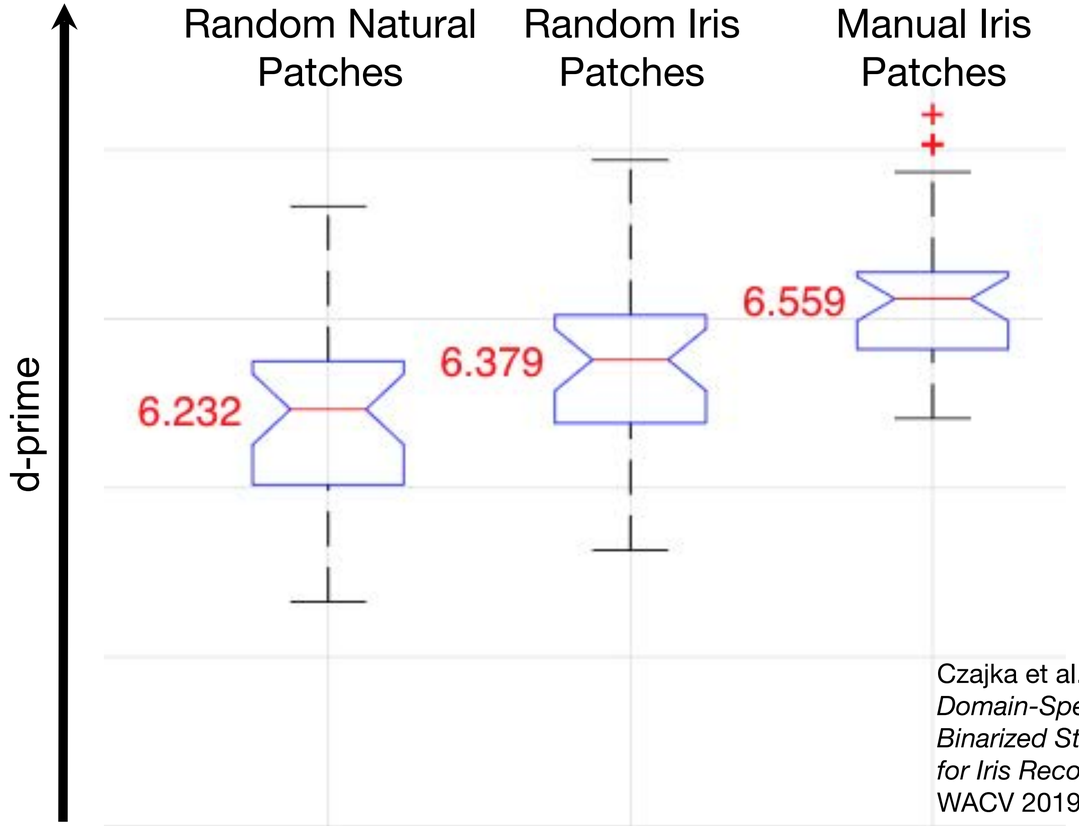

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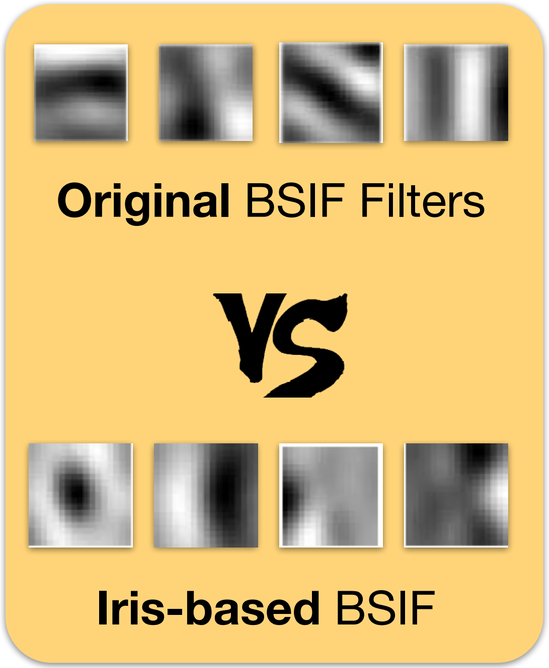

