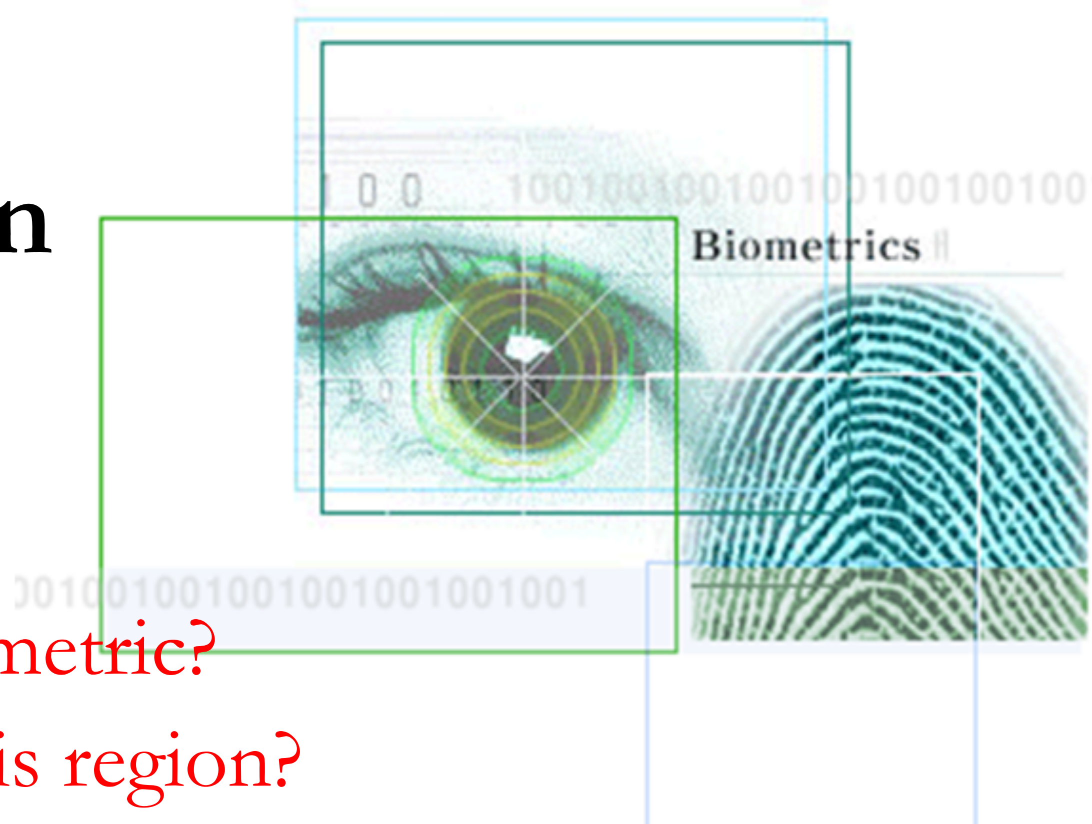
Iris Recognition



- What is Iris as a Biometric?
- How to extract the iris region?
- Iris Normalization, Feature Extraction and Matching

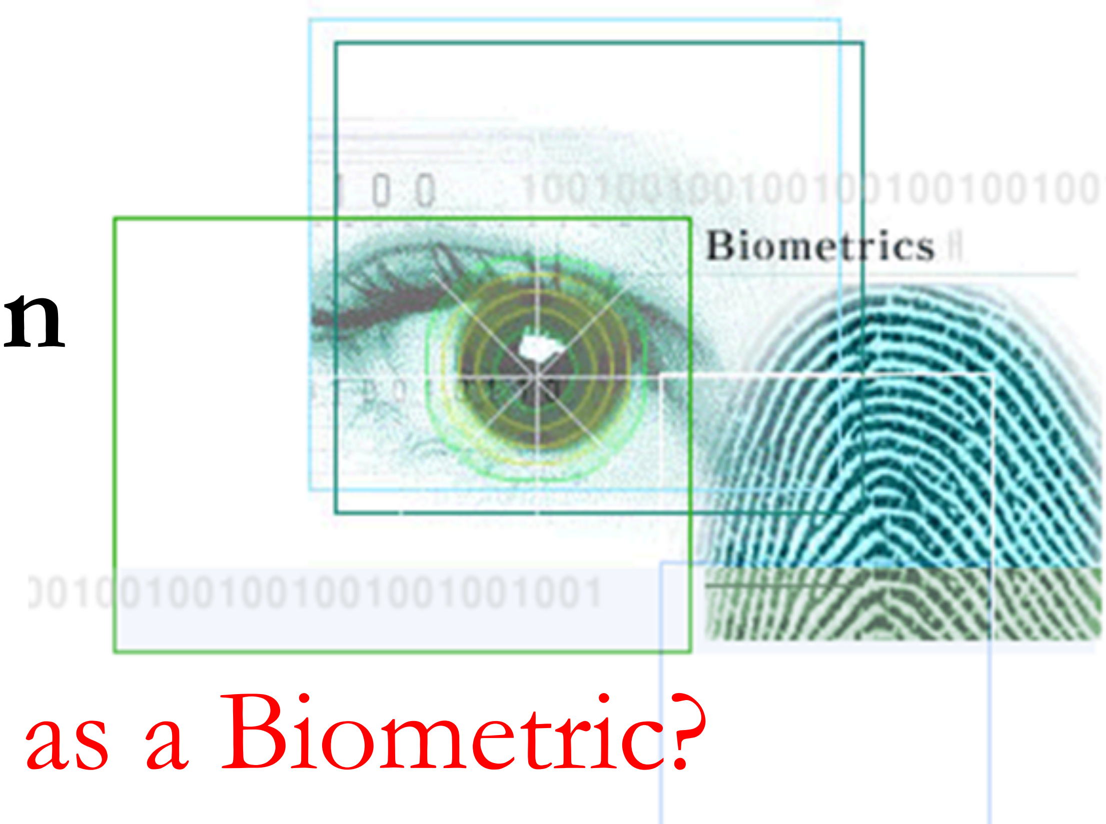
By

Shireen Y. Elhabian

University of Lousiville, CVIP Lab

November 2009

Iris Recognition



Q1 :

What is Iris as a Biometric?

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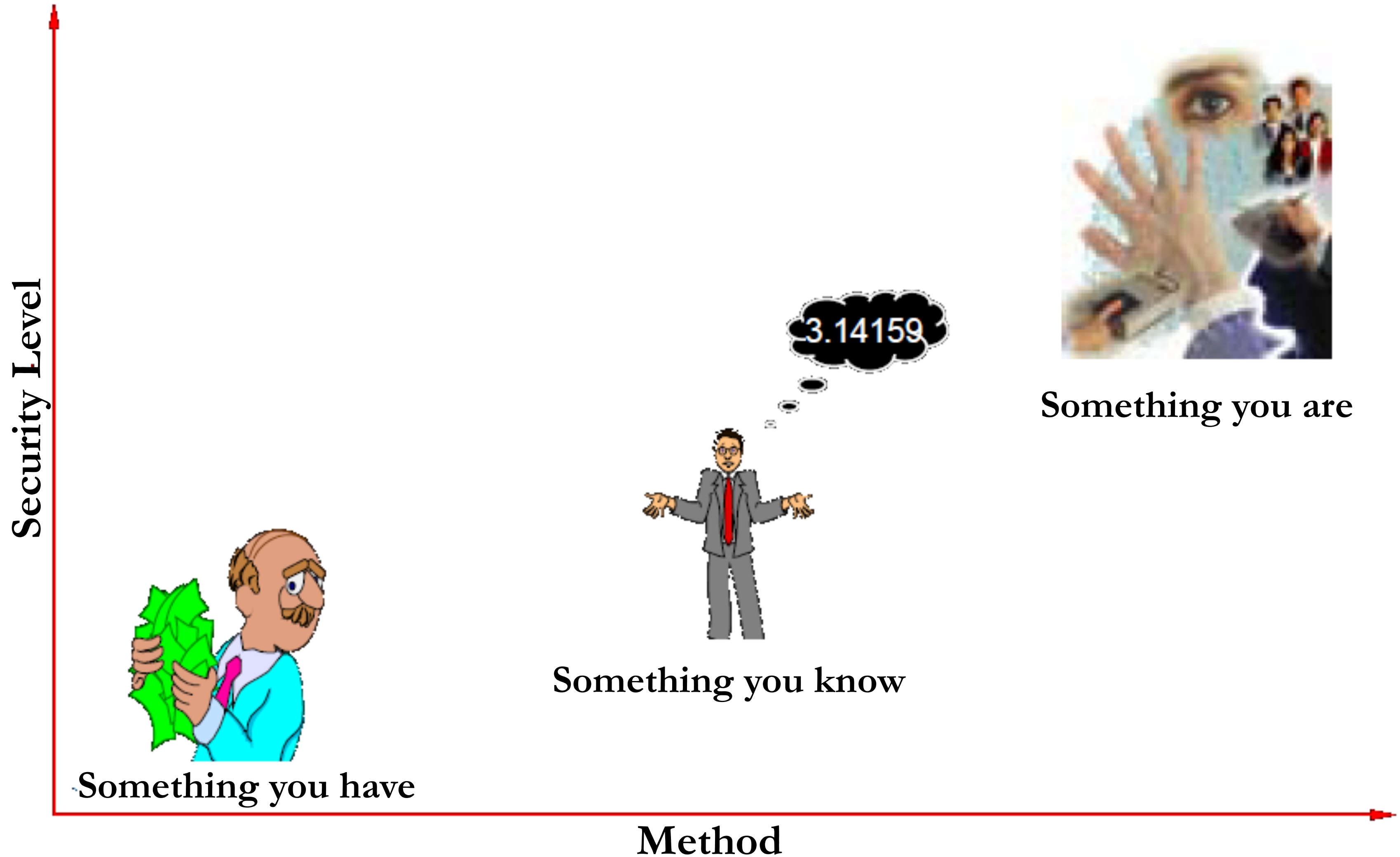
Who am I? How can I prove it?

- There are three common ways of identifying an individual's identity :
  - **Token**
    - What the individual has
    - An identification card, badge, magnetic stripe card, or ID card
  - **Secret/Knowledge**
    - What the individual knows or owns (A password, or Personal Identification Number (PIN))
  - **Biometric**
    - What the individual is or does.

Biometrics ?!!!

- Biometrics utilize **"something you are"** to authenticate identification.
- This might include fingerprints, retina pattern, **iris**, hand geometry, vein patterns, voice password, or signature dynamics.
- Biometrics is "the automated recognition of individuals based on their behavioral and biological characteristics"

Why Biometrics ?!!!



