Iris Recognition III

COMP 388-002/488-002 Biometrics

Daniel Moreira

Fall 2026



LOYOLA
UNIVERSITY CHICAGO

Today we will…

Get to know
Iris description and matching.

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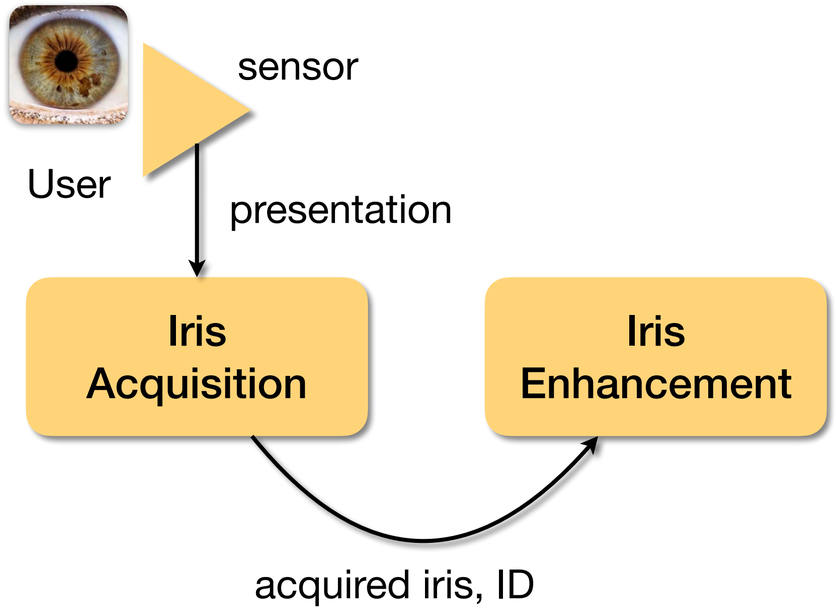
Today's Attendance

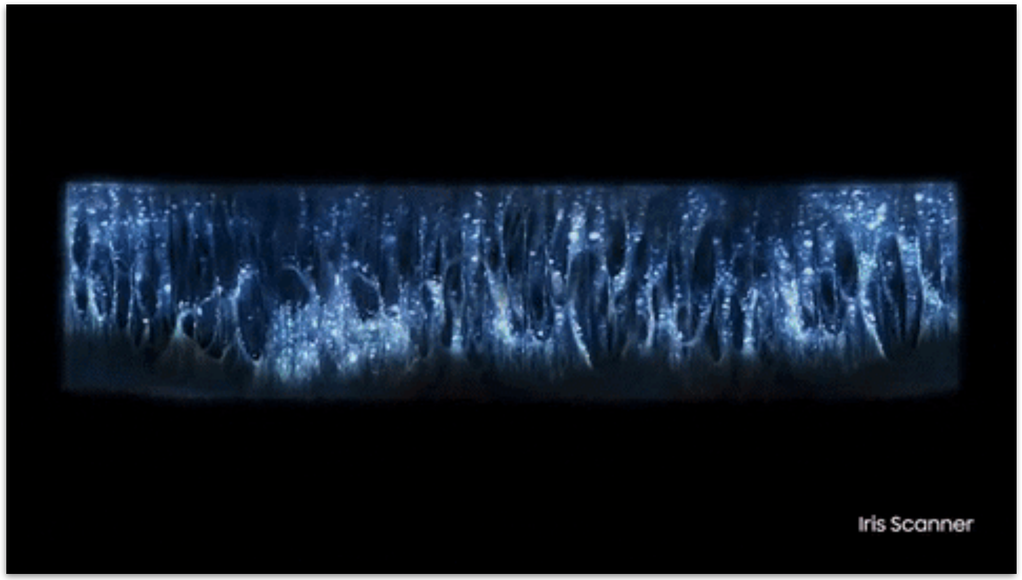
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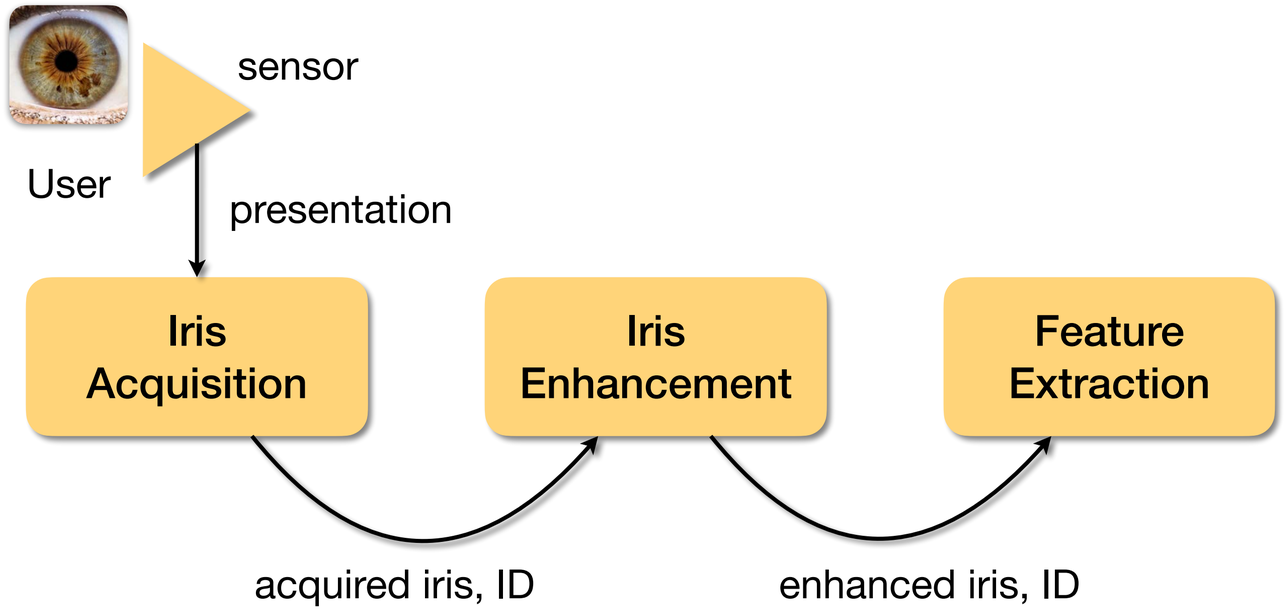
Iris Recognition





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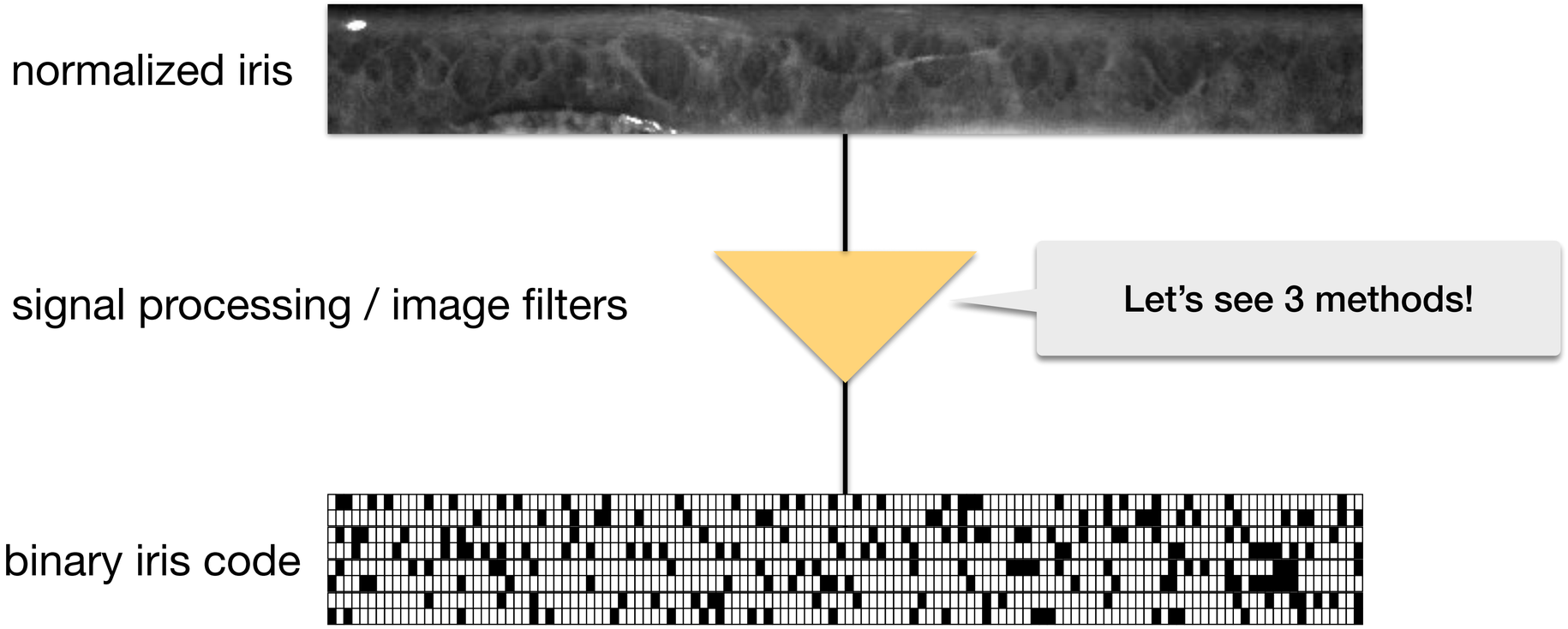
Iris Recognition



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Feature Extraction

Typical Description Framework



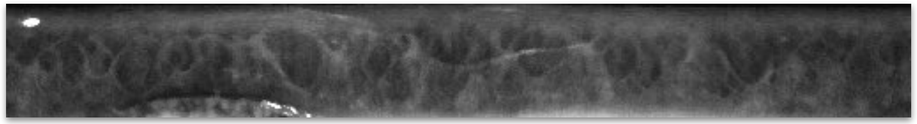
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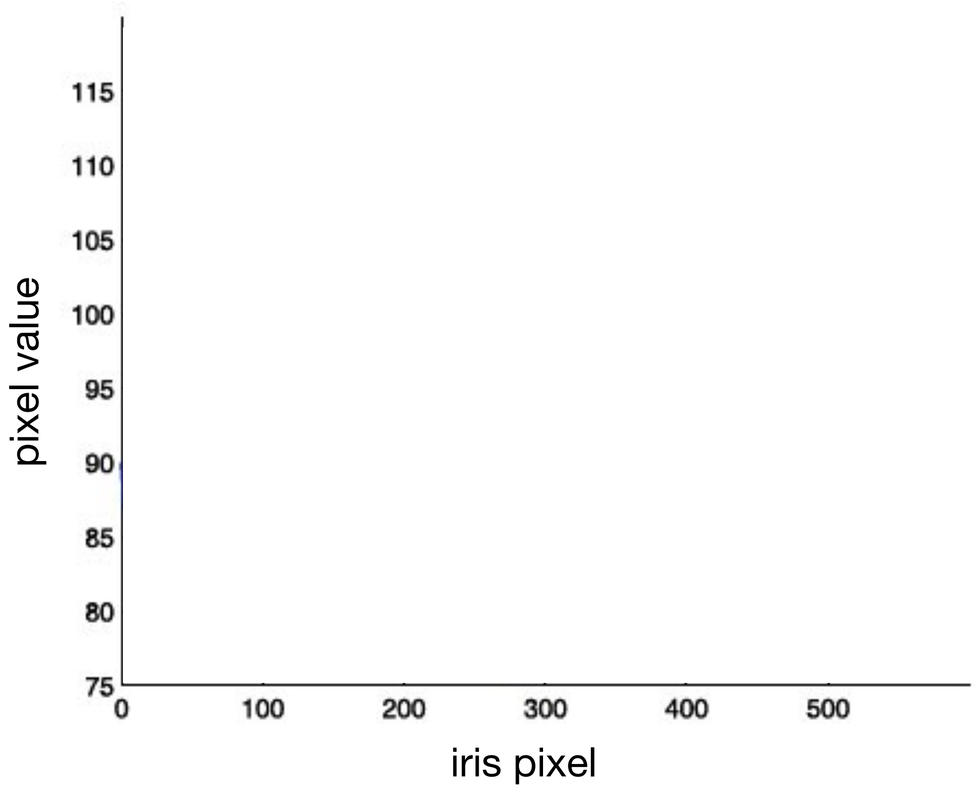
Feature Extraction

Zero-Crossing Approach (1/3)

Proposed by W. W. Boles.

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





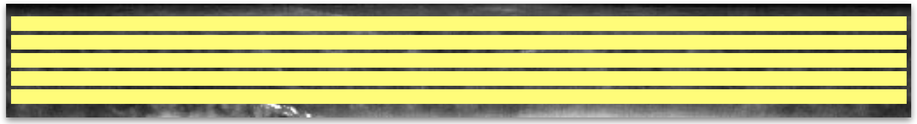
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Feature Extraction

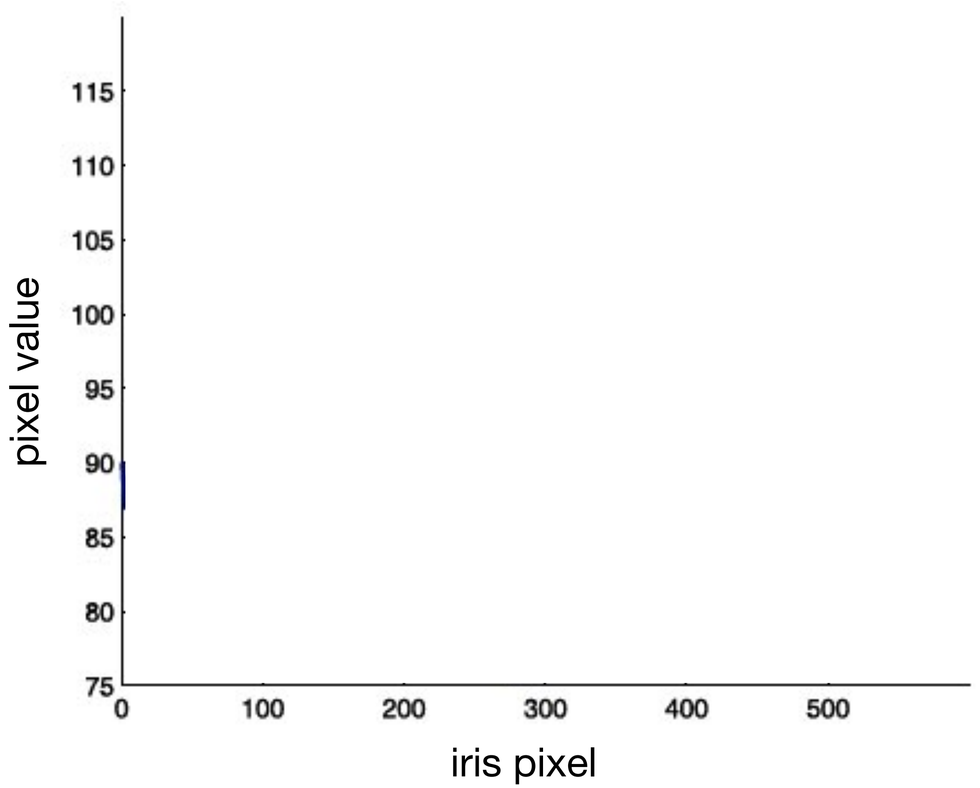
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Dr. Adam Czajka