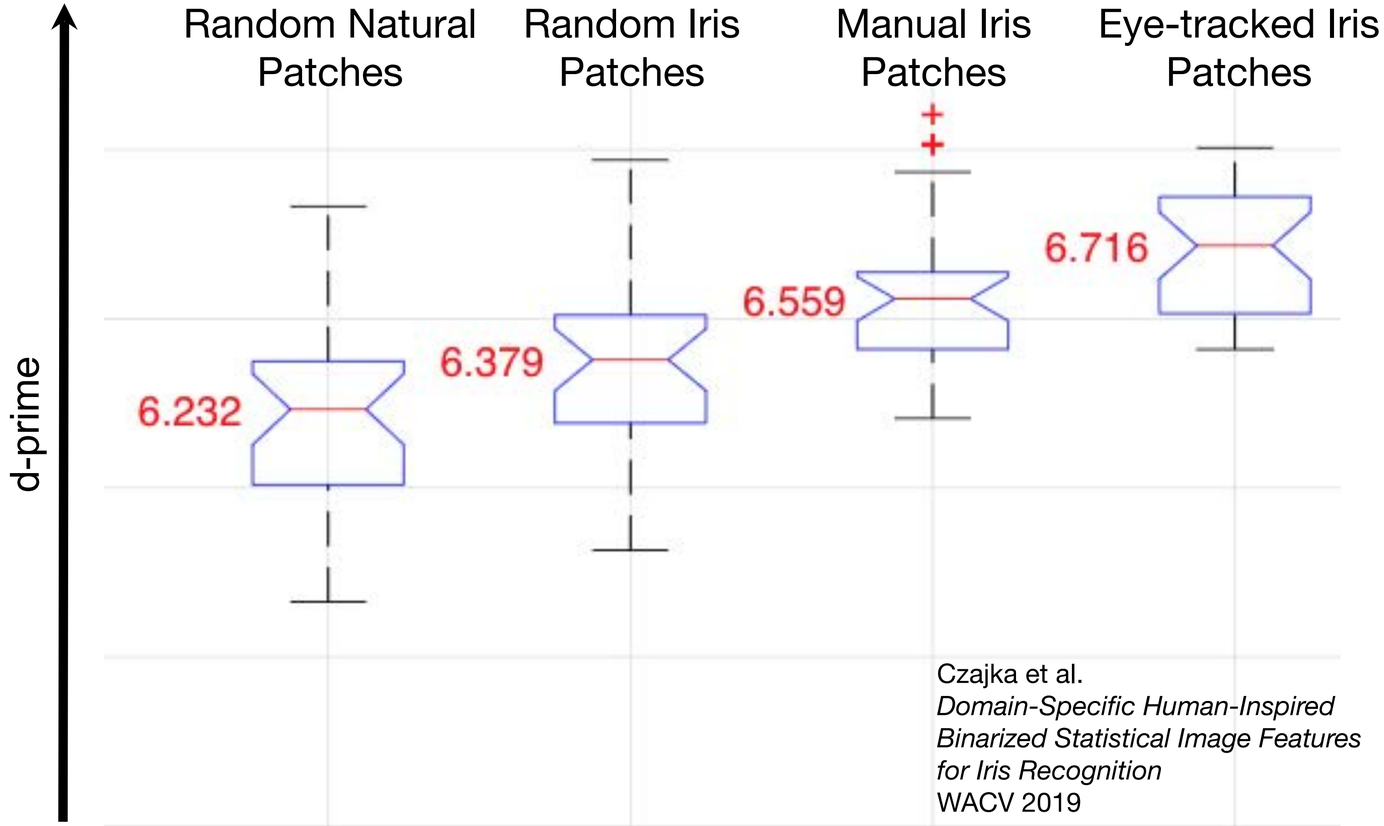

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Coding Class

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