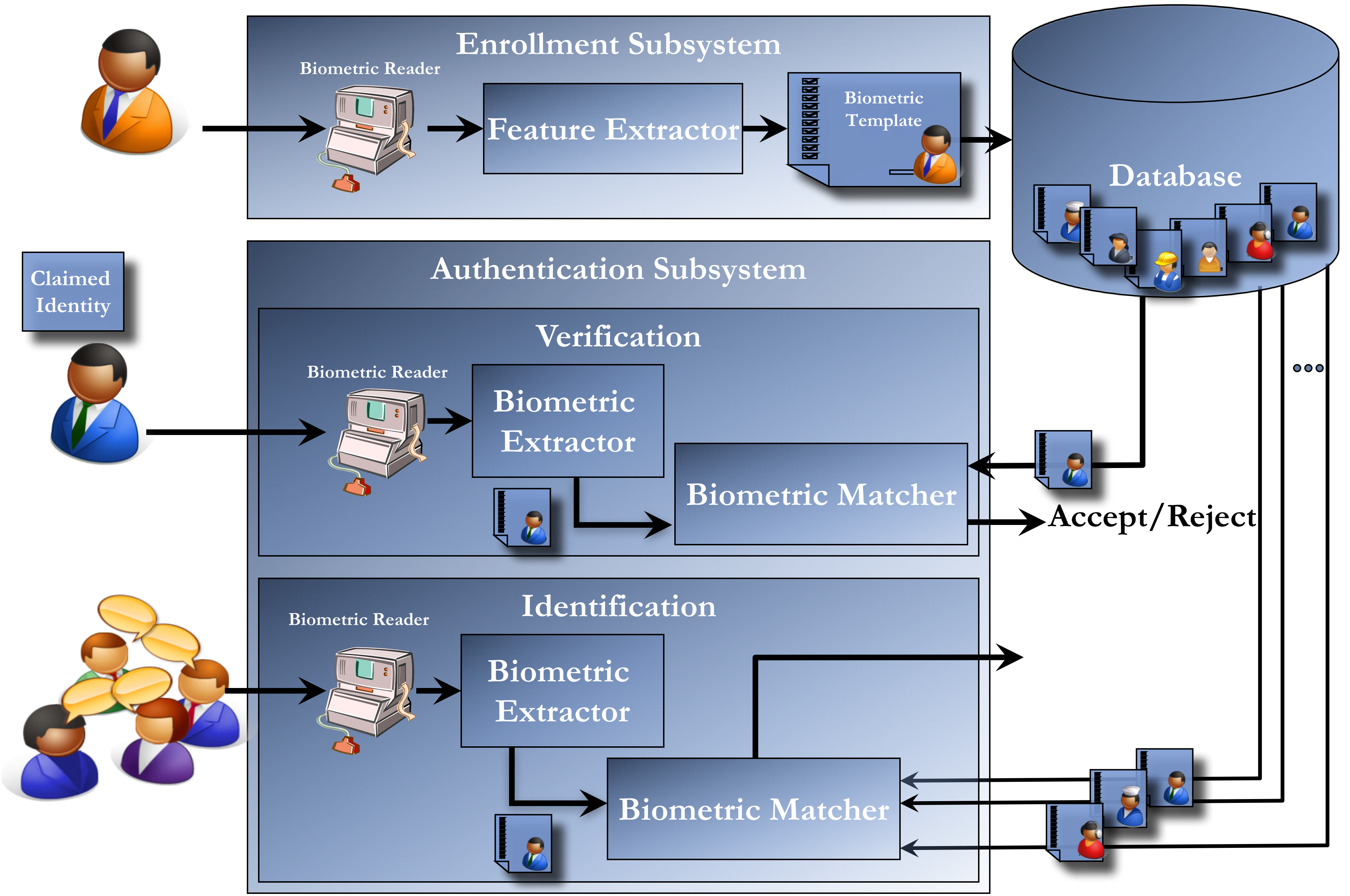
Good Biometric Should be …

- Universal
  - Each person should have the specific biometric trait
- Unique (just distinguishable)
  - Any two people should be sufficiently different in terms of the characteristic
- Collectible
  - Biometric traits must be obtainable
- Permanent
  - Traits remain invariable over time, allowing for repeatable measures

Different Types of Biometrics

- Each biometric has its own strength and weakness points.
- No biometric trait or technology is "optimal".
- Several types of biometrics:
  - *Biological/Physiological biometrics* includes God created characteristics *possessed* by the individual such as : Face, hand geometry, DNA, finger print, iris, vein, retinal imaging, ear and odor
  - *Behavioral biometrics* refer to characteristics *acquired* by the individual throughout his life time, such as signature, voice, key stroke and pattern of walking (gait).

Biometric System Model



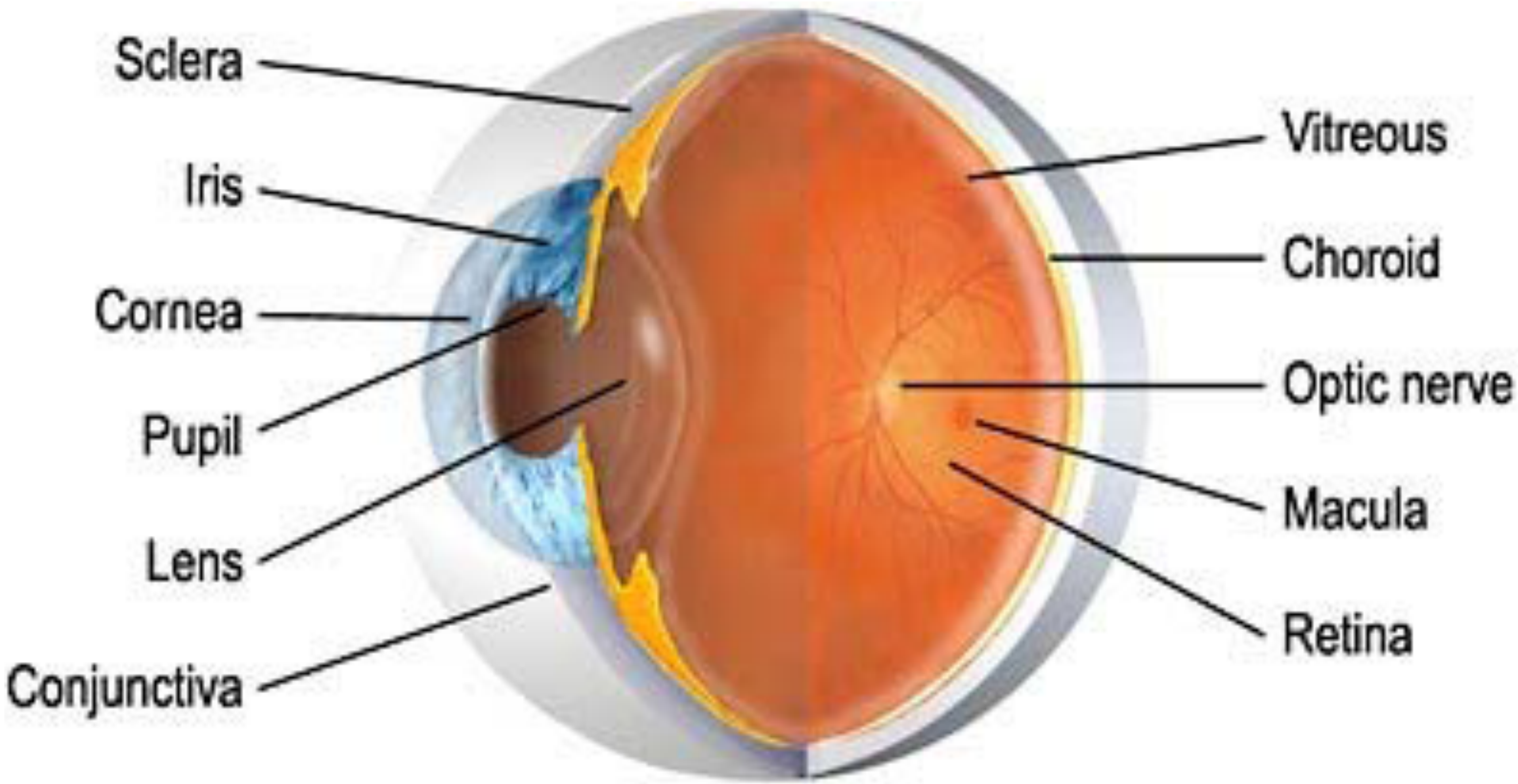
Building Blocks

- **Biometric reader (sensor)**
  - A sensor that responds to biological stimulus, such as fingerprints, iris, voice, retinas, Thumb pressure dynamics to generate signal that can be measured or interpreted.
- **Feature extraction algorithm**
  - A feature extraction algorithm detects and isolates portions of digital signal emanated out of a sensor which contains identifying properties. The algorithm creates descriptors or characteristic features per signal. An identifying feature is stored in a file called *template*.
- **Search and match algorithm**
  - A search & match algorithm takes an input characteristic feature and compares it with stored feature(s) and outputs either success or failure of the outcome.
- **Identity database**
  - An Identity database is collection of templates on which a given search & match algorithm operates to find whether a given input characteristic matches or not.

Who are they ?!!!

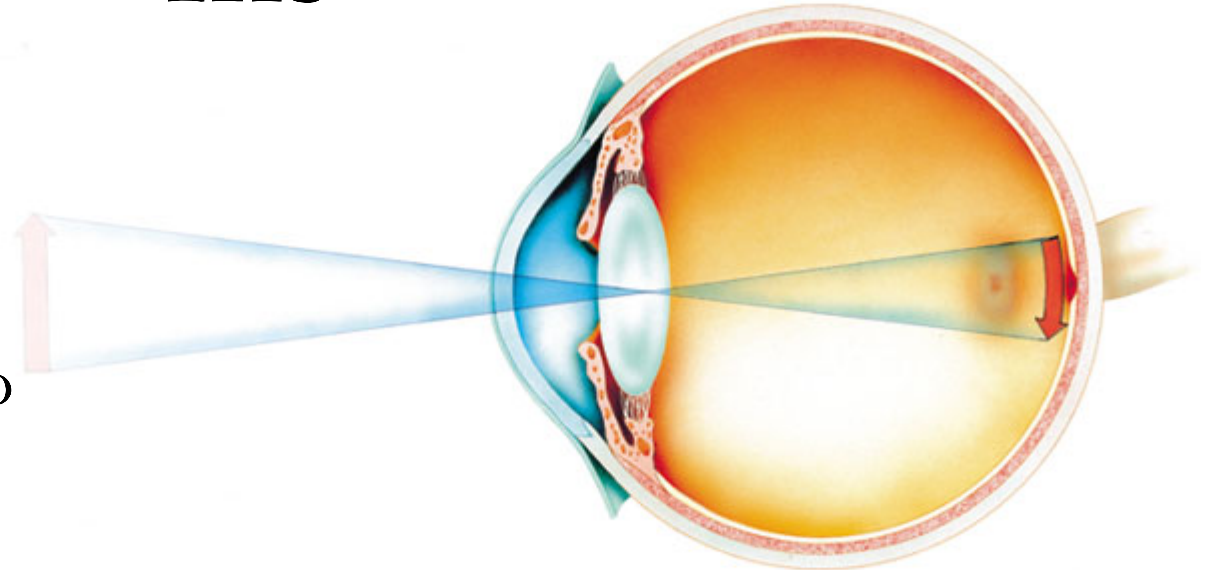
All have Eyes ☺

Anatomy of the Eye



Eye = Camera
Cornea: bends, refracts, and focuses light.
Retina : Film for image projection (converts image into electrical signals).
Optical nerve transmits signals to the brain.