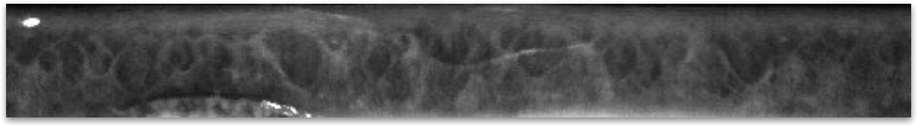
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Feature Extraction

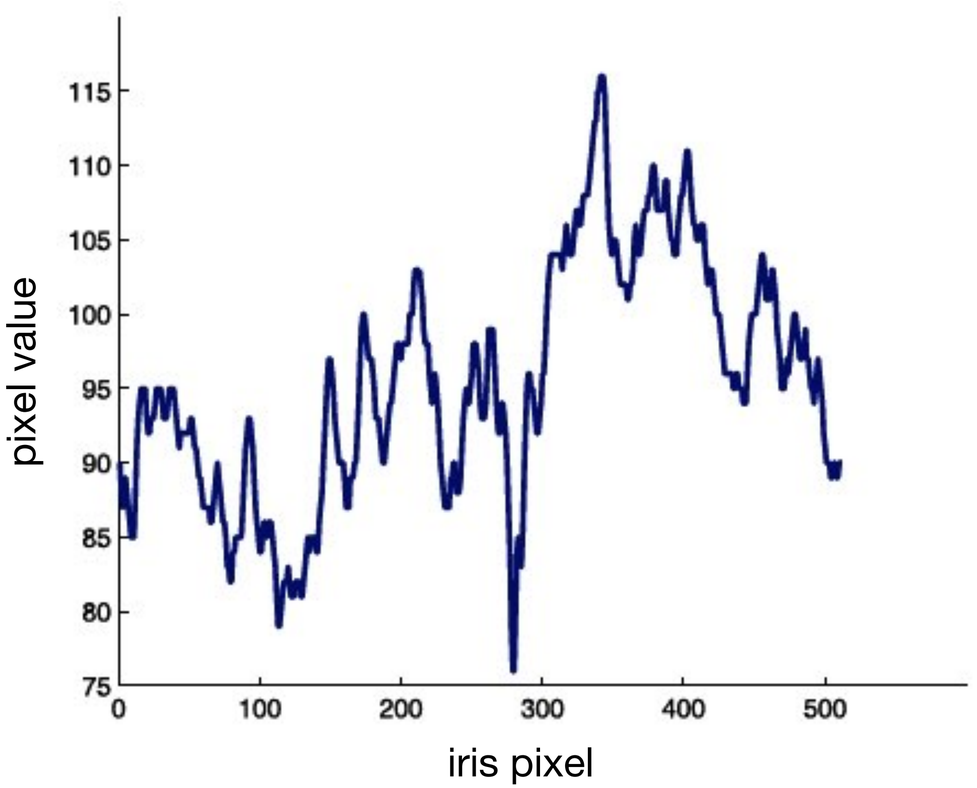
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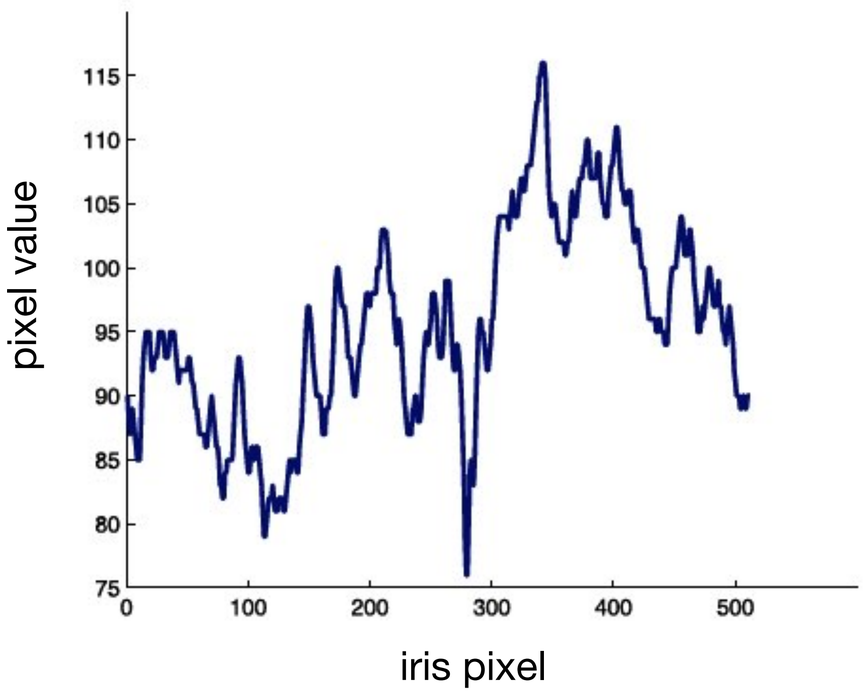


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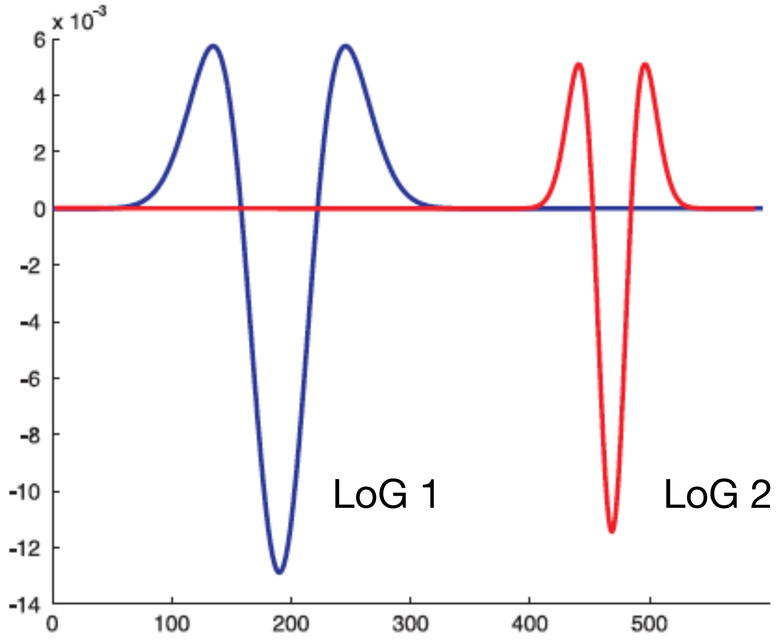
Feature Extraction

Zero-Crossing Approach (1/3)

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



Laplacians of Gaussians



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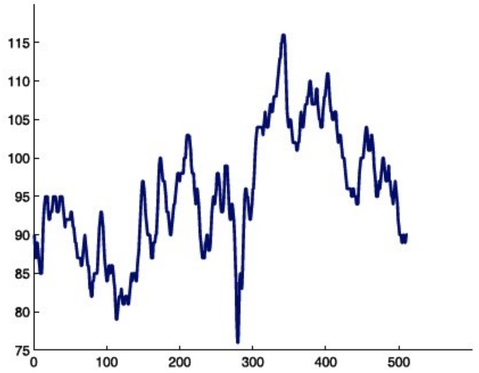
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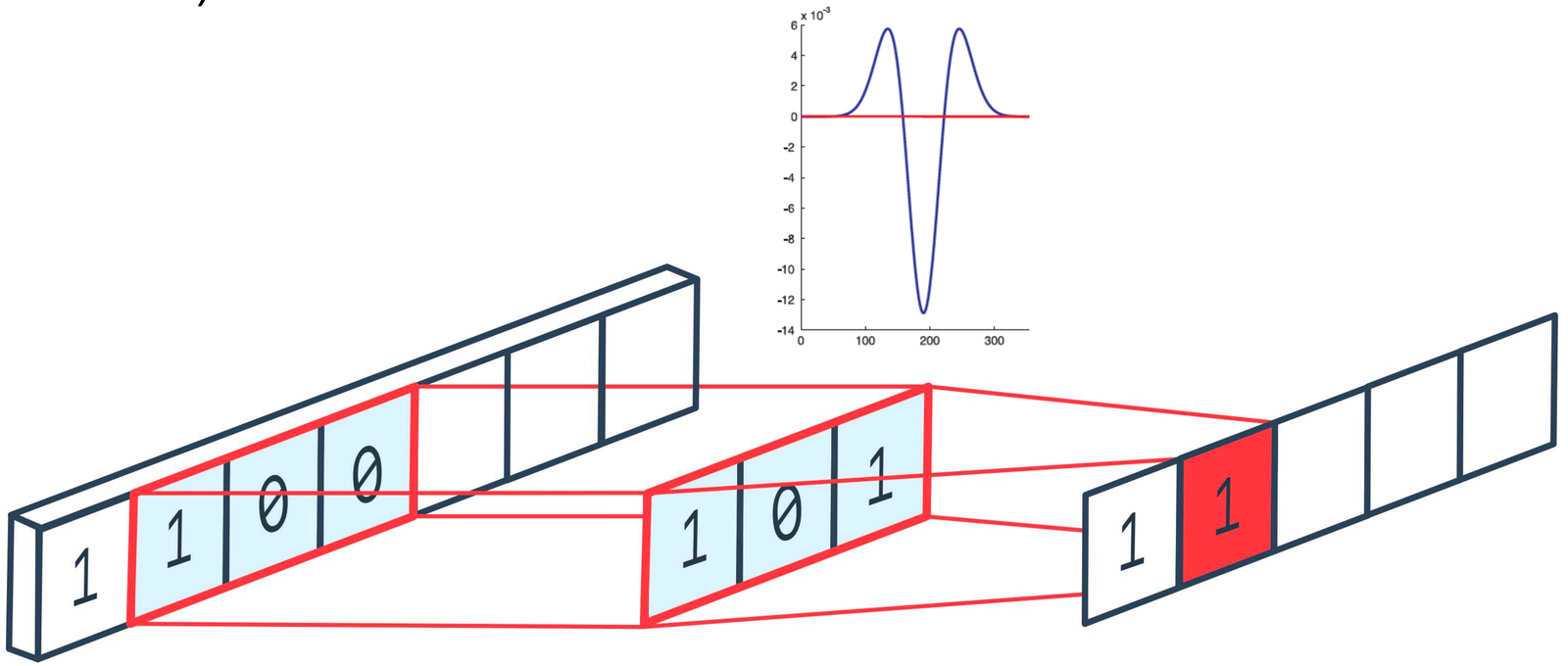
Feature Extraction

Zero-Crossing Approach (1/3)

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

1D Convolution



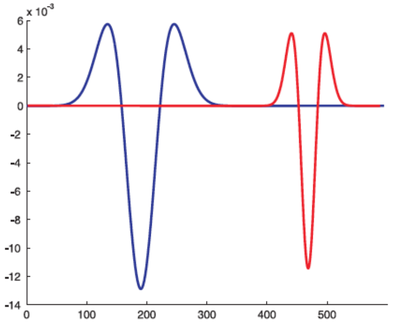


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Feature Extraction

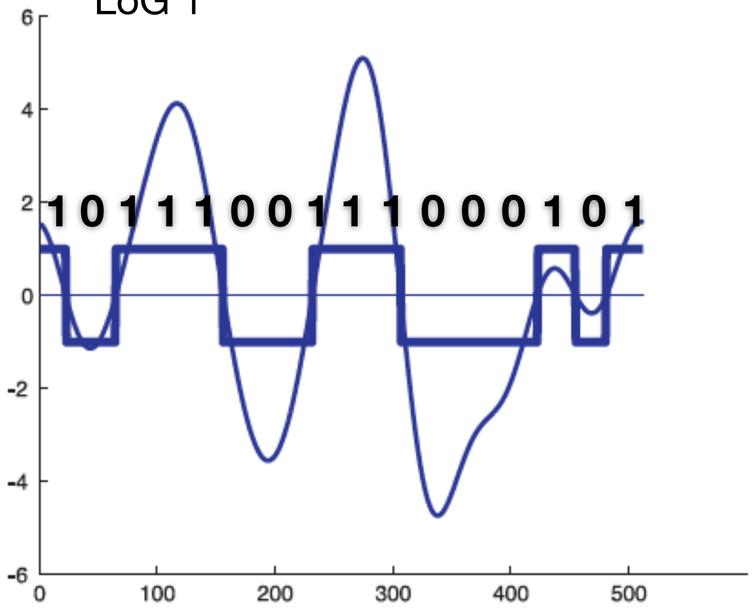
Zero-Crossing Approach (1/3)