Iris



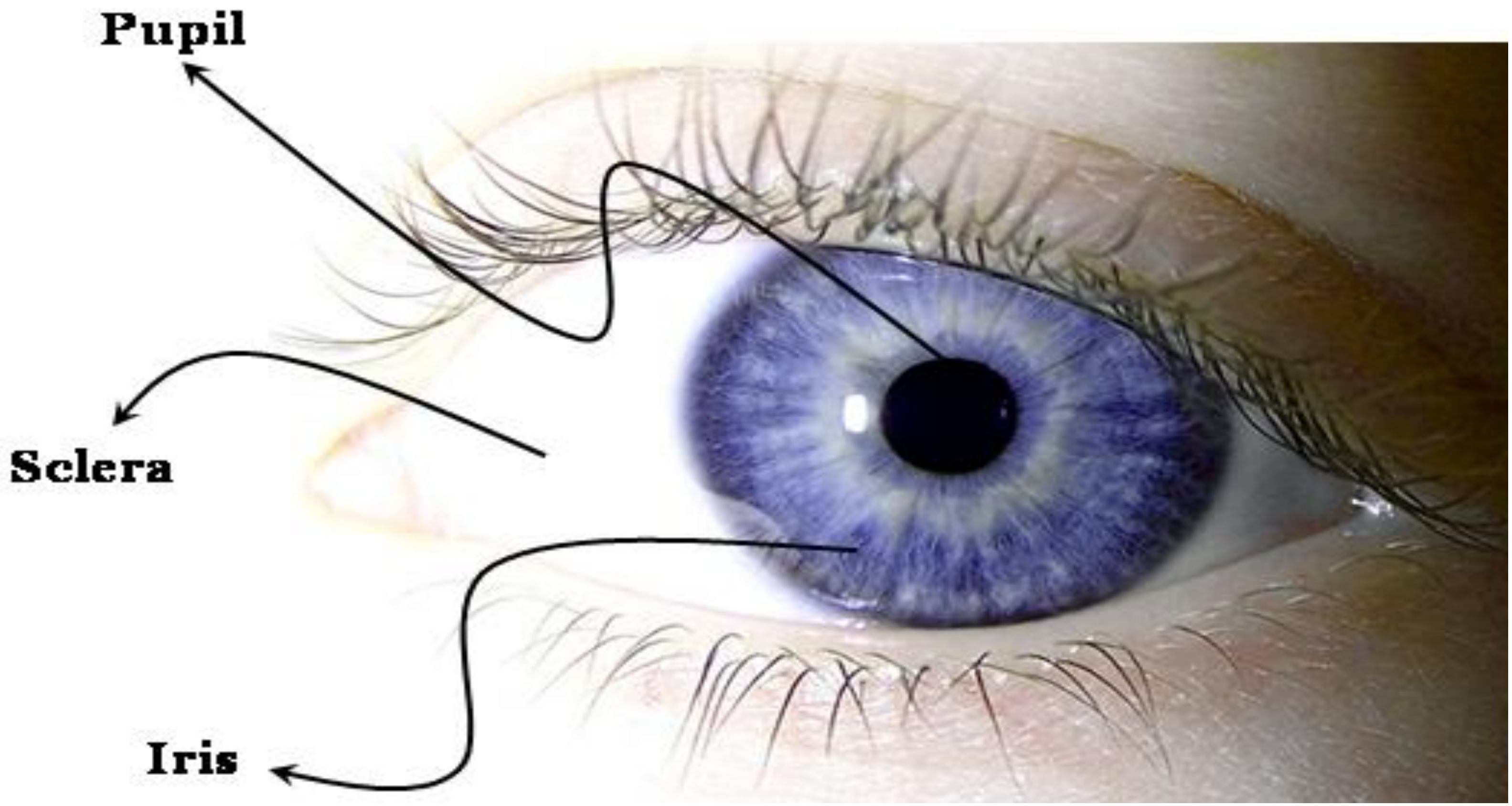
- Iris controls the amount of light to enter the eye.

- The dimmer the surrounding light, the wider the pupil.

- Iris color comes from microscopic pigment cells called *melanin*.

- It is an internal organ, yet can be easily seen.

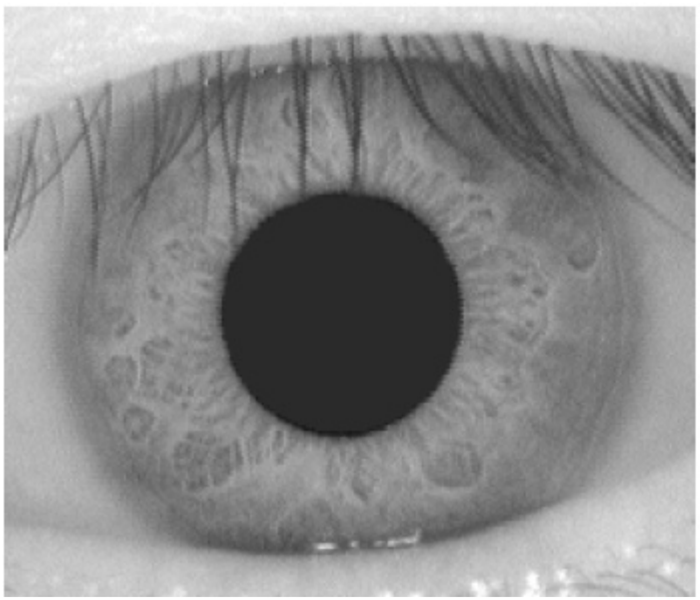
Iris

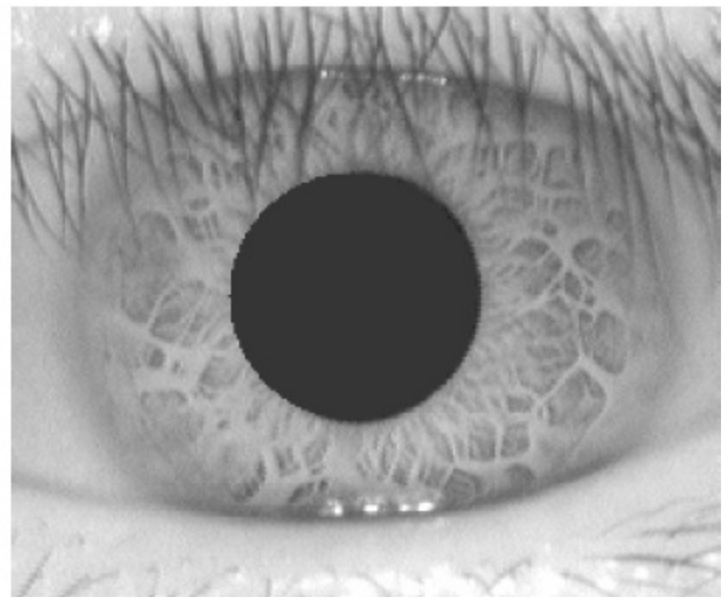


- Visual texture of the iris stabilizes during the first two years of our life.
- Iris texture carries distinctive information useful of identification.

Iris

- Iris is the annular portion between the dark pupil and white sclera





- It has got a rich texture information which could be exploited for a biometric recognition system.

Why Iris ?!!!

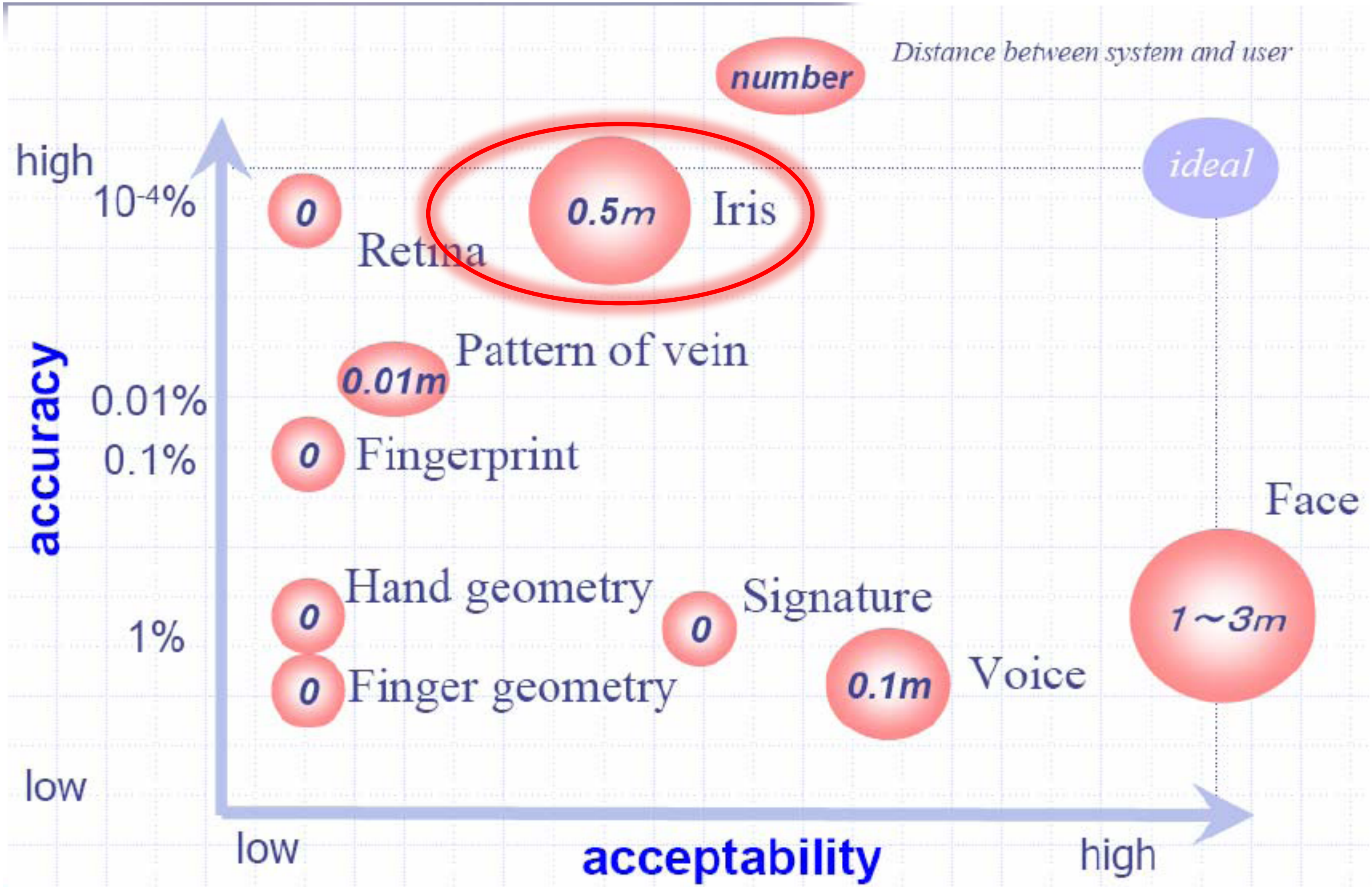
- Its error rate is extremely low
- Extremely data-rich physical structure
- Iris is a permanent biometric (patterns apparently stable throughout life).
- User acceptability is reasonable
- Real time biometric verification
- Physical protection by a transparent window (the cornea), highly protected by internal organ of the eye.
- Externally visible, so noninvasive — patterns imaged from a distance.
- genetic independence — no two eyes are the same.

Why Iris ?!!!

Biometric identifier	Universality	Distinctiveness	Permanence	Collectability	Performance	Acceptability	Circumvention
DNA	H	H	H	L	H	L	L
Ear	M	M	H	M	M	H	M
Face	H	L	M	H	L	H	H
Facial thermogram	H	H	L	H	M	H	L
Fingerprint	M	H	H	M	H	M	M
Gait	M	L	L	H	L	H	M
Hand geometry	M	M	M	H	M	M	M
Hand vein	M	M	M	M	M	M	L
Iris	H	H	H	M	H	L	L
Keystroke	L	L	L	M	L	M	M
Odor	H	H	H	L	L	M	L
Palmprint	M	H	H	M	H	M	M
Retina	H	H	M	L	H	L	L
Signature	L	L	L	H	L	H	H
Voice	M	L	L	M	L	H	H

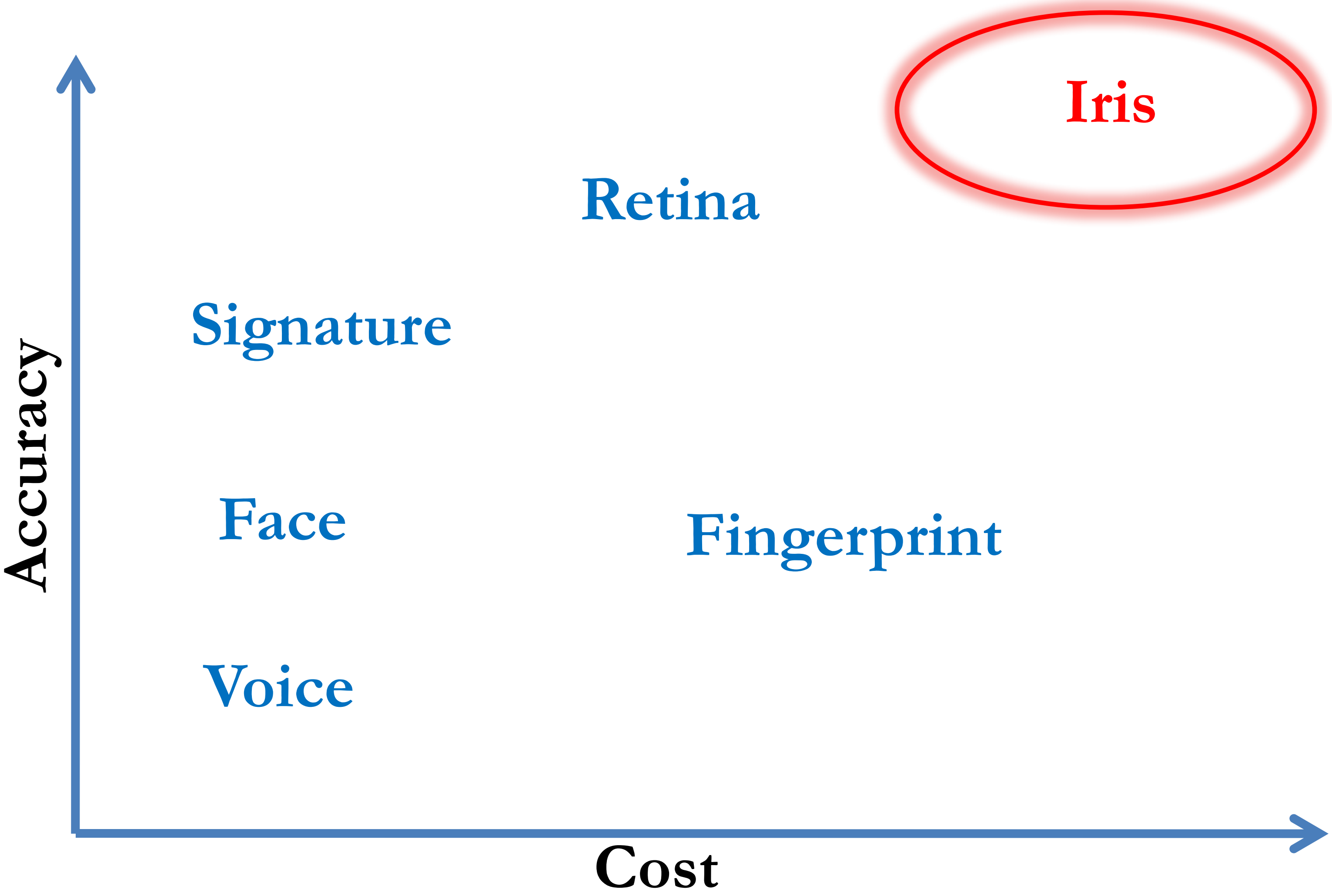
Source**: *IEEE Transactions on Circuits and Systems for Video Technology, Special Issue on Image- and Video-Based Biometrics, Vol. 5*** *14, No. 1, January 2004*

Why Iris ?!!!



Source: ***Lecture Slides of EE851N, by Dr. Ajay Kumar Pathak, Jan-May, 2006***

Why Iris ?!!!



Iris
Retina
Signature
Accuracy
Face
Fingerprint
Voice
Cost

Iris Variability Among People

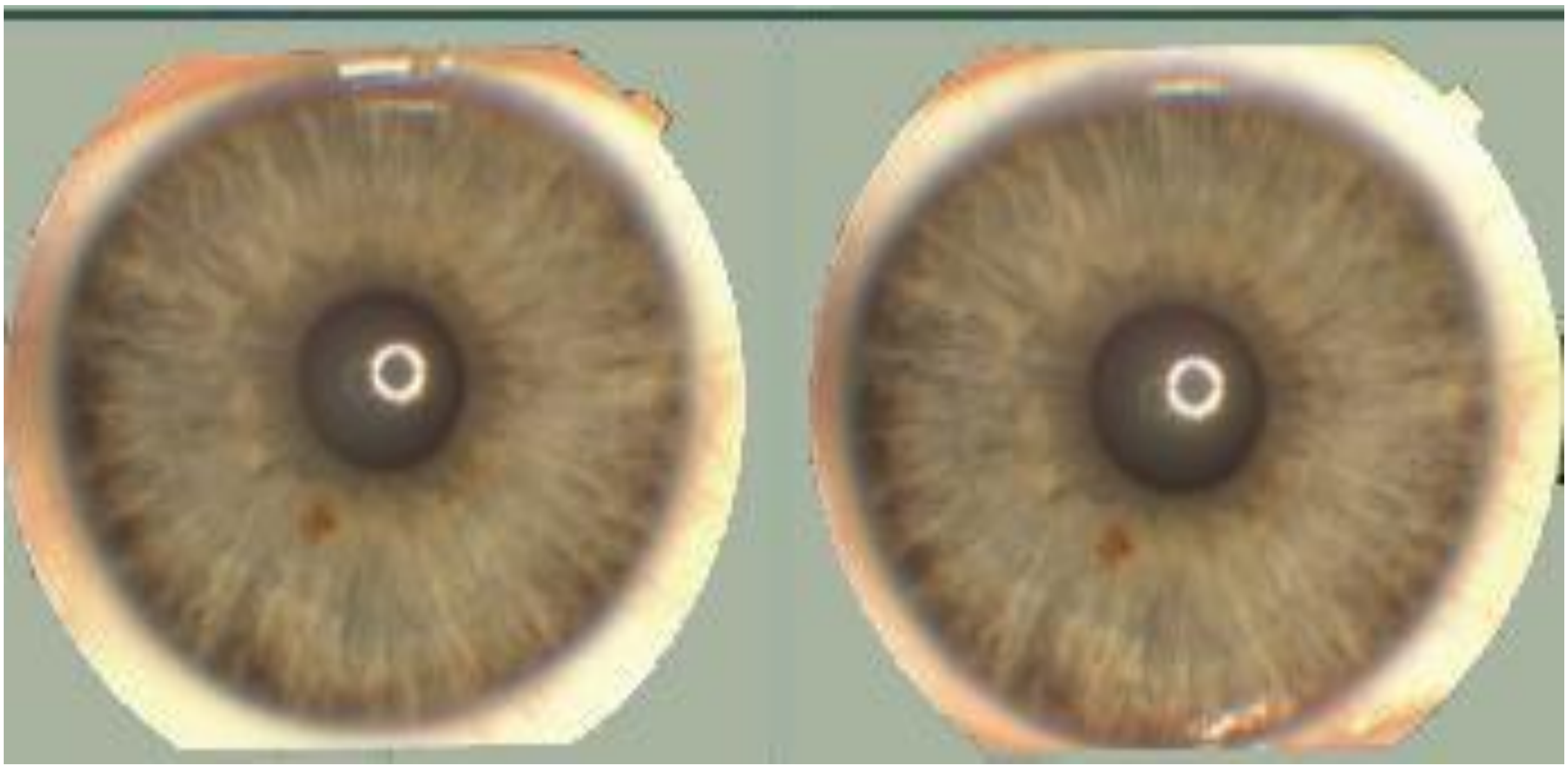
The probability that two irises could produce exactly the same iris pattern is approximately 1 in 10^{78}. (The population of the earth is around 10^{10}).

Frankin Cheung, "*Iris Recognition*", BSc thesis, University of Queensland, Australia, 1999

Iris Variability Among People

Even Twins have different irises

Iris Variability Among People



Left and right irises for an individual are different

Iris Pattern Stability

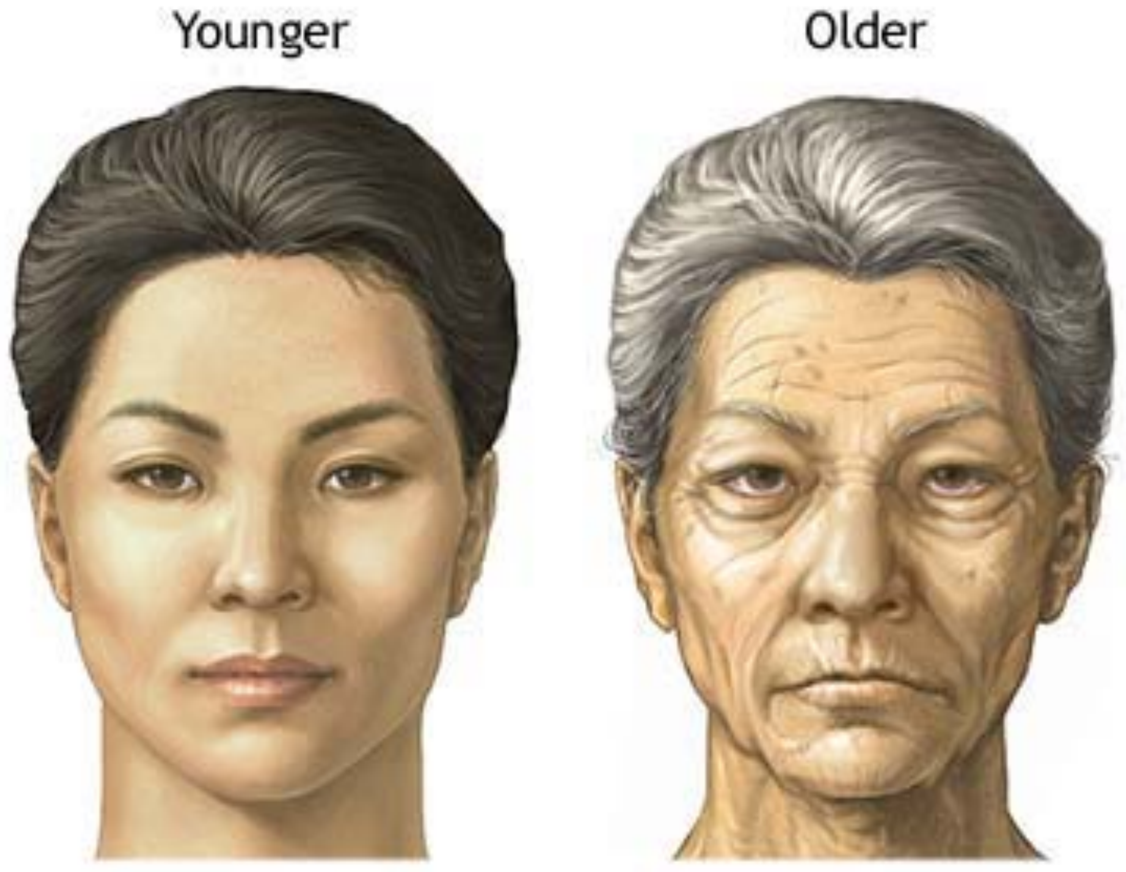
- Irises do not change, even with expression.