LoG 1 LoG 2

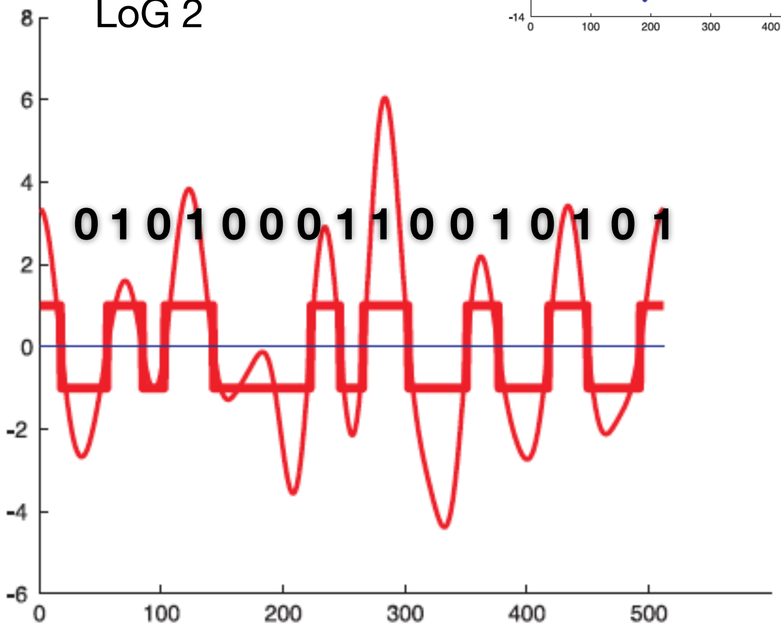


2. Zero-crossings lead to bits up; everything else is zero.

LoG 1



LoG 2

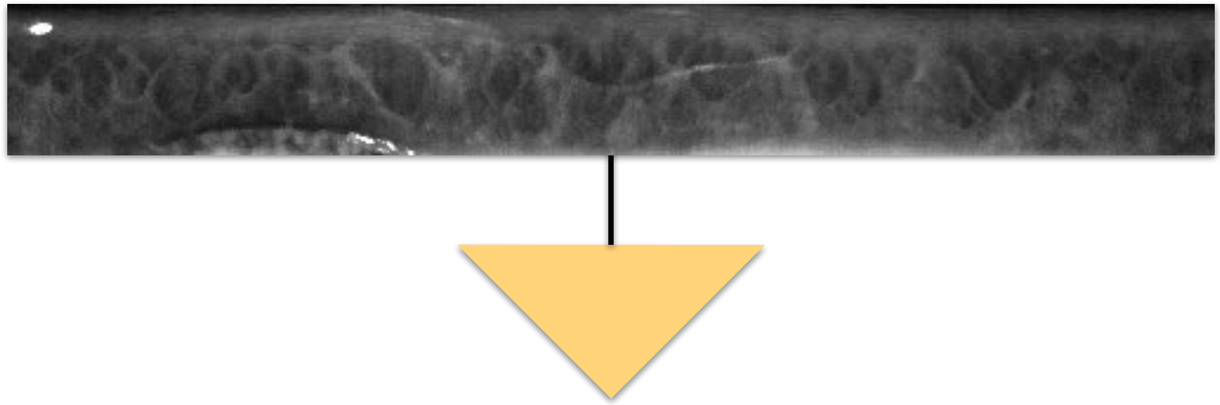


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Feature Extraction

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

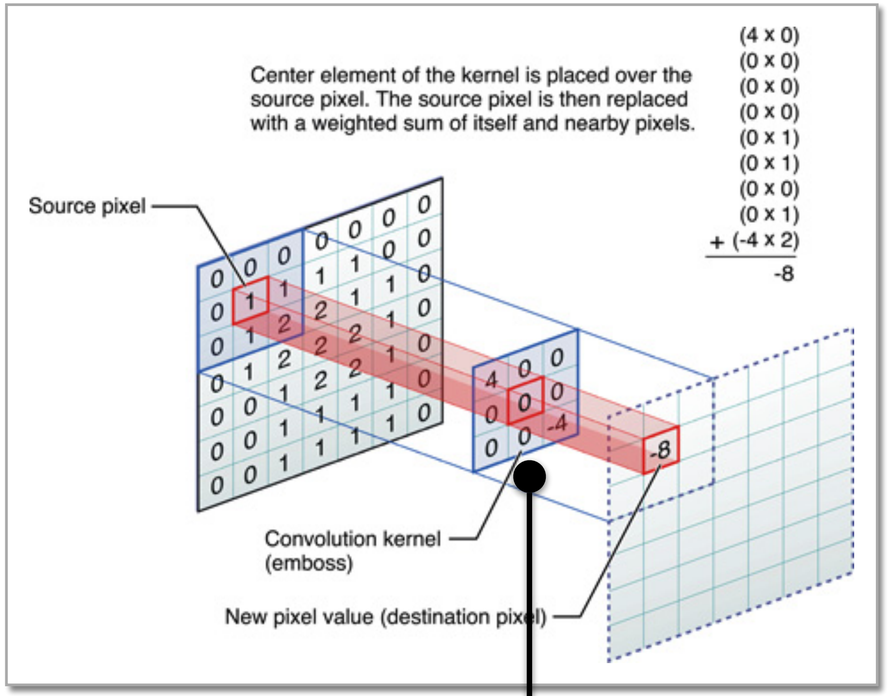
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Feature Extraction

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

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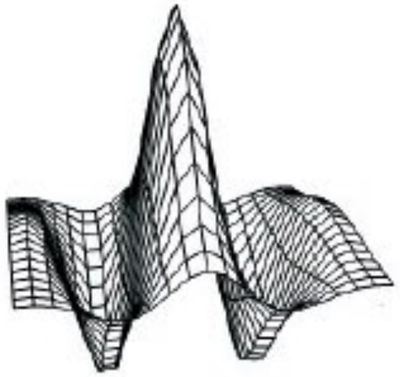
Feature Extraction

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

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

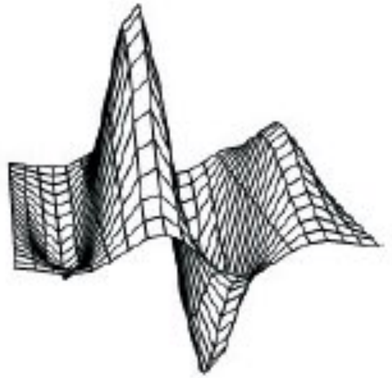
Gabor wavelets are a good model of neural receptive fields found in the visual cortex.

Filter 1



wavelet real component

Filter 2



wavelet imaginary component

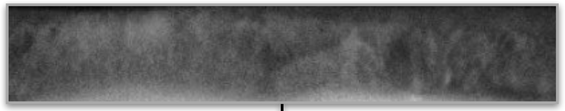
J. Daugman
Probing the Uniqueness and Randomness of IrisCodes: Results from 200 Billion Iris Pair Comparisons.
IEEE Proceedings, 2006

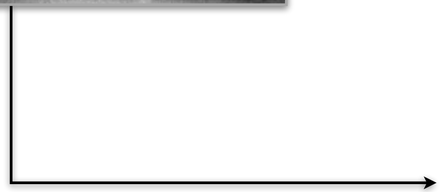
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Feature Extraction

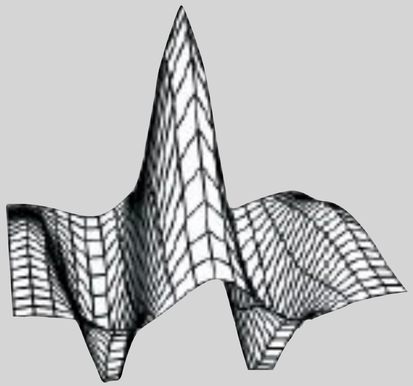
2D-Gabor Filtering Approach (2/3)

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





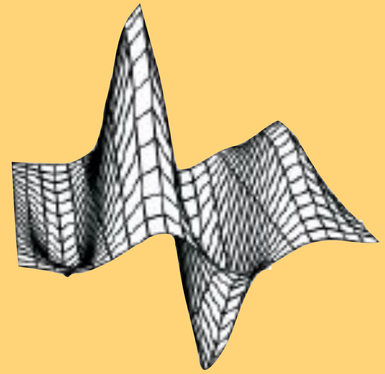
Filter 1



wavelet real component



Filter 2



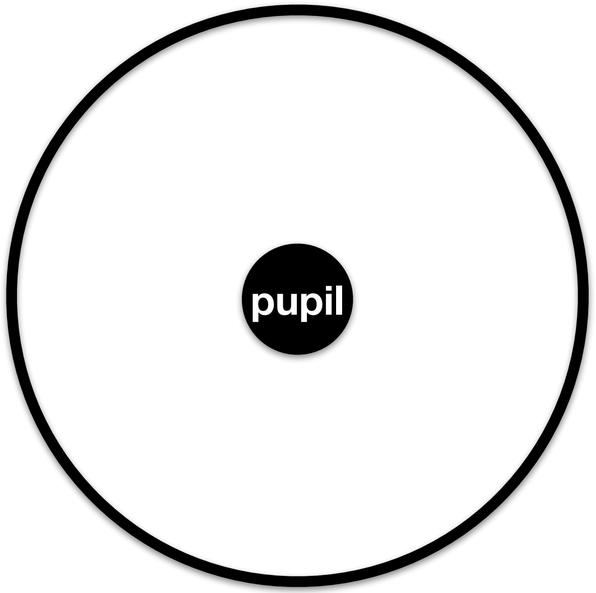
wavelet imaginary component

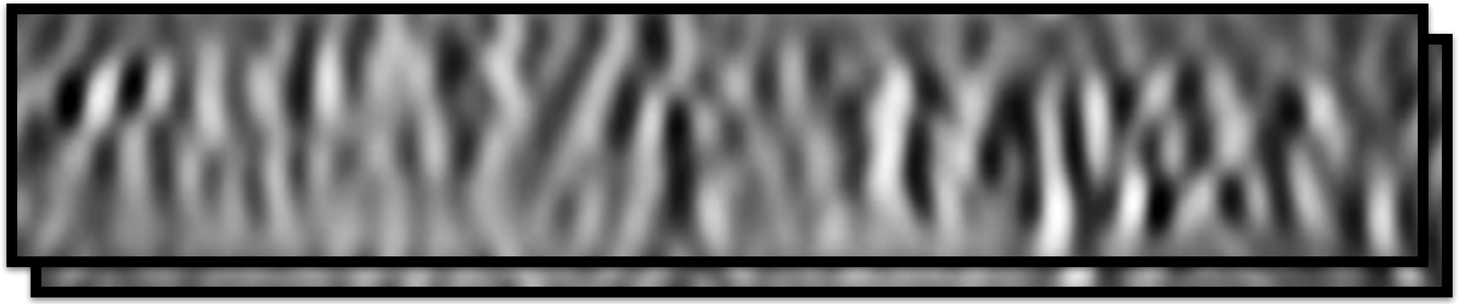


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Feature Extraction

2D-Gabor Filtering Approach (2/3)

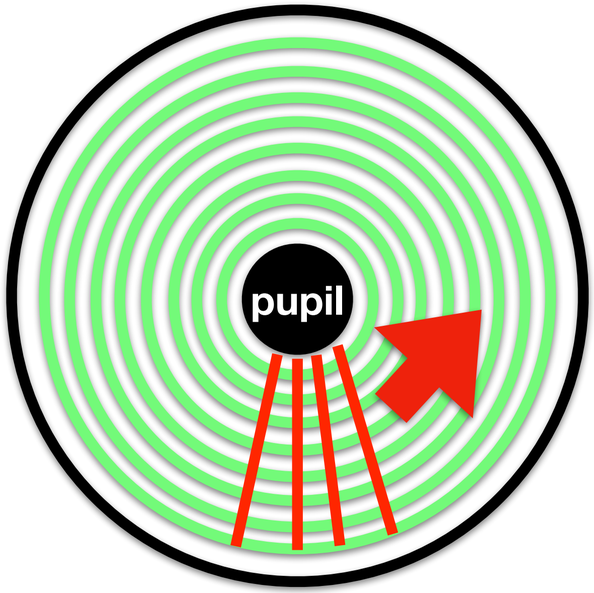


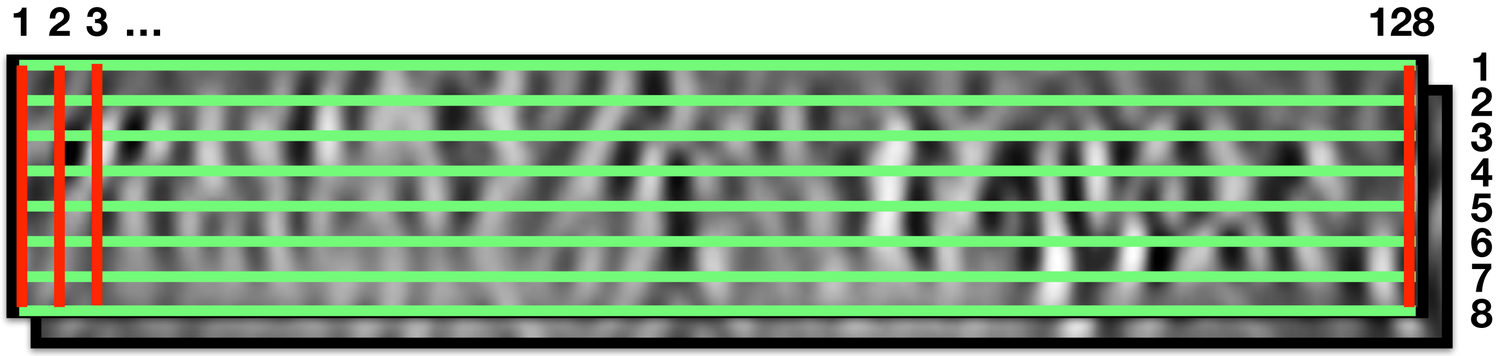


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Feature Extraction

2D-Gabor Filtering Approach (2/3)



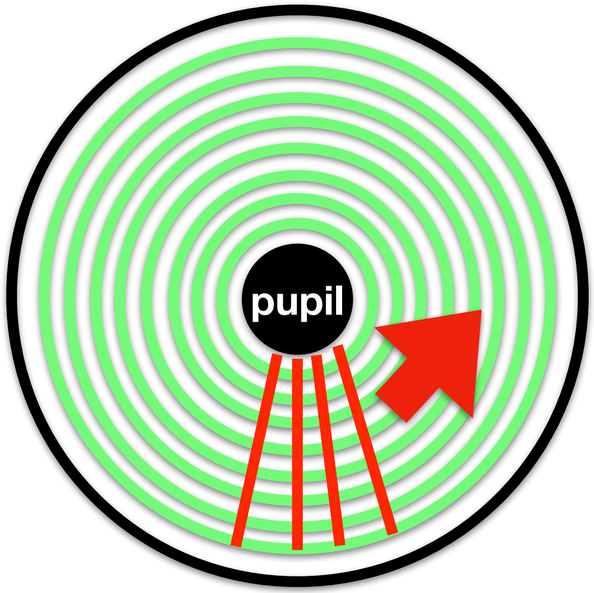


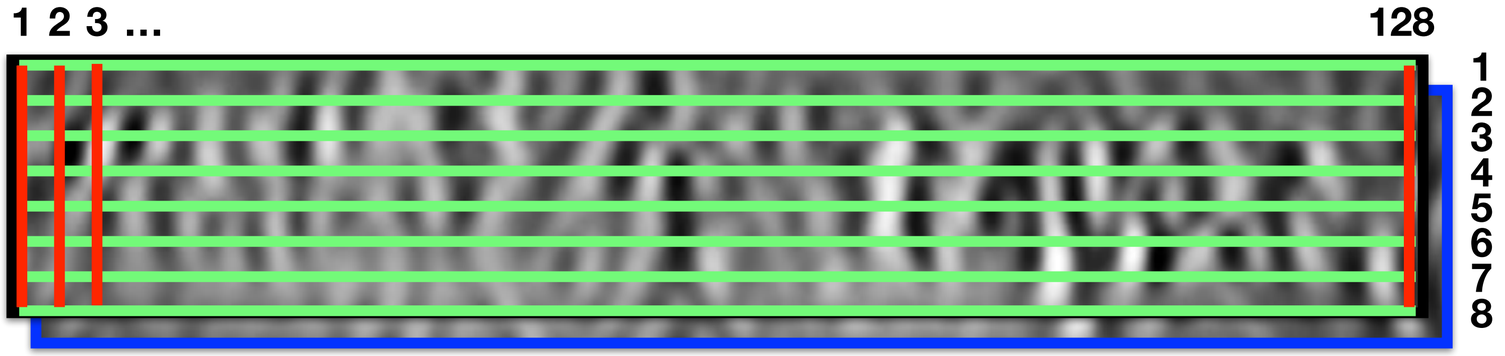
Number of cells: 8 x 128 = 1024

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Feature Extraction

2D-Gabor Filtering Approach (2/3)





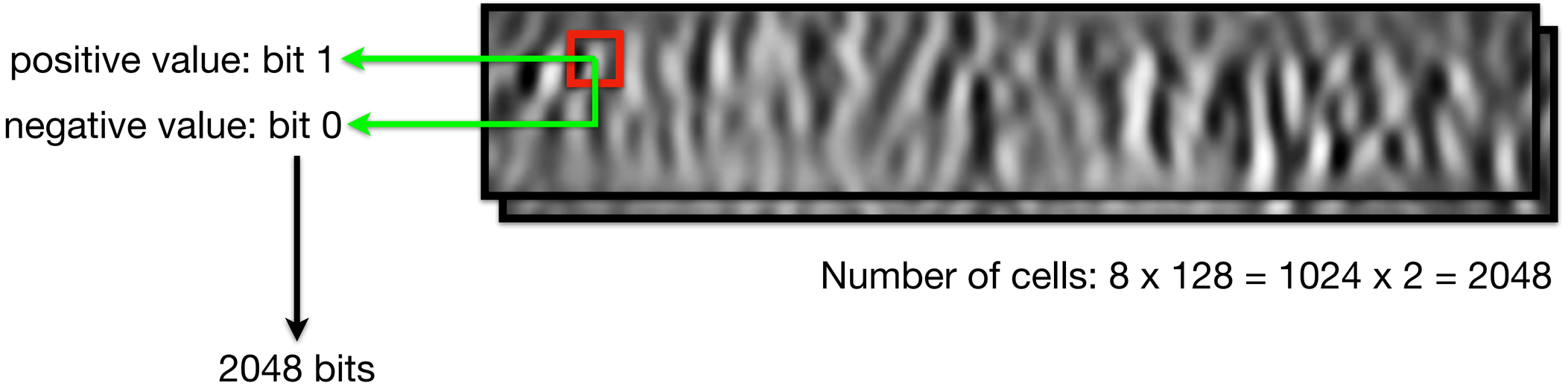
Number of cells: 8 x 128 = 1024 **x 2 = 2048**