Iris Pattern Stability

- Irises do not change, even with pose.

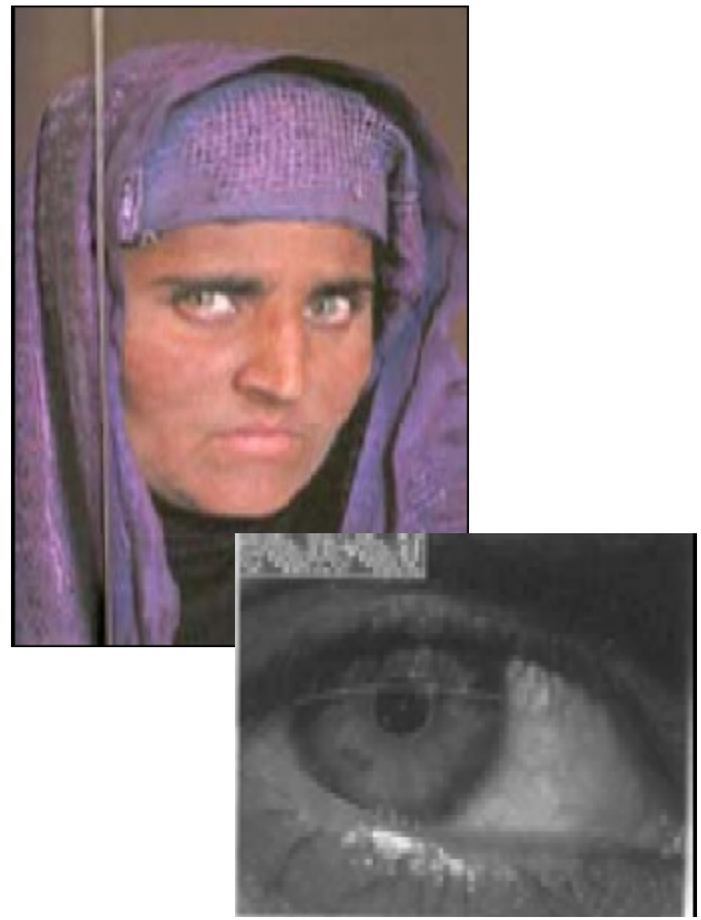
Iris Pattern Stability

- Irises do not change, even with age.



Iris Pattern Stability

- Afghan girl’s picture in 1984 and 2002.

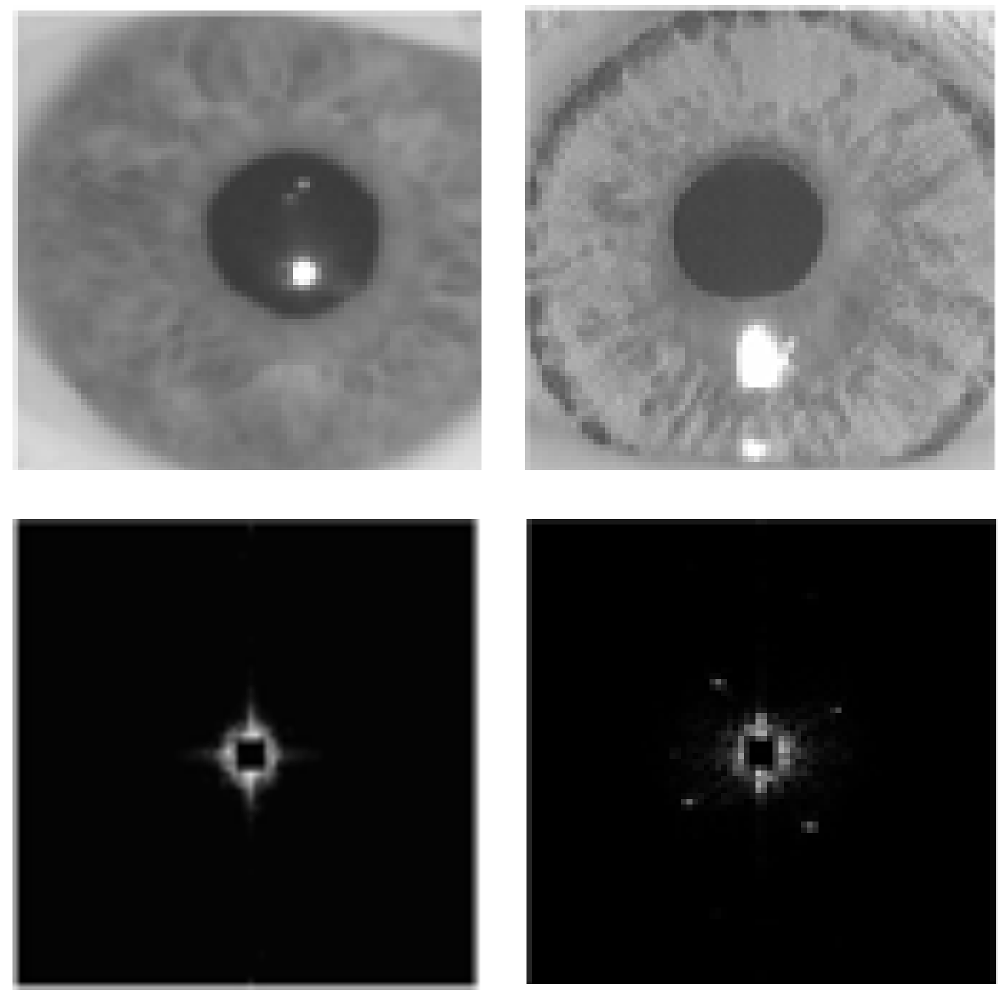


Iris Pattern Stability

- Irises do not change, even with makeup

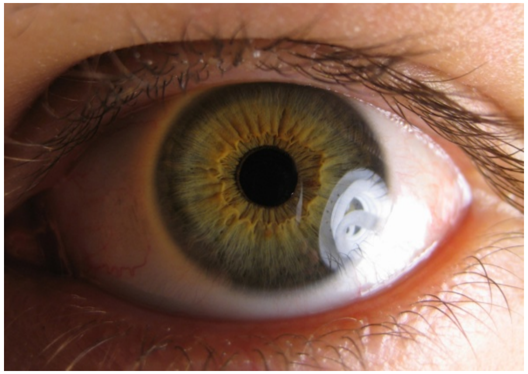
Live versus Printed Iris

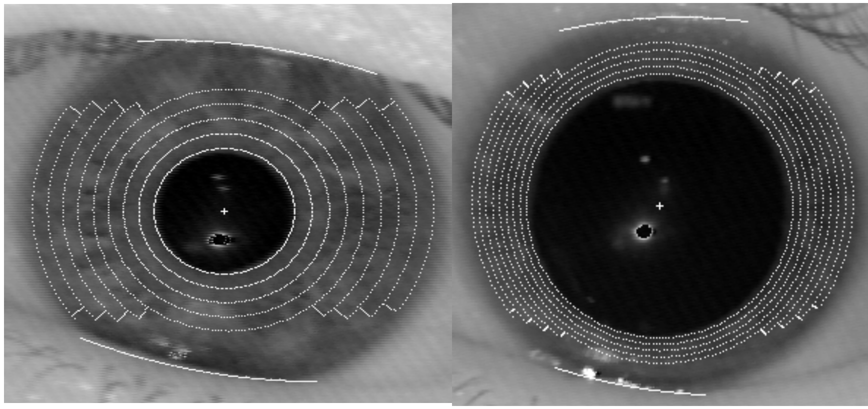
- 2D Fourier spectrum shows periodicity in the printed iris while there is no such periodicity in the natural iris.



However … ☹

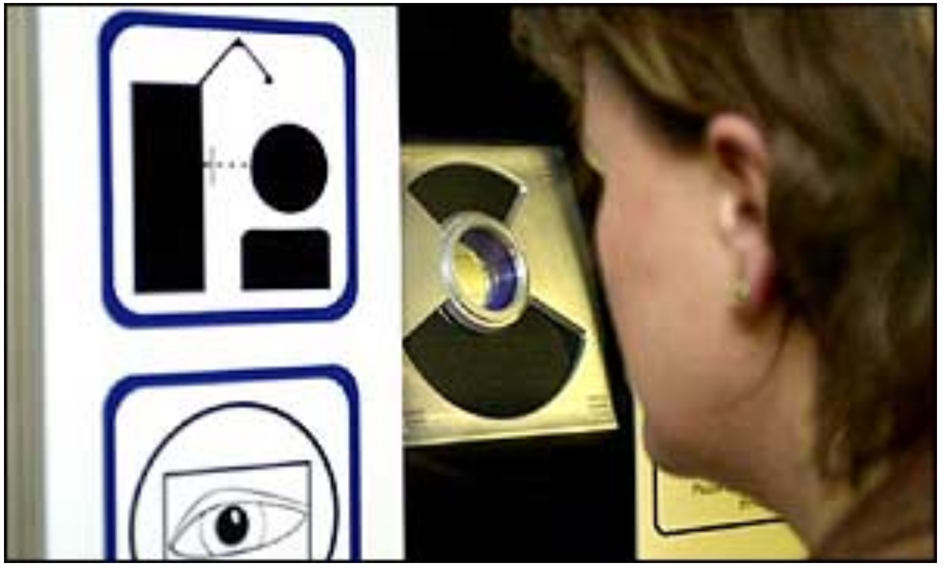
- The *disadvantages* to use iris as a biometric measurement are
  - Small target (1 cm) to acquire from a distance (about 1 m)
  - Moving target
  - Located behind a curved, wet, reflecting surface.
  - Obscured by eyelashes, lenses, reflections.
  - Partially occluded by eyelids, often drooping
  - Deforms non-elastically as pupil changes size
  - Illumination should not be visible or bright





However … ☹

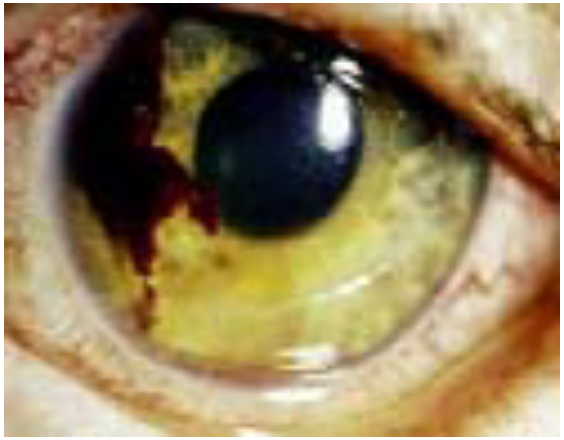
- Cooperative subjects needed.



http://news.bbc.co.uk/1/hi/uk/1816221.stm

However … ☹

- Iris change due to eye disease.