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Feature Extraction

2D-Gabor Filtering Approach (2/3)

Take one cell…

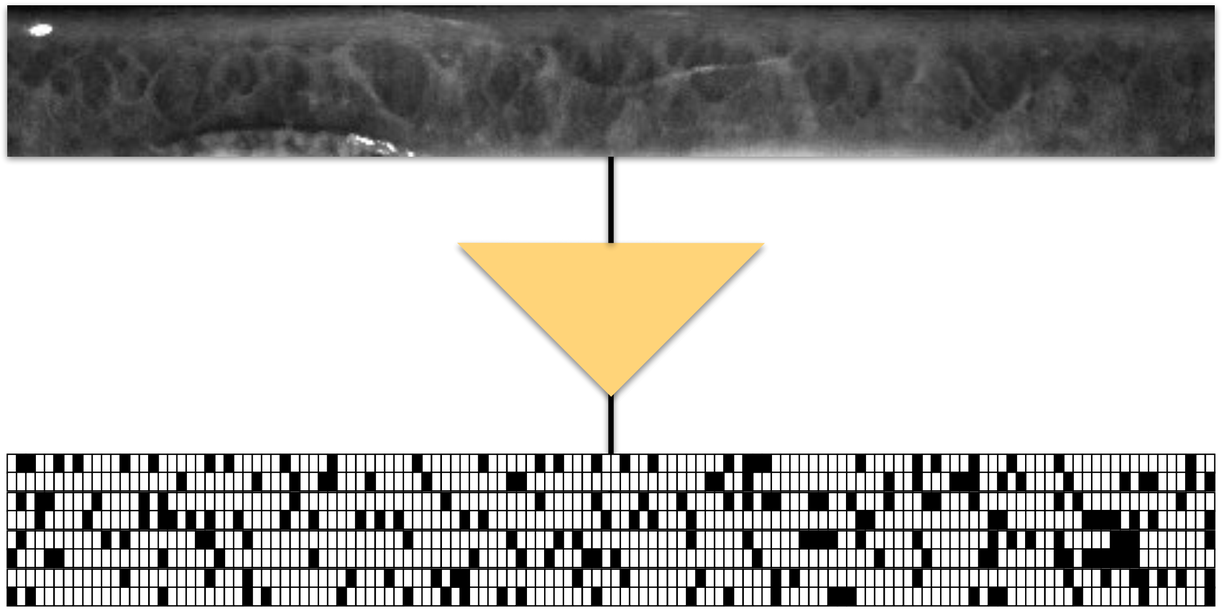


Number of cells: 8 x 128 = 1024 x 2 = 2048

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Feature Extraction

2D-Gabor Filtering Approach (2/3)



2048 bits
IrisCode

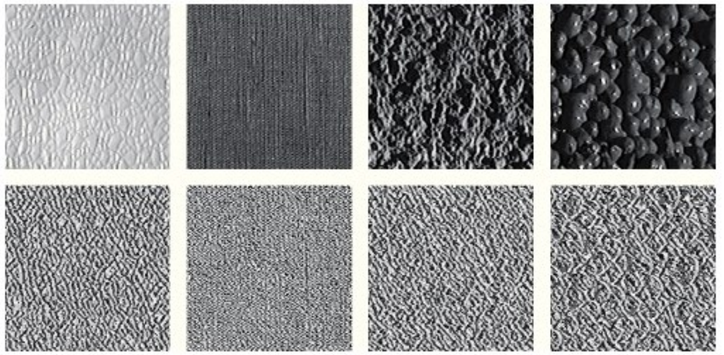
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Feature Extraction

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.

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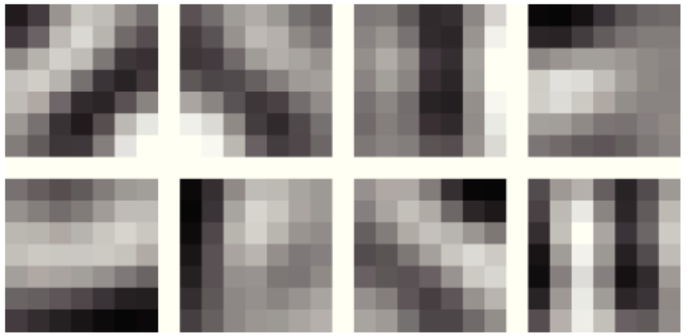
Feature Extraction

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.

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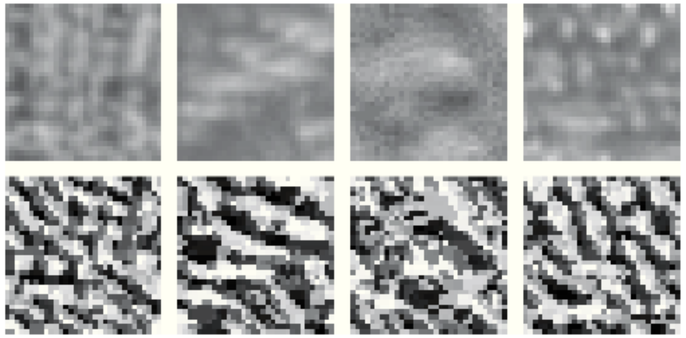
Feature Extraction

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

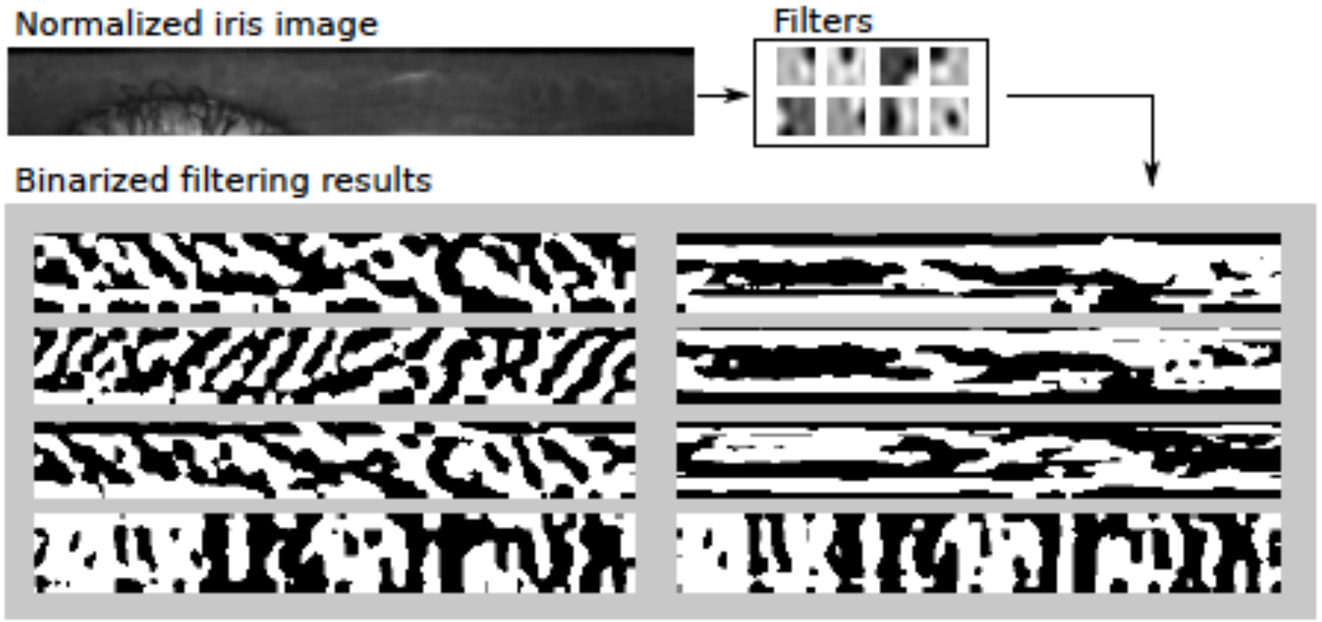
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Feature Extraction

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

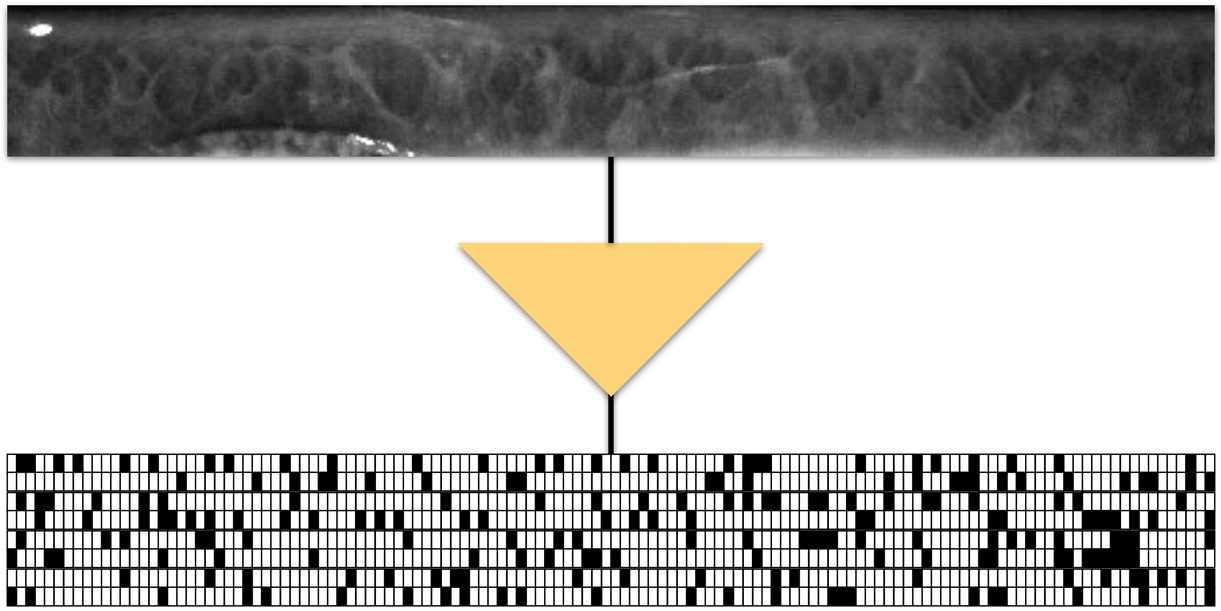


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Feature Extraction

BSIF Approach (3/3)

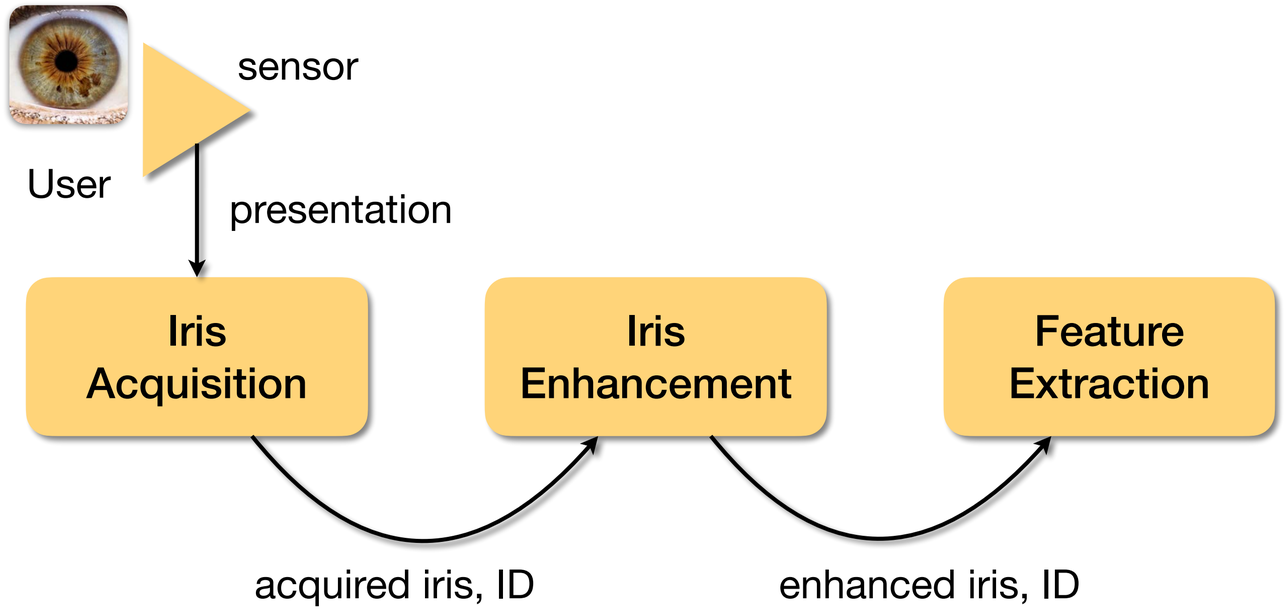
In the case of irises…



BSIF Code

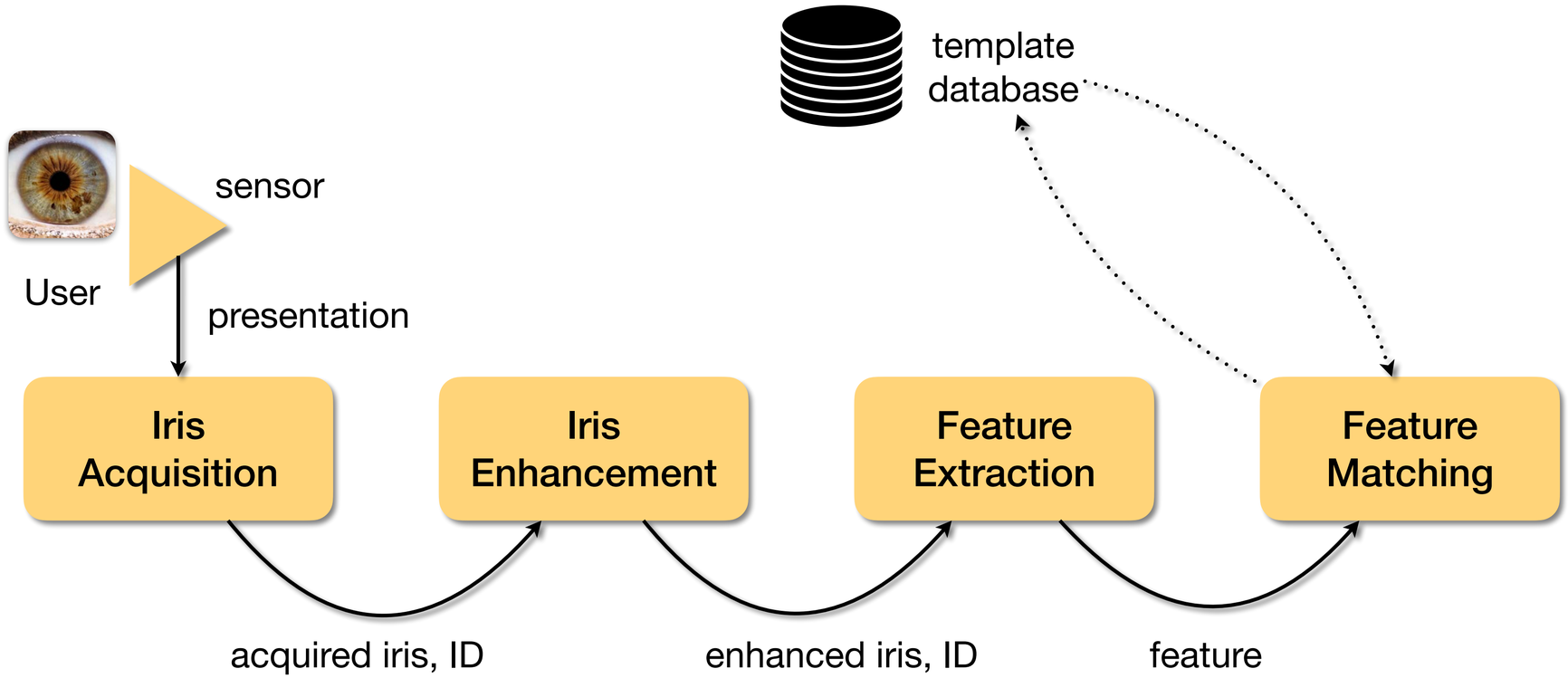
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Iris Recognition



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Iris Recognition



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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

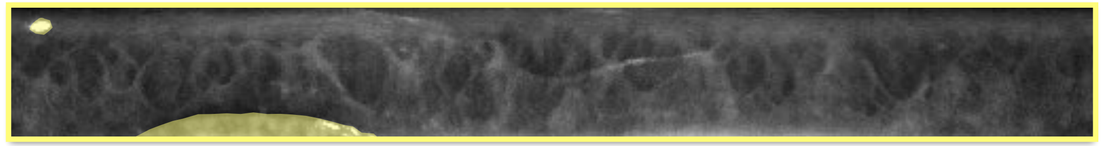
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Feature Matching

How to Compare Binary Codes?

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

Iris 1





Mask 1

Iris 2





Mask 2

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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.

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Feature Matching

How to Compare Binary Codes?

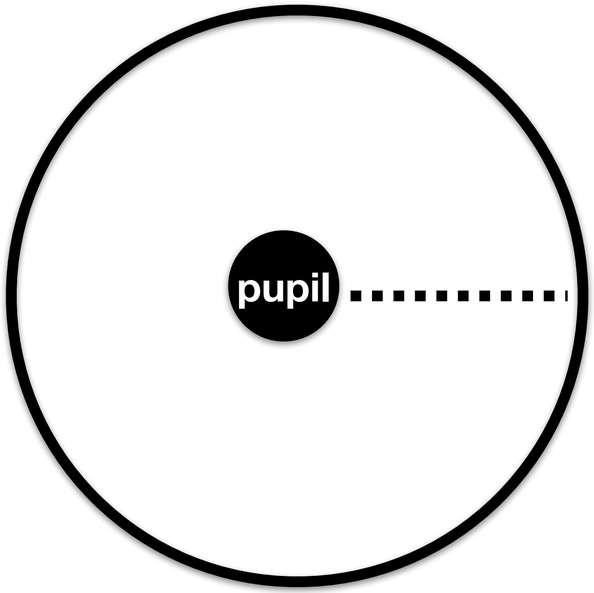
Problems (2/2)
How to deal with iris rotations?
They happen when heads are tilted…

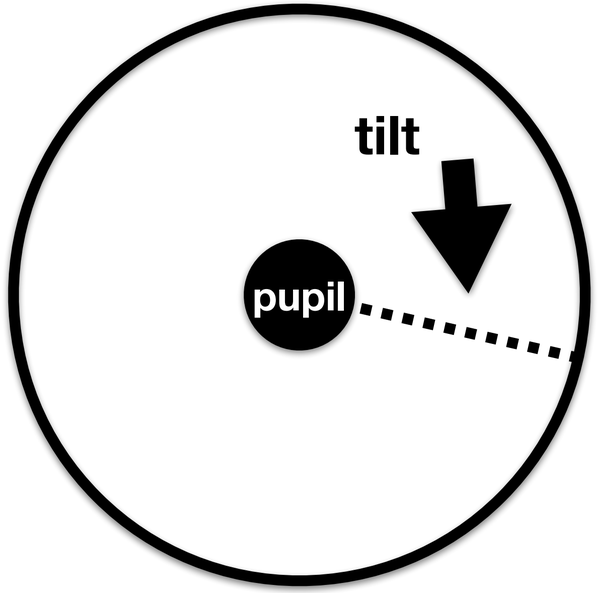


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Feature Matching

How to match with iris rotations?

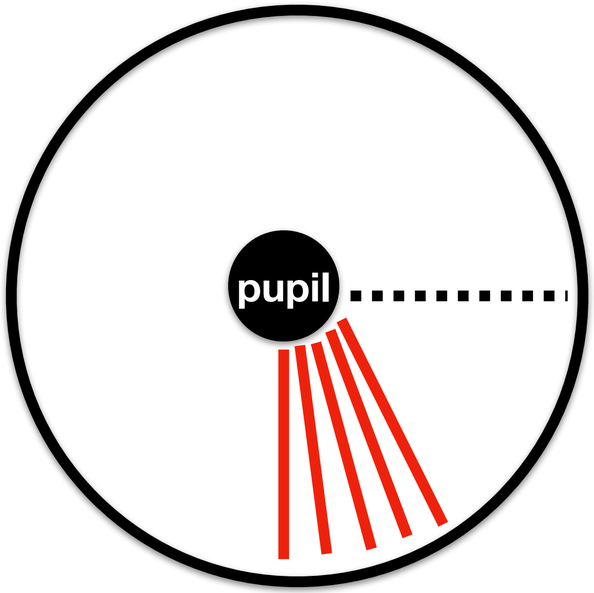


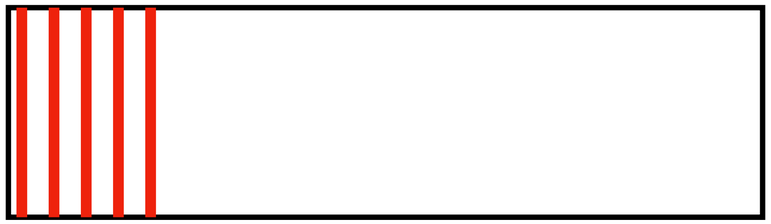


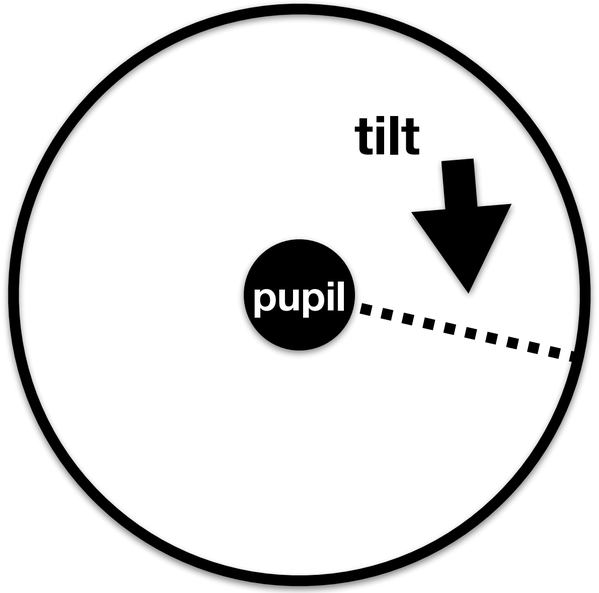
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Feature Matching

How to match with iris rotations?



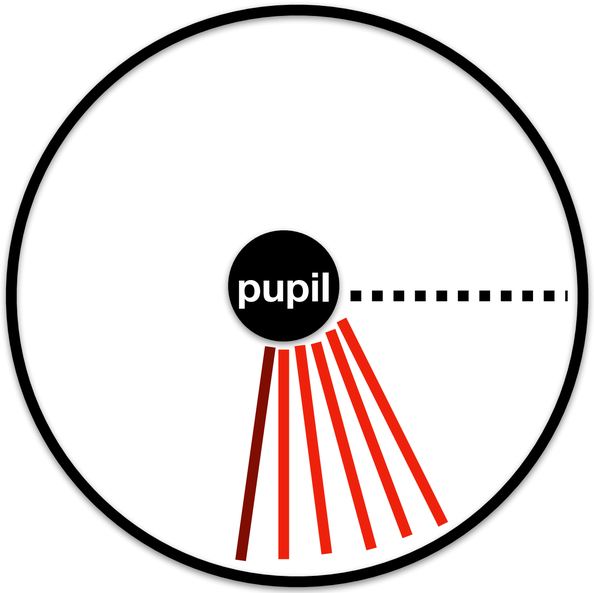


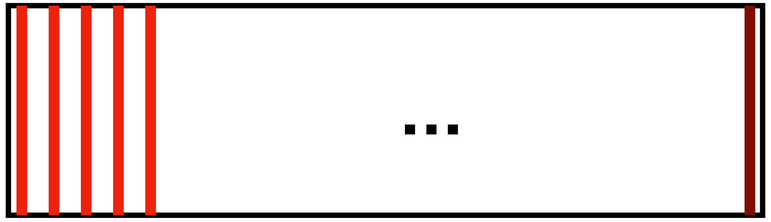


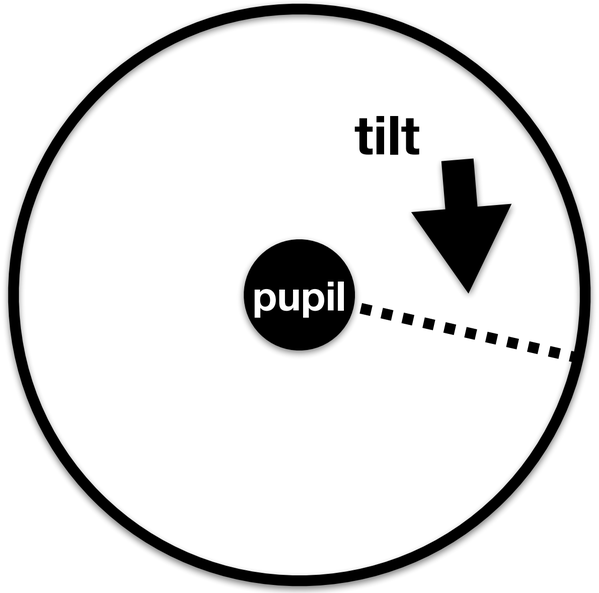
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Feature Matching

How to match with iris rotations?



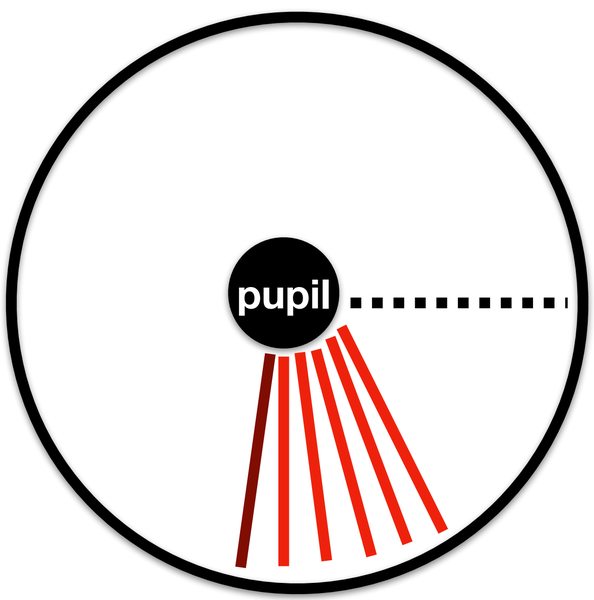


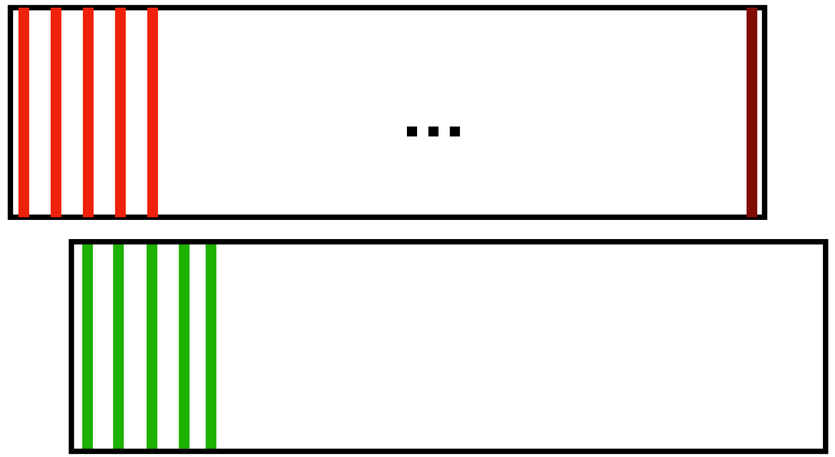


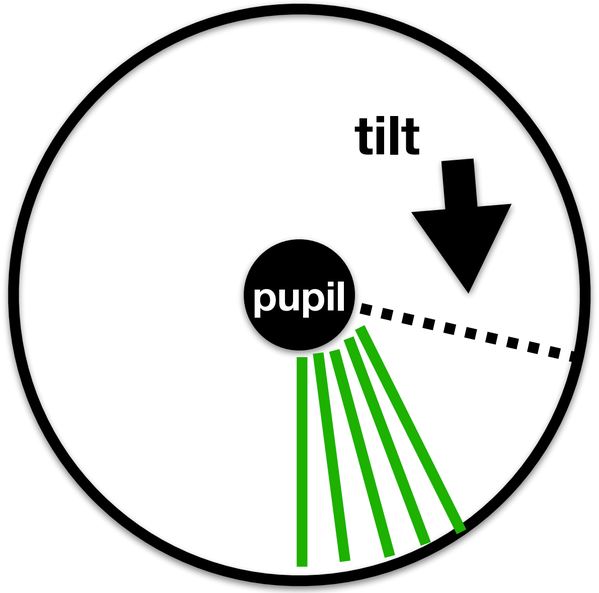
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Feature Matching

How to match with iris rotations?