Iris Recognition History

- The idea of using iris patterns for personal identification was originally proposed in 1936 by ophthalmologist **Frank Burch**.
- In the 1980's the idea appeared in *James Bond* movies, but it remained science fiction.
- It was not until 1987, two American ophthalmologists, **Leonard Flom** and **Aran Safir** patented Burch's concept but they were unable to develop such a process.
- So instead they turned to **John Daugman**, who was teaching at Harvard University and now at Cambridge University, to develop actual algorithms for iris recognition. These algorithms, which Daugman developed in 1994, are the basis for all current iris recognition systems.

Iris Recognition Schematic

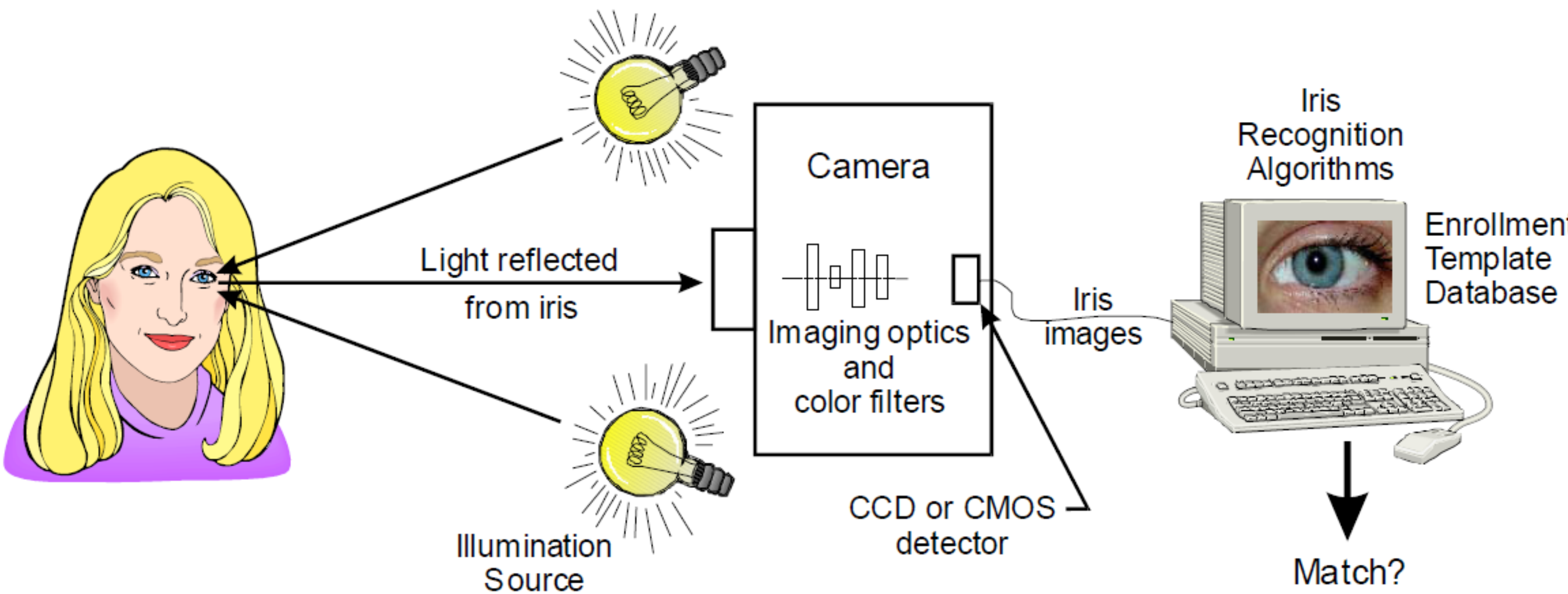
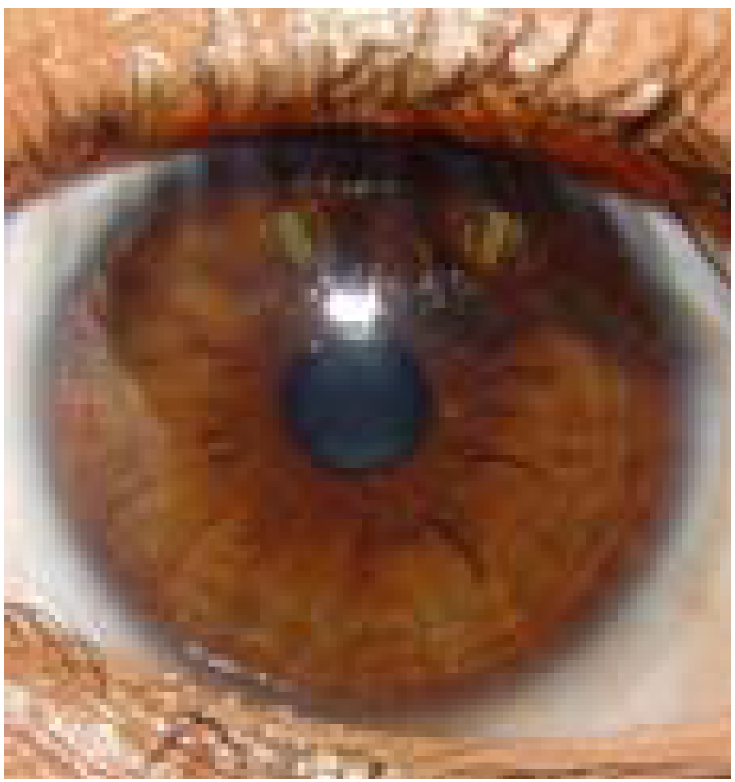


Image Acquisition

- Why important?
  - One of the major challenges of automated iris recognition is to capture a high-quality image, revealing much features/texture of the iris while remaining non-invasive to the human operator.
- Concerns on the image acquisition rigs
  - Obtained images with sufficient resolution and sharpness
  - Good contrast in the interior iris pattern with proper illumination
  - Well centered without unduly constraining the operator.
  - Artifacts eliminated as much as possible.

Image Acquisition

- Visible light reveals lesser texture for <u>dark</u> eyes than infrared light.



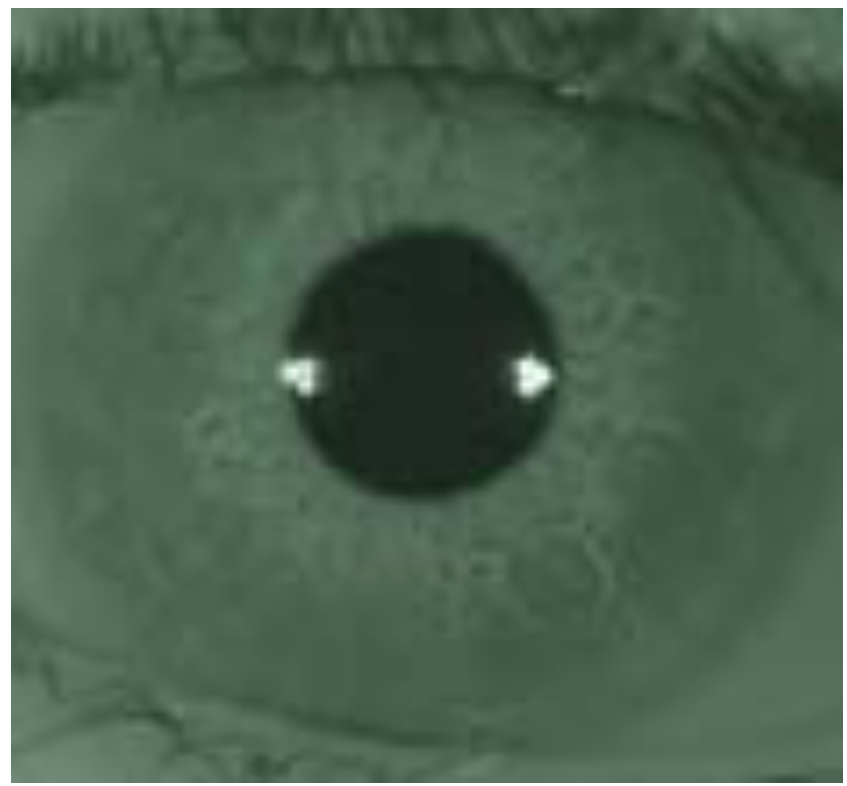
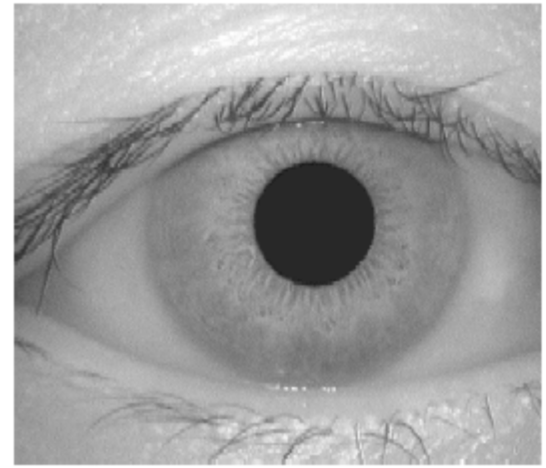
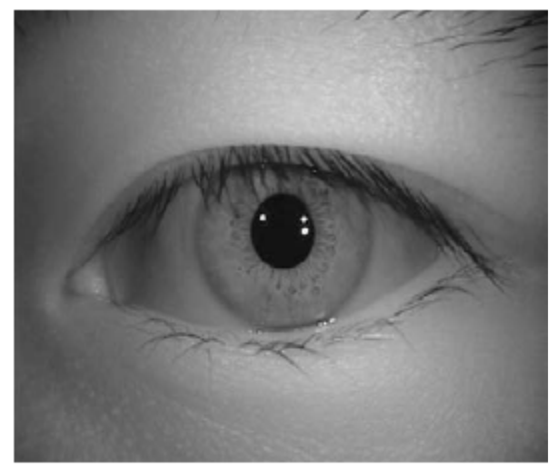