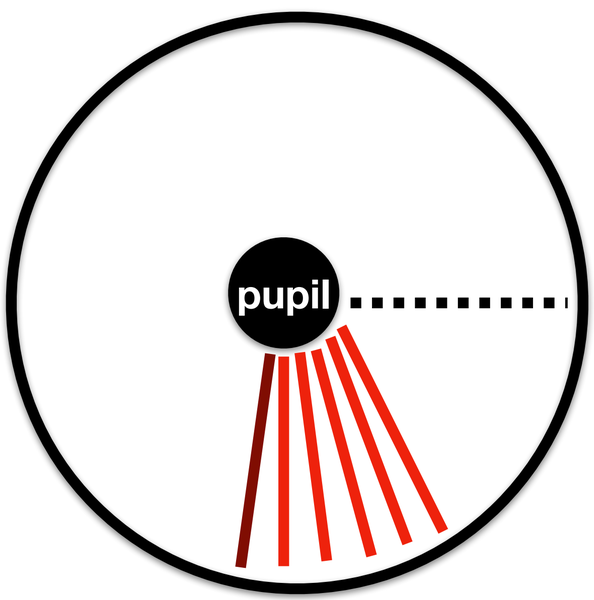


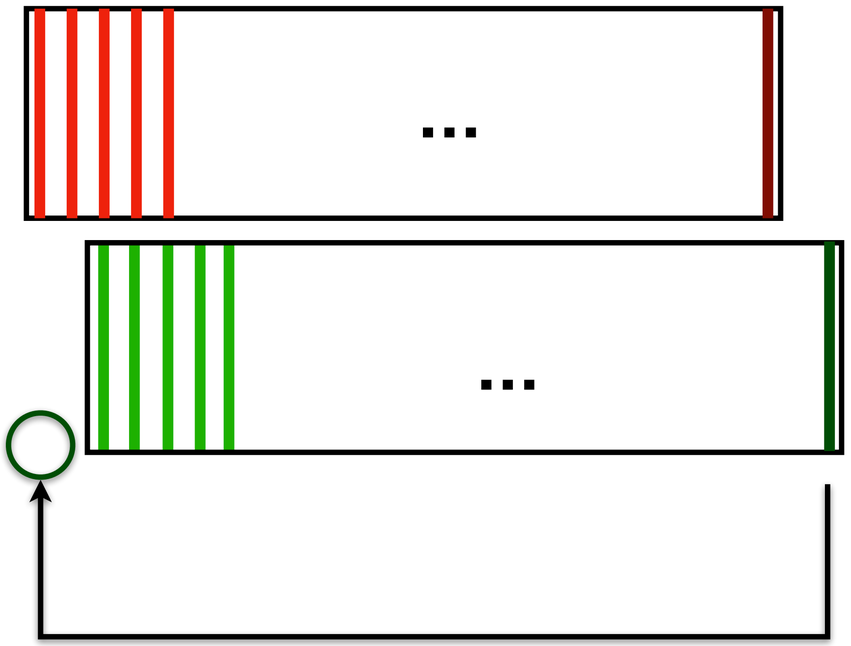


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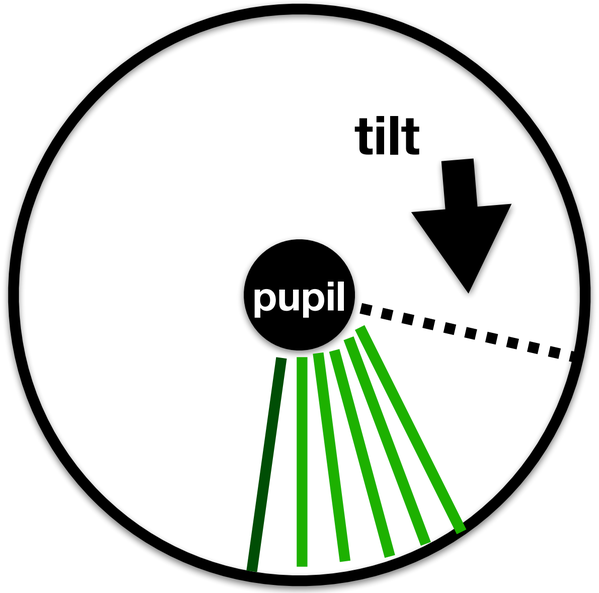
Feature Matching

How to match with iris rotations?





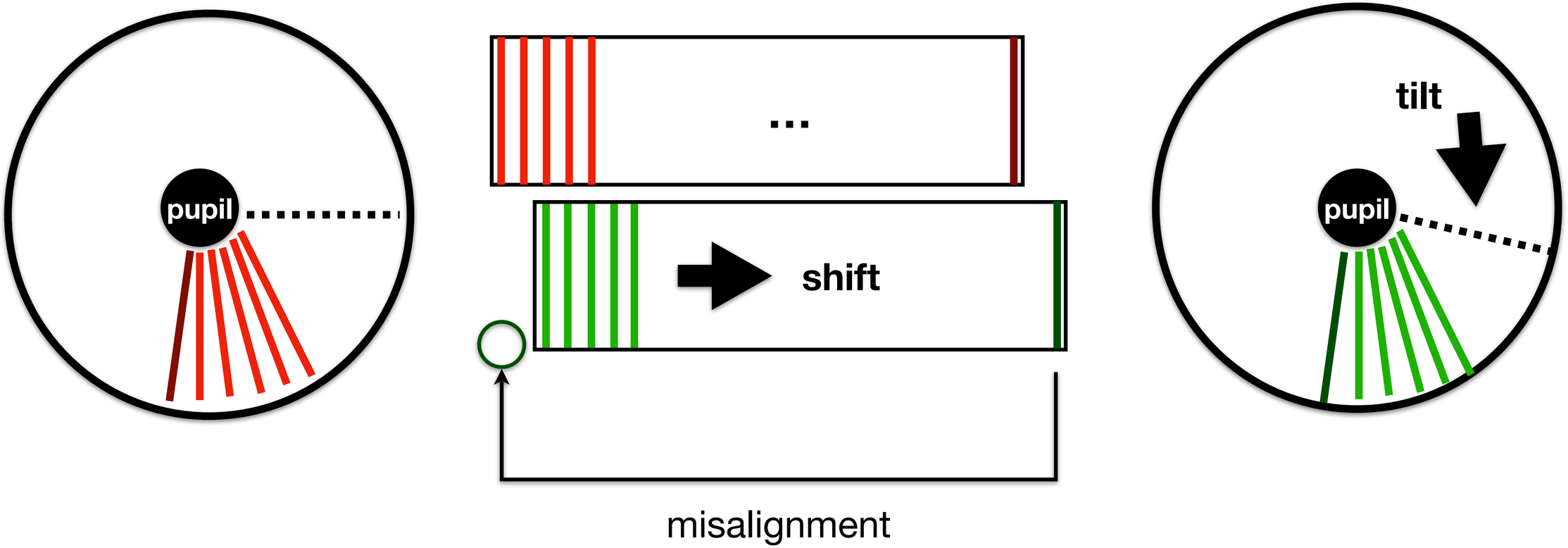
misalignment



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Feature Matching

How to match with iris rotations?

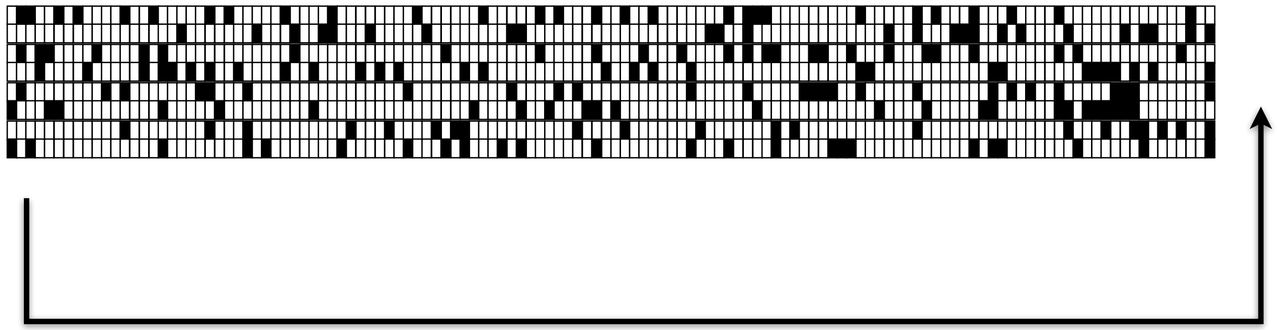


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Feature Matching

How to Compare Binary Codes?

Problems (2/2)
How to deal with iris rotations?
Solution: provide different shifts for one of the iris codes.



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Feature Matching

How to Compare Binary Codes?

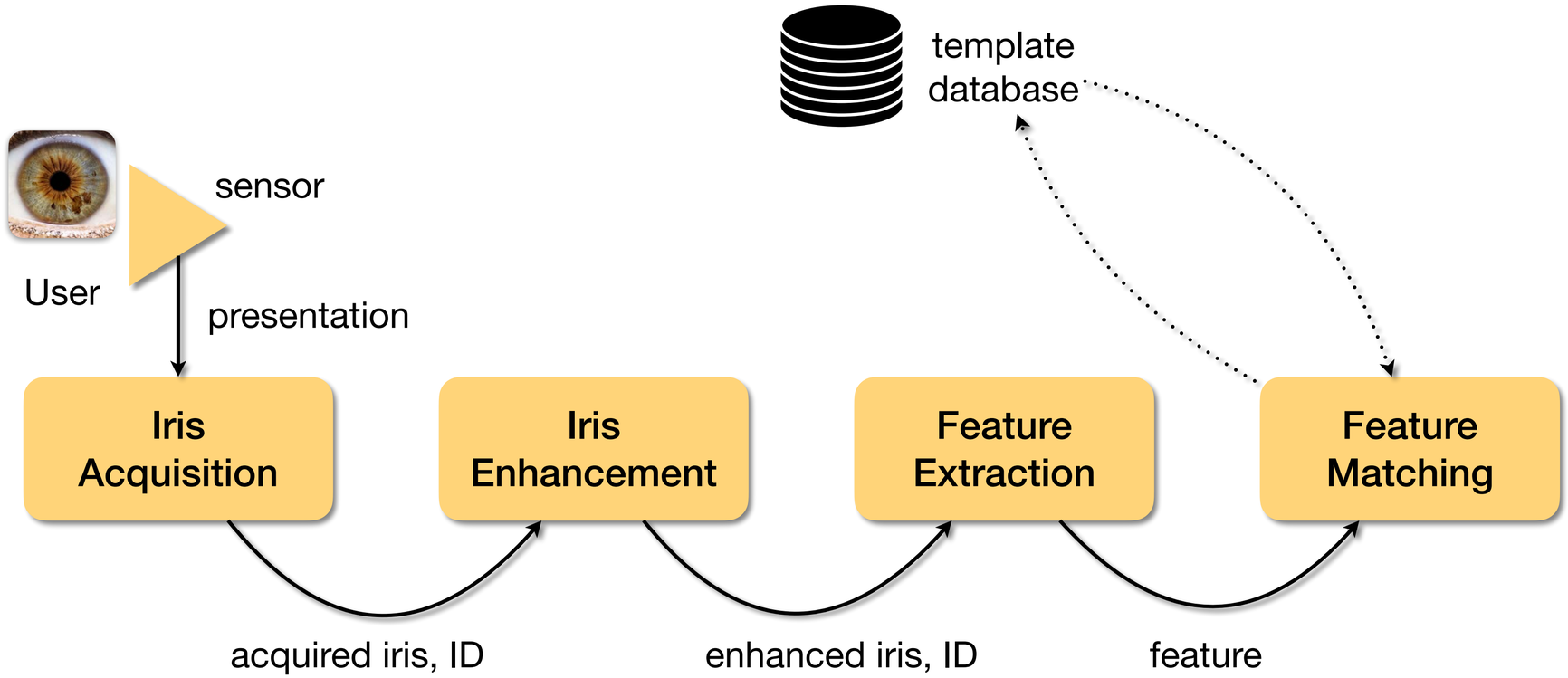
Problems (2/2)
How to deal with iris rotations?
Solution: provide different shifts
for one of the iris codes.
Compute various normalized
Hamming distances (one for each shift).

Take the smallest distance as the score.



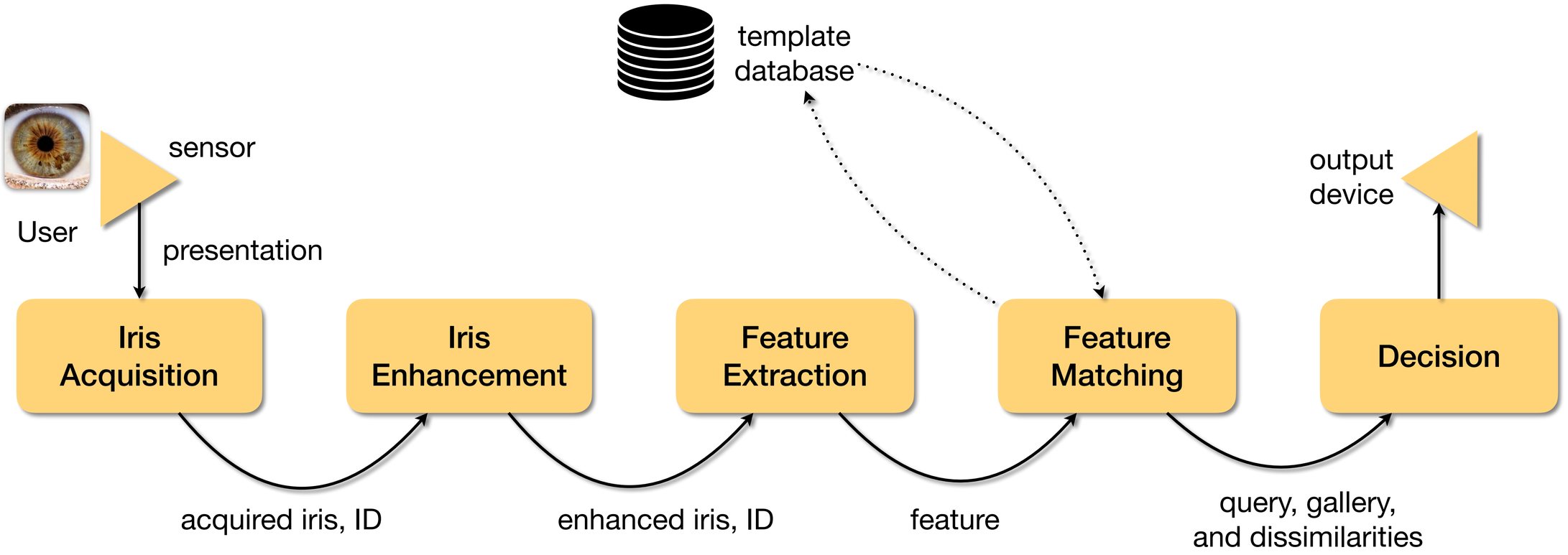
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Iris Recognition