Image Acquisition

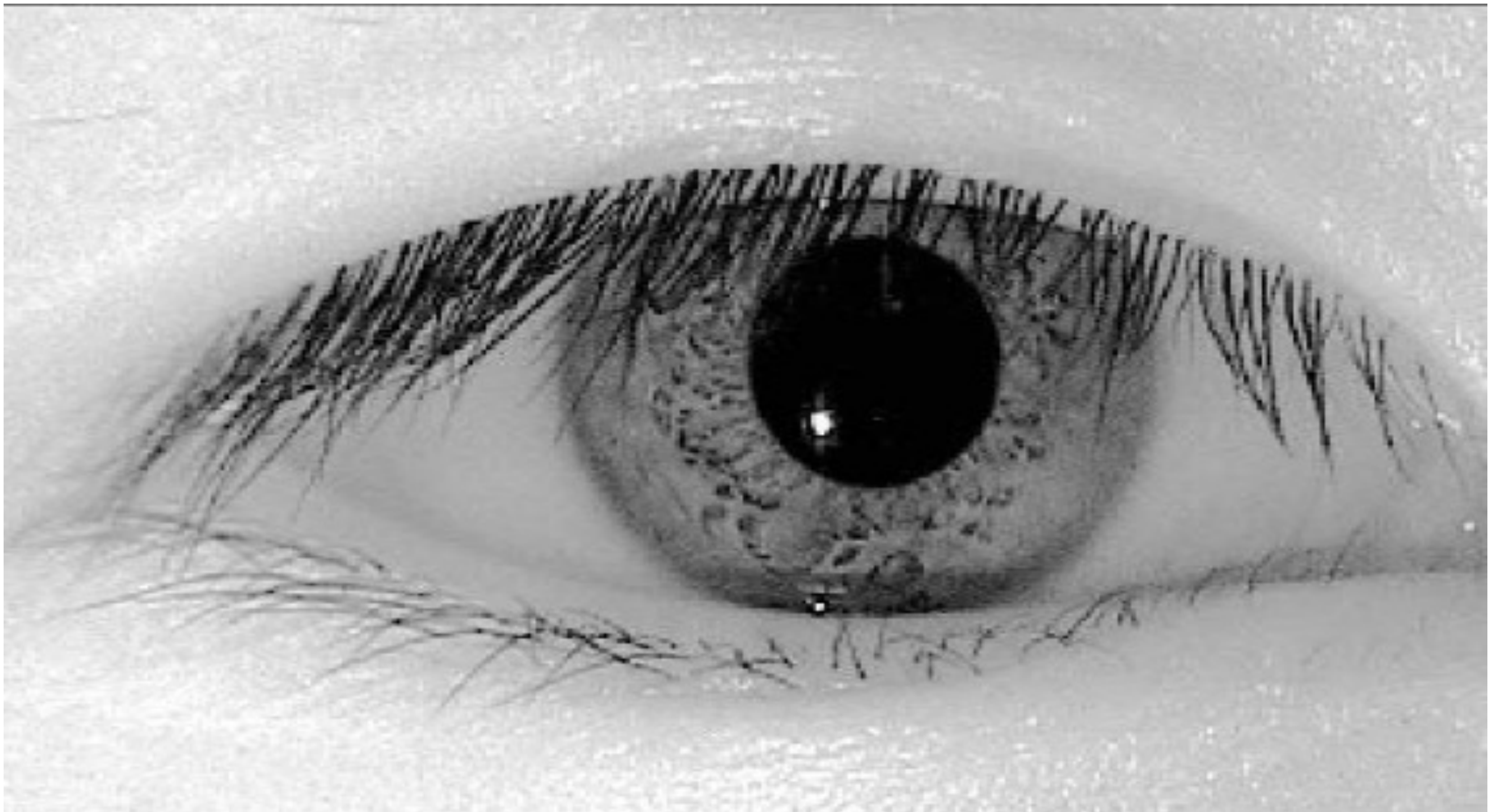


- Images are generally acquired in near infra red illumination
- The distance between the eye and the camera may vary from 4-50 cm
- Iris diameter typically should be between 100-200 pixels for extracting good texture



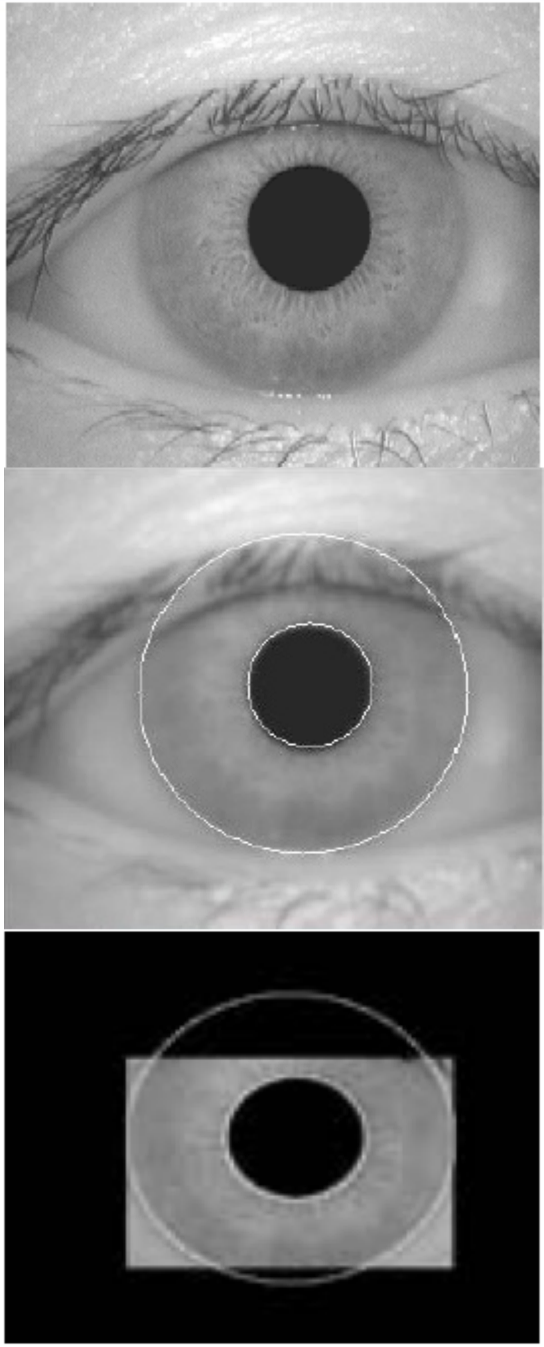
Infrared Iris Image

In infrared light, even <u>dark brown</u> eyes show rich iris texture.



Iris Localization

- Purpose:
  - Localize that portion of the acquired image that corresponds to an iris
- In particular, it is necessary to localize that portion of the image derived from inside the limbus (the border between the sclera and the iris) and outside the pupil.
- Desired characteristics of iris localization:
  - Sensitive to a wide range of edge contrast
  - Robust to irregular borders
  - Capable of dealing with variable occlusions



Pattern Matching

- Four steps:

  1) bringing the newly acquired iris pattern into spatial alignment with a candidate data base entry – **alignment/normalization**

  2) choosing a representation of the aligned iris patterns that makes their distinctive patterns apparent – **feature encoding**

  3) evaluating the goodness of match between the newly acquired and data base representations – **feature matching**

  4) deciding if the newly acquired data and the data base entry were derived from the same iris based on the goodness of match - **decision**

Take home messages

- Now it is your turn to figure out how can we implement each stage of Daugman framework.
- Next class, each one of you will present his own ideas regarding each block in this framework.
- It gonna be fun ☺

References

- Li. Ma, Y. Wang, and T. Tan, “Iris recognition using circular symmetric filters,” in *Proc. 16th Int. Conf. Pattern Recognition, vol. II, 2002, pp. 414-417*
- Li. Ma, Y. Wang, and T. Tan, “Iris recognition based on multi-channel Gabor filtering,” in *Proc. 5th Asian Conf. Computer Vision, vol. I, 2002, pp. 279-283*
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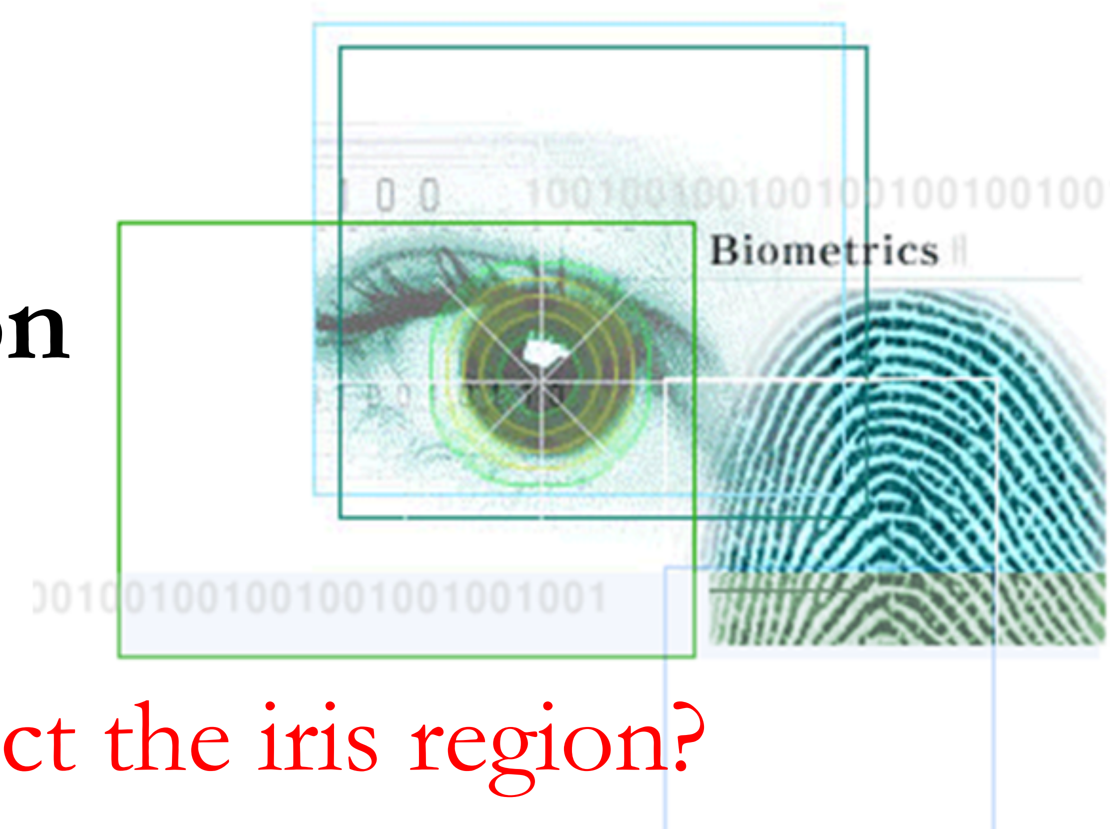
- Daugman, J. The importance of being random: Statistical principles of iris recognition. *Pattern Recognition, vol. 36, num. 2, pp. 279-291, 2003*
- Ma Li, Tan T., Wang Y. and Zhang, D. (2004): Efficient Iris Recognition by characterizing Key Local Variations, *IEEE Trans. Image Processing, vol 13,* no.6, pp. 739-750
- A. Poursaberi, B. N. Araabi, "A Novel Iris Recognition System Using Morphological Edge Detector and Wavelet Phase Features", *ICGST International Journal on Graphics, Vision and Image Processing, P1150517004, June* 2005

Iris Recognition



Q2 :

How to extract the iris region?