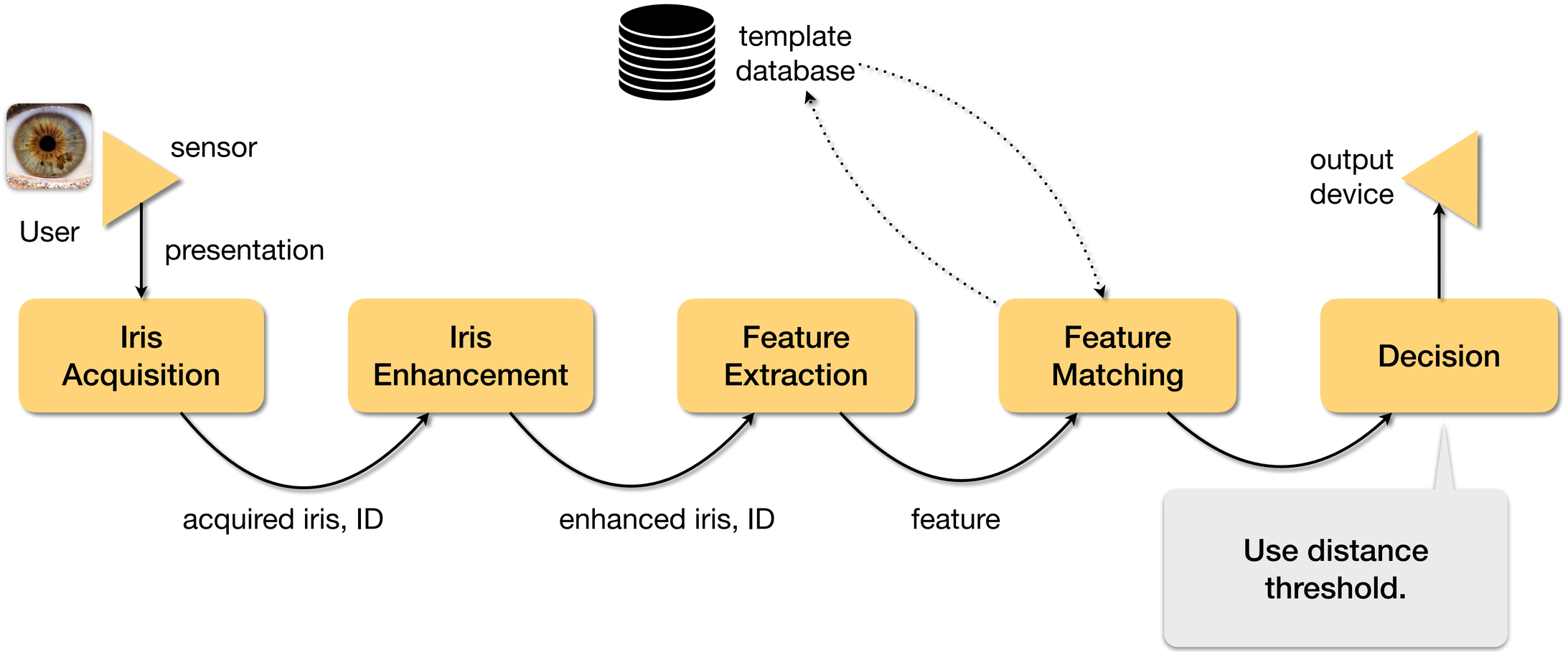
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Iris Recognition



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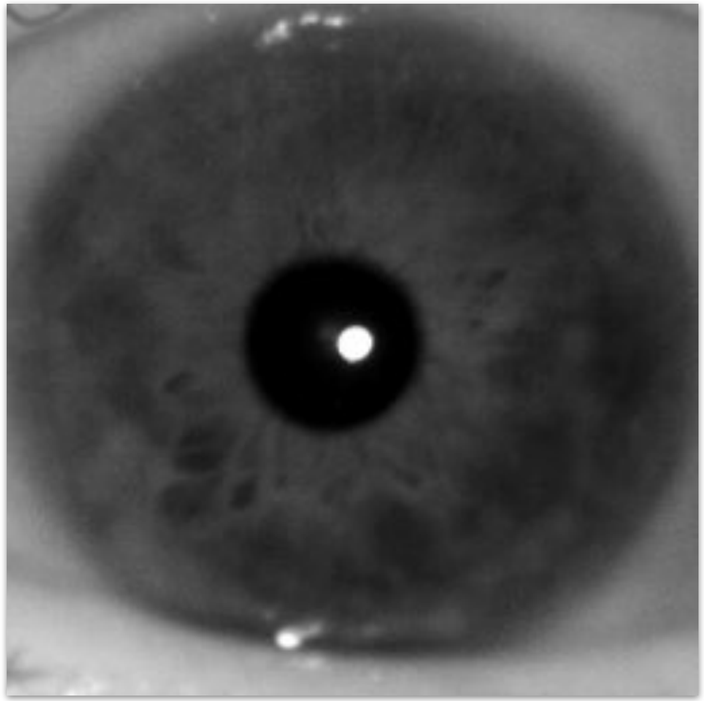
Iris Recognition



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Domain-Specific BSIF Codes





Original BSIF:
Natural images to learn filters.

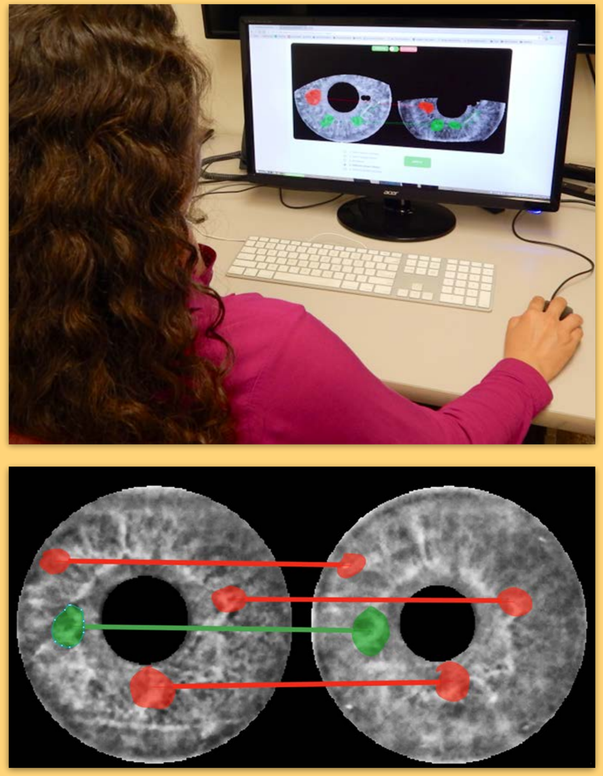
What is the gain of learning from irises?

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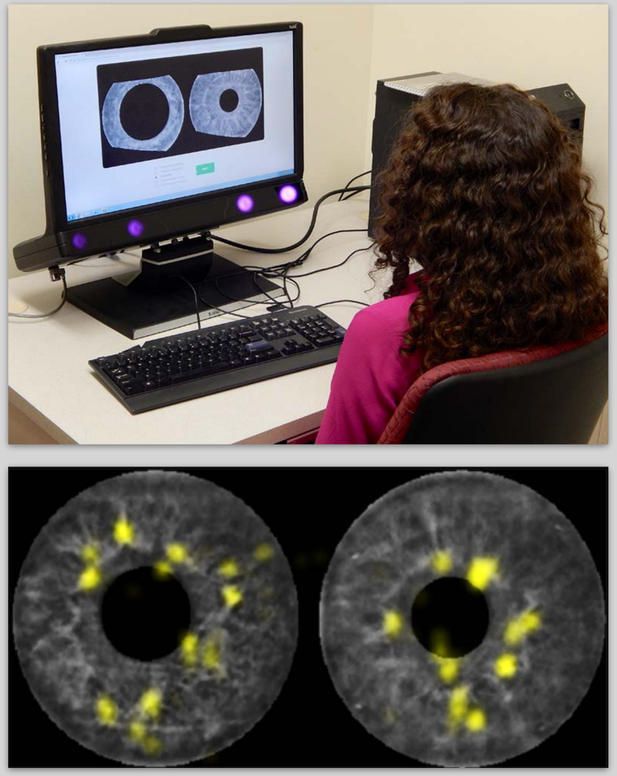
Domain-Specific BSIF Codes

How to Select Iris Patches?

Manual Annotation



Eye-Tracker Data



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Domain-Specific BSIF Codes

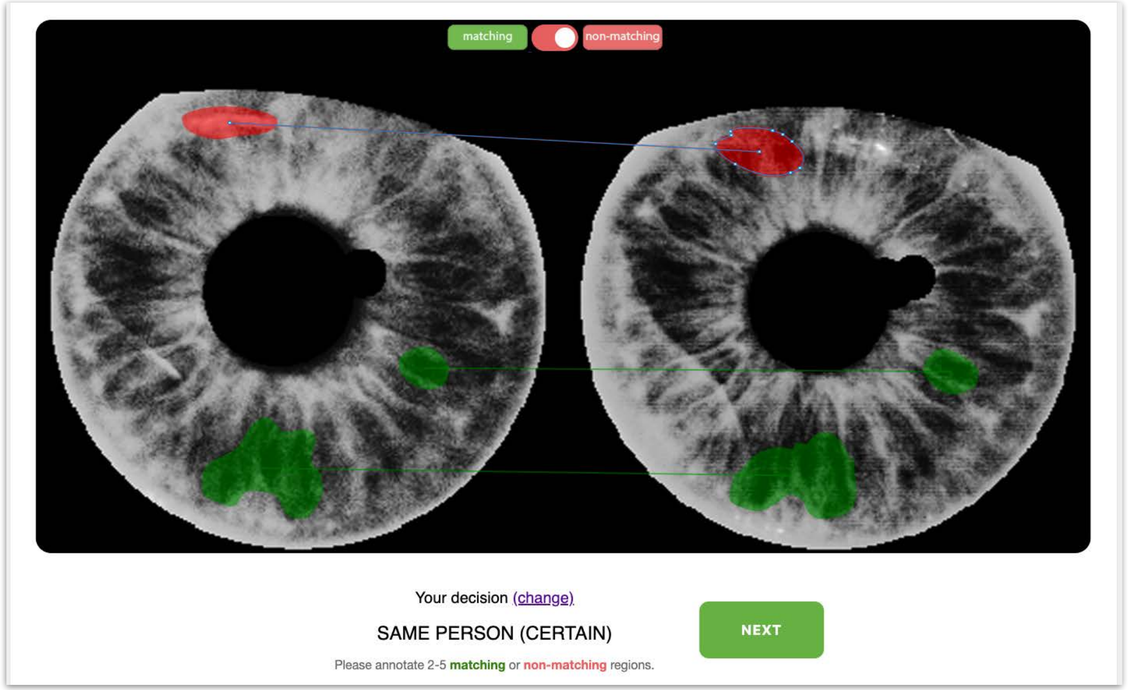
Annotation Tool



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



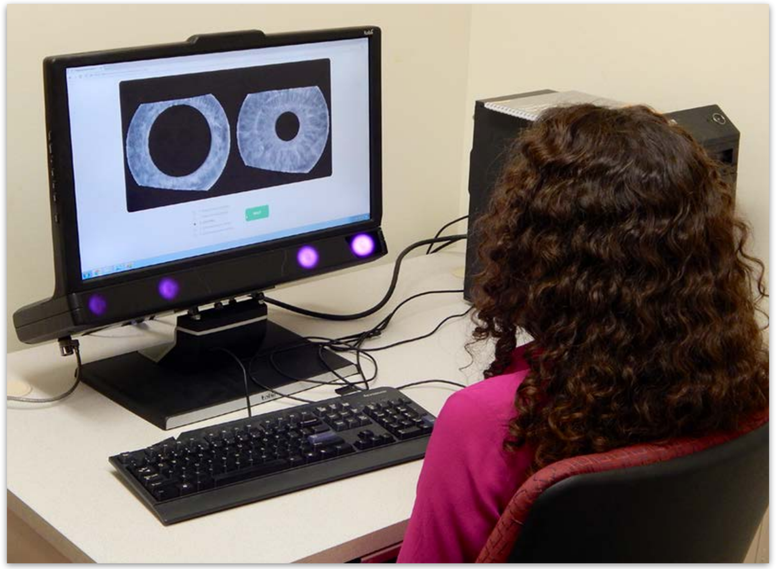
Paper.js
Web-browser drawing library.



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Domain-Specific BSIF Codes

Eye Tracker

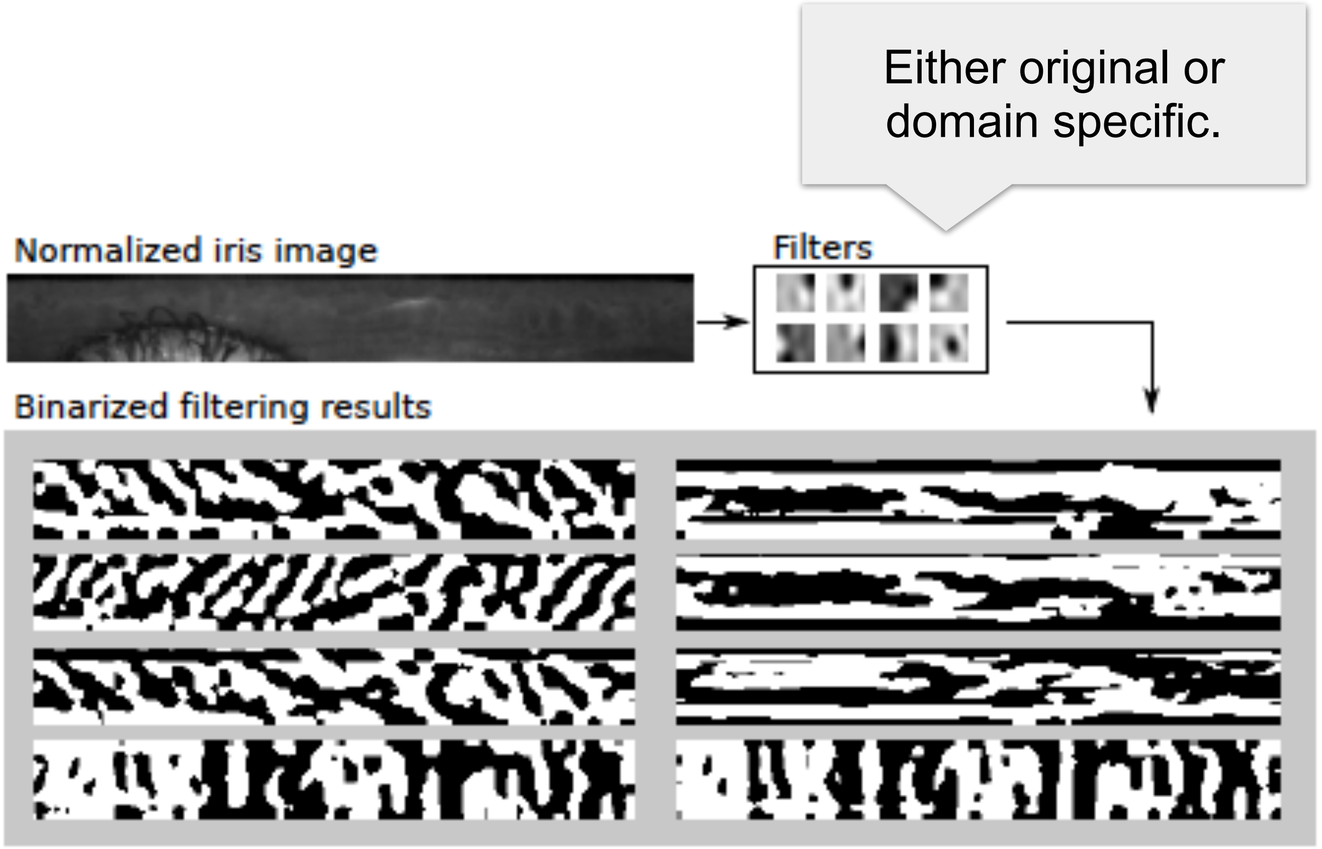




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Domain-Specific BSIF Codes

Application

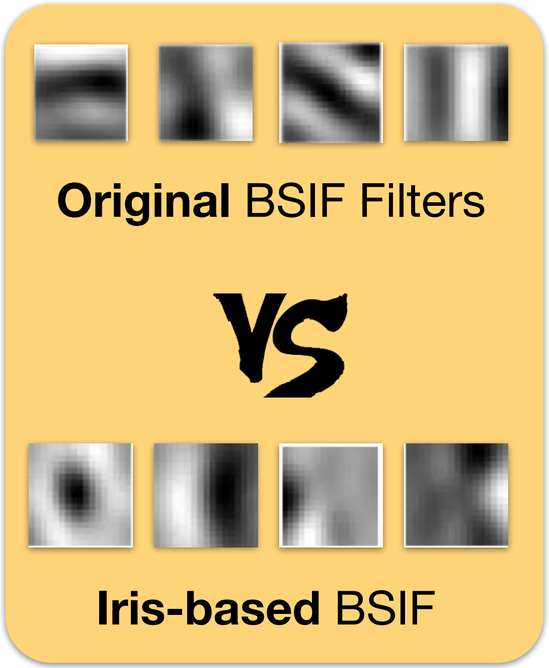


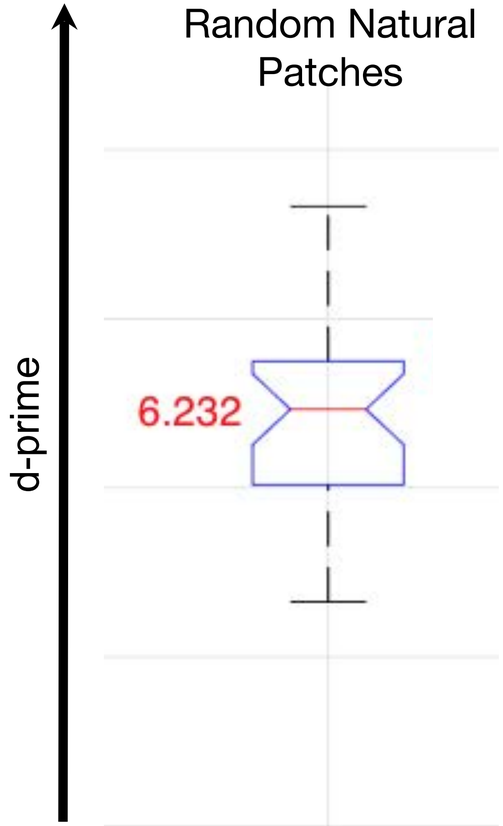
Czajka et al.
Domain-Specific Human-Inspired Binarized Statistical Image Features for Iris Recognition
WACV 2019