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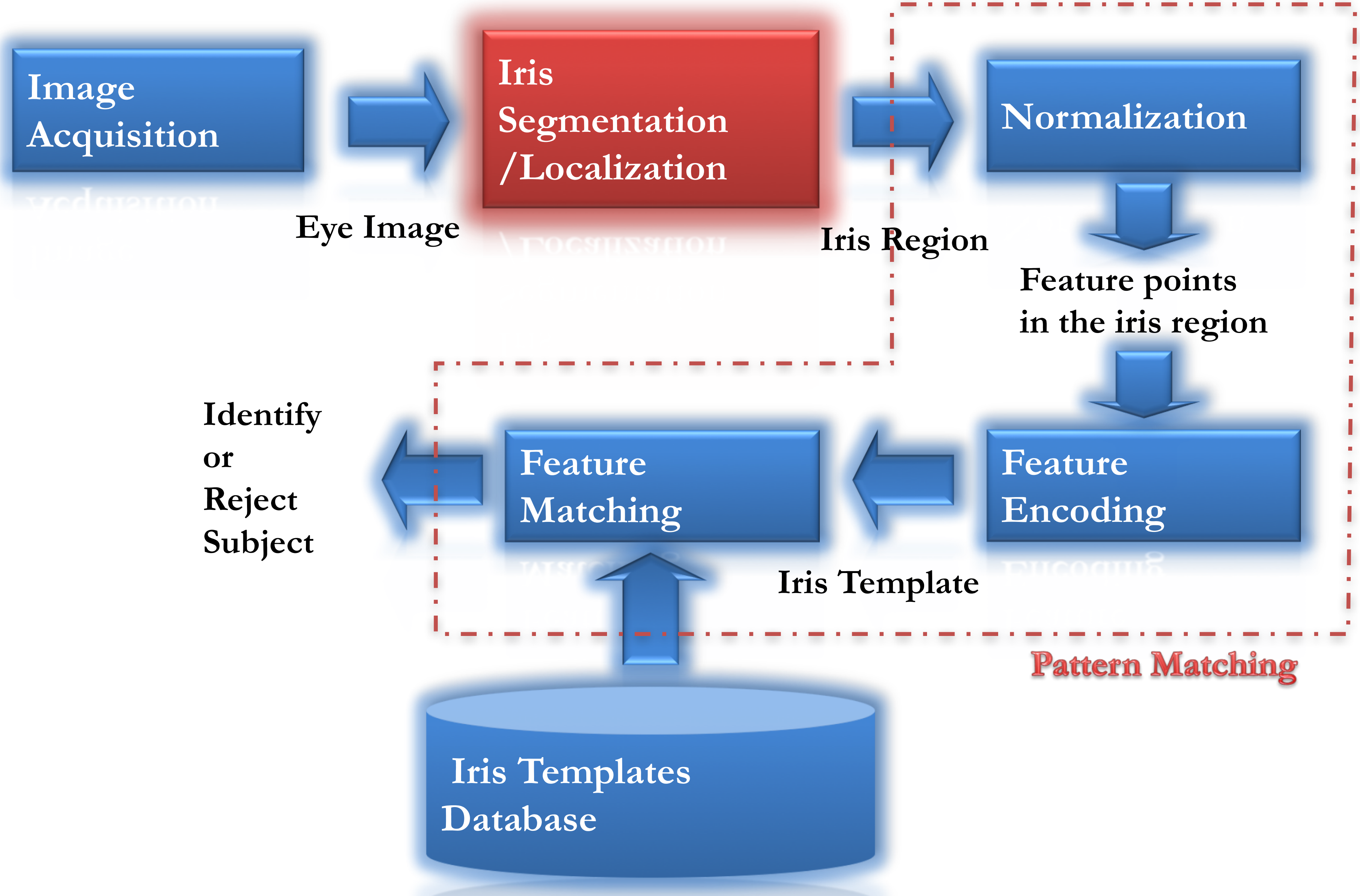
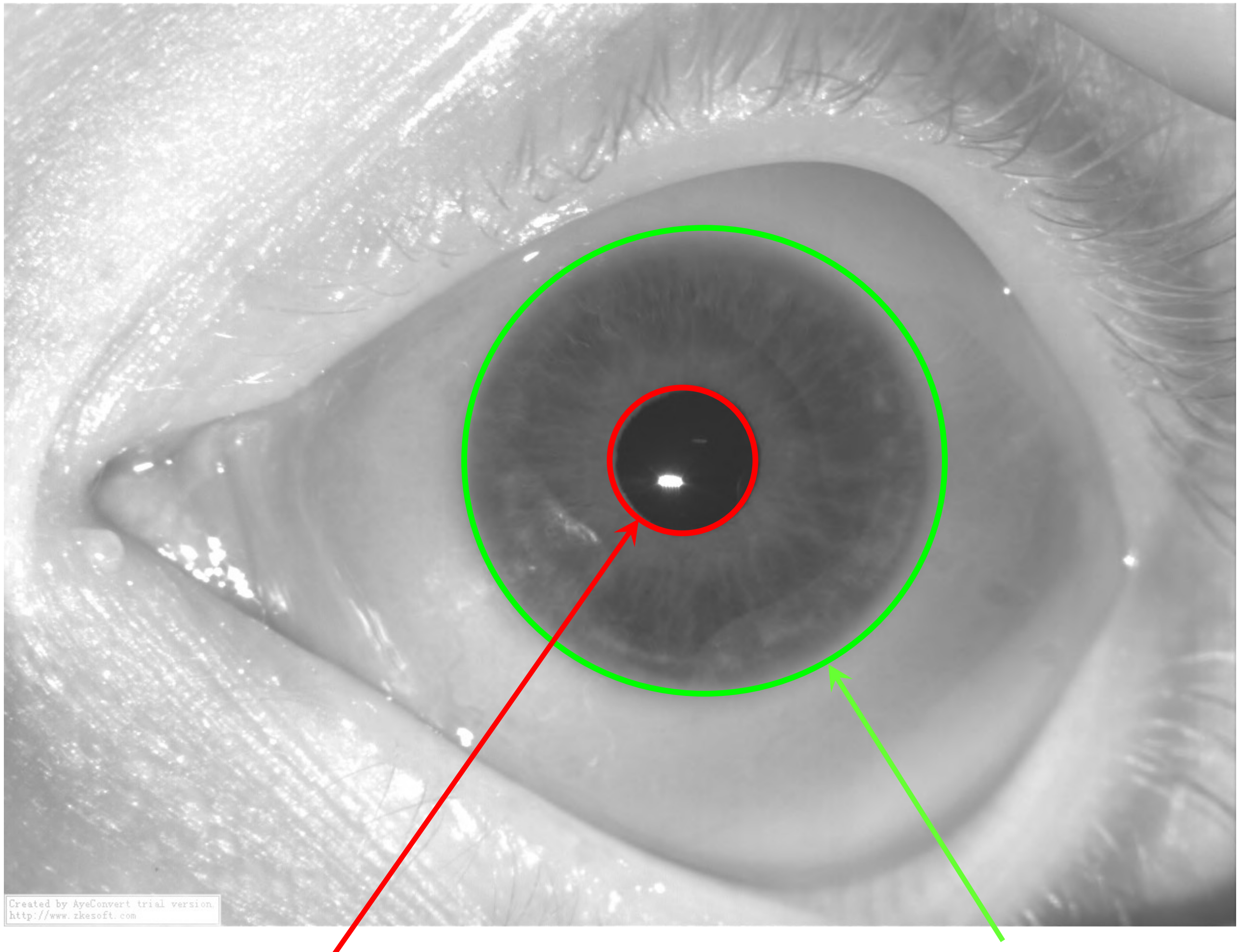
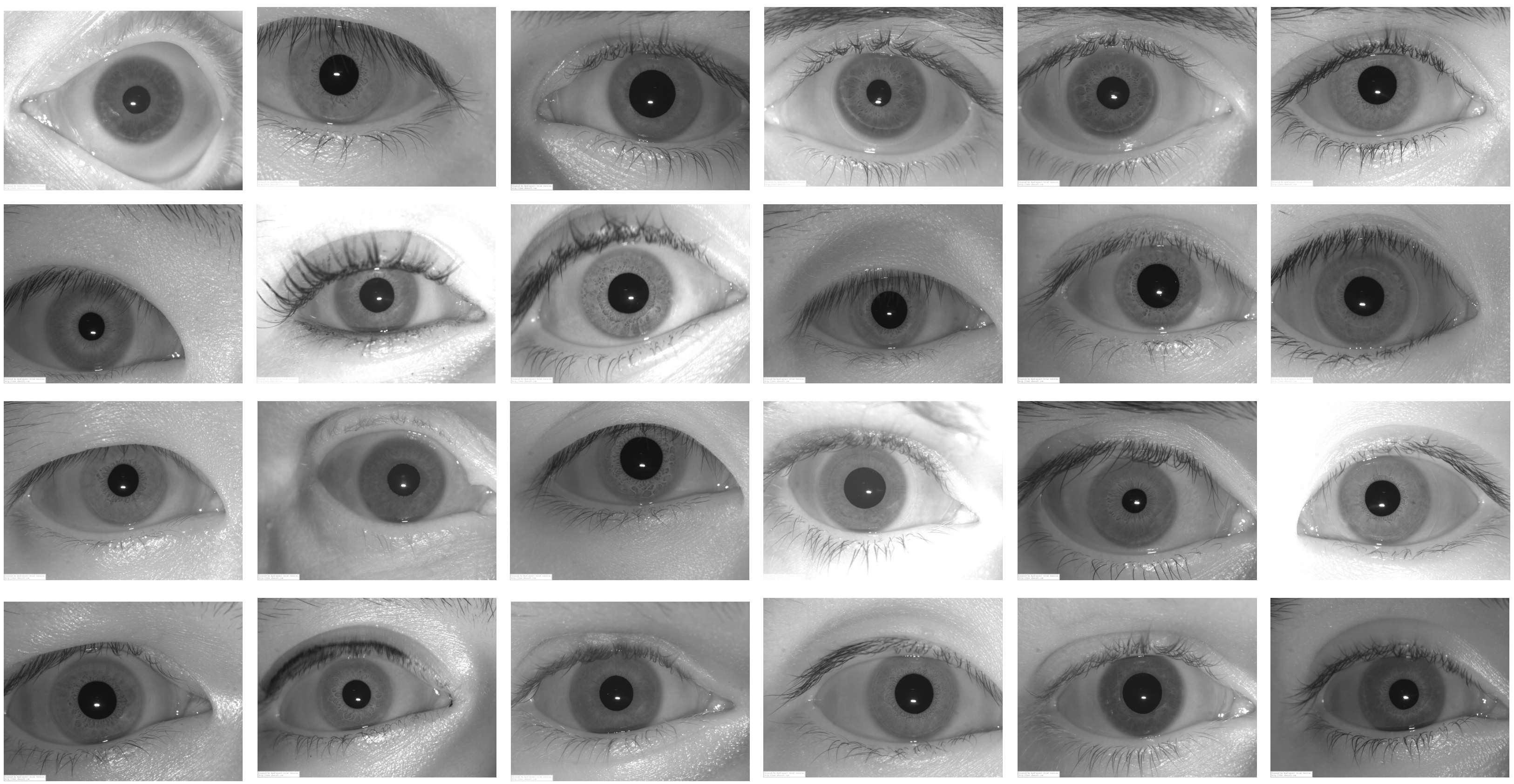
Daugman Model for Iris Recognition



Iris Geometry



Pupil Boundary Extraction