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Domain-Specific BSIF Codes

Results



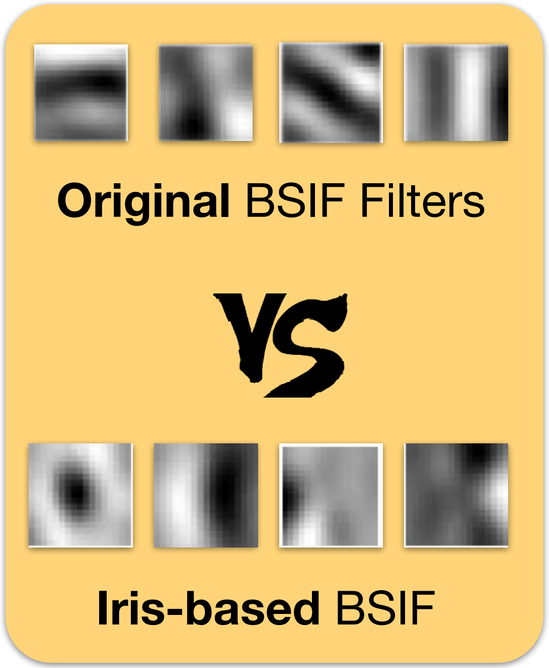


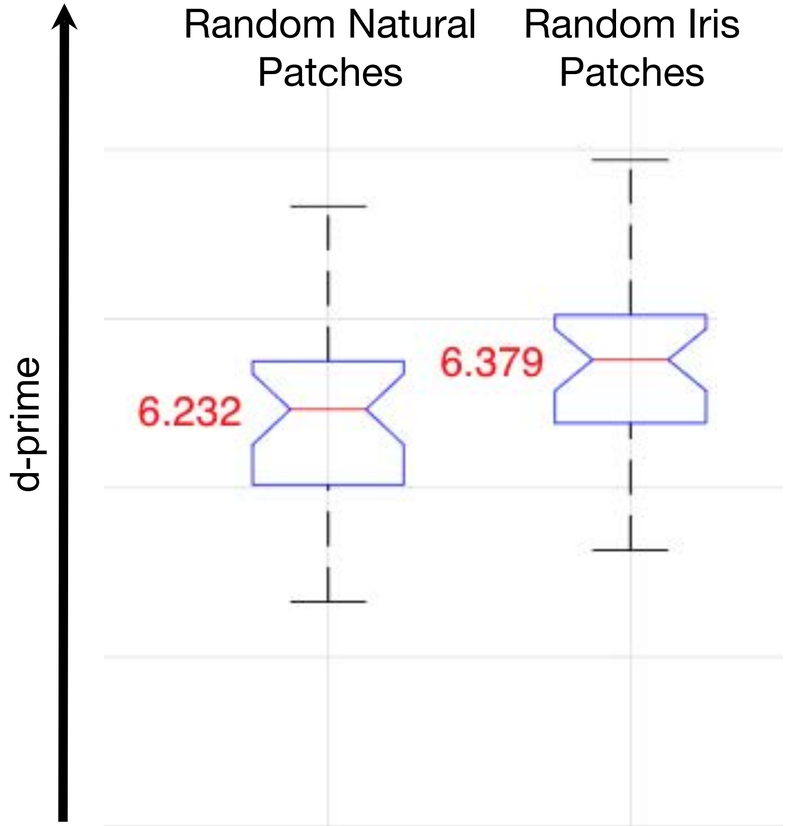
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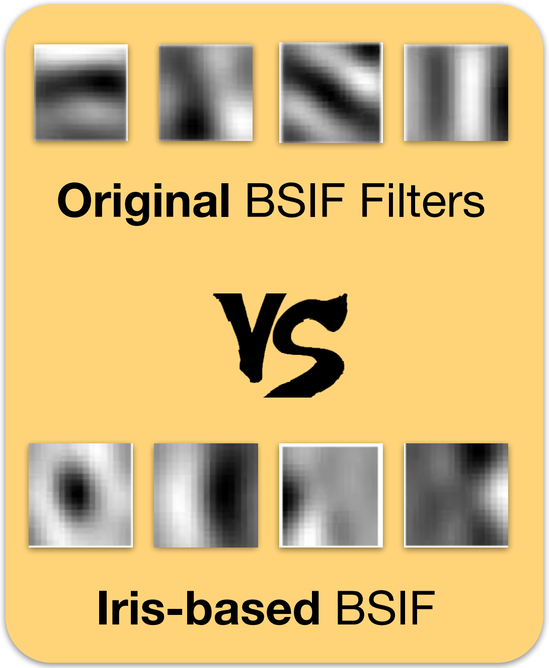


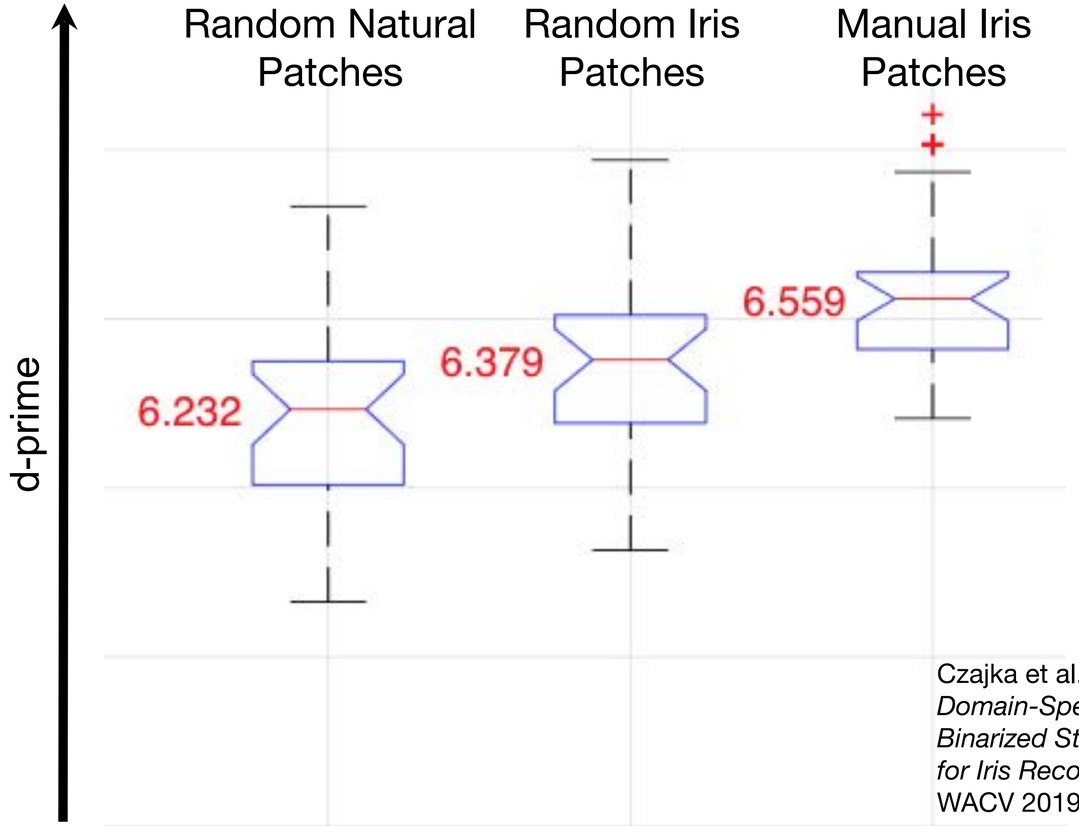
Czajka et al.
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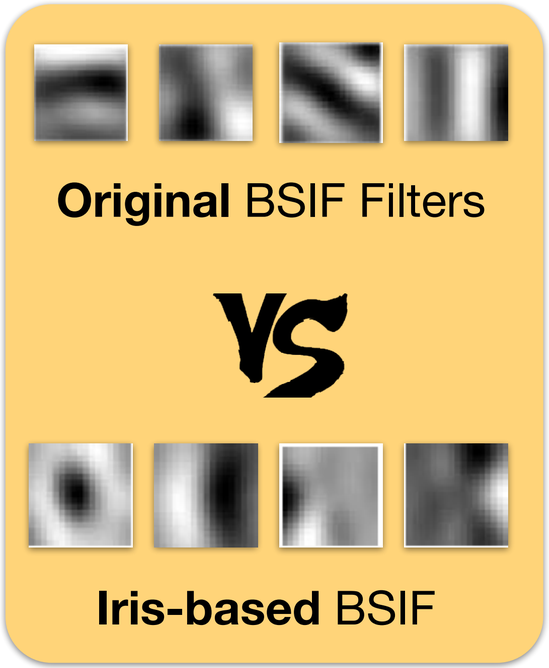


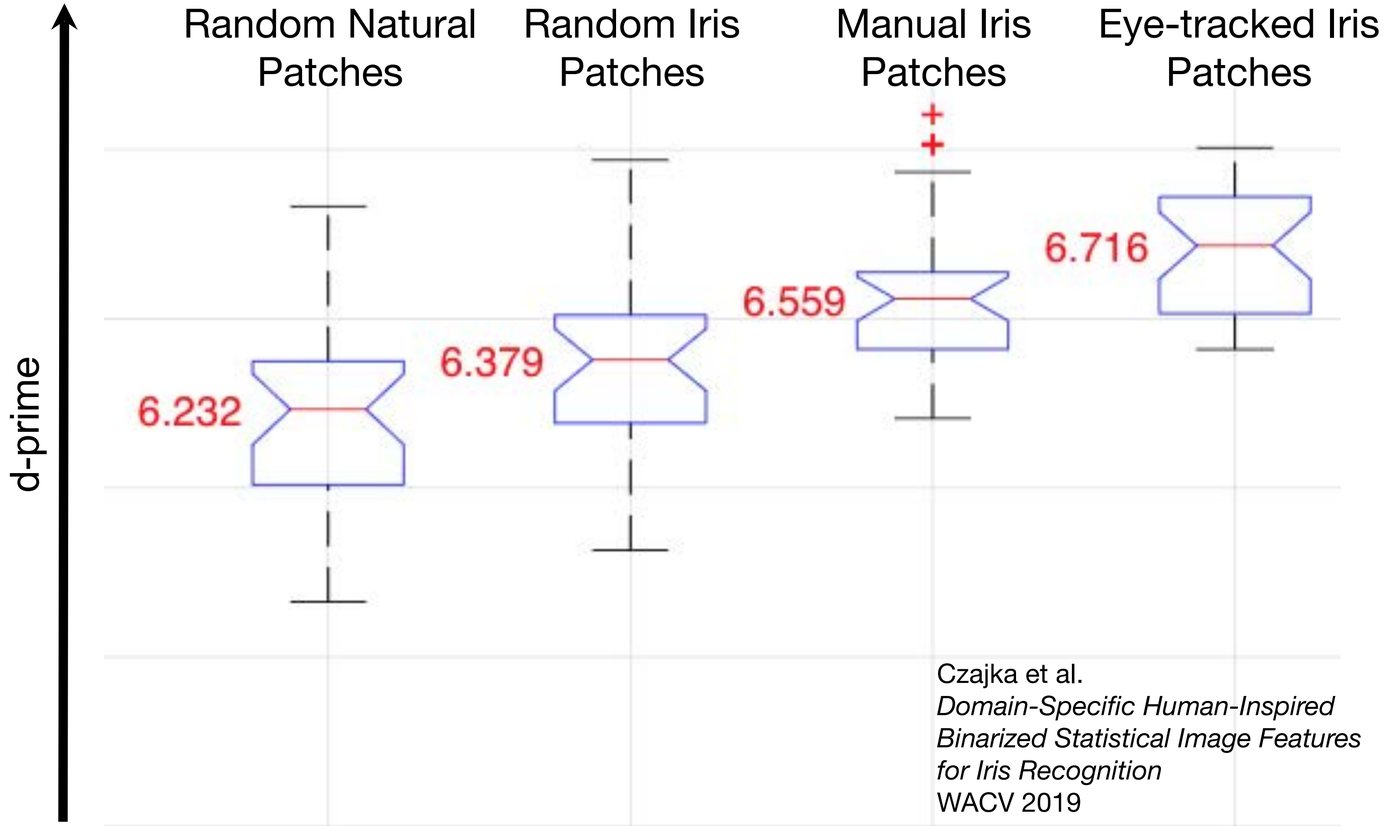
Czajka et al.
Domain-Specific Human-Inspired Binarized Statistical Image Features for Iris Recognition
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Domain-Specific BSIF Codes

Results





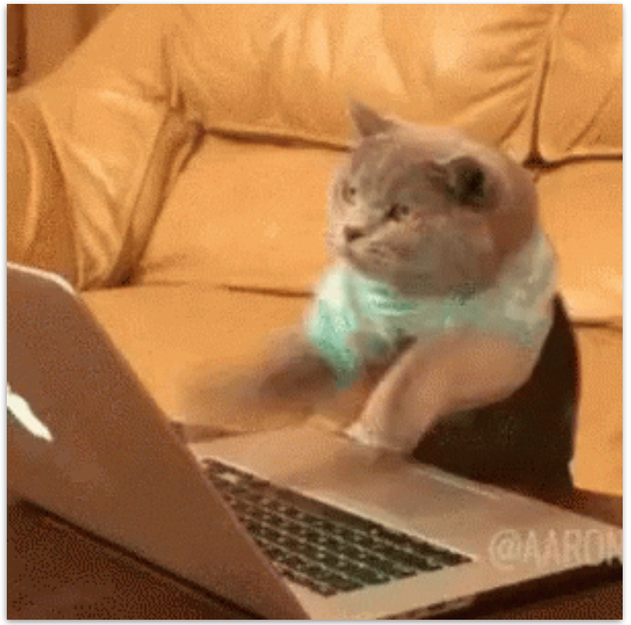
Czajka et al.
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WACV 2019

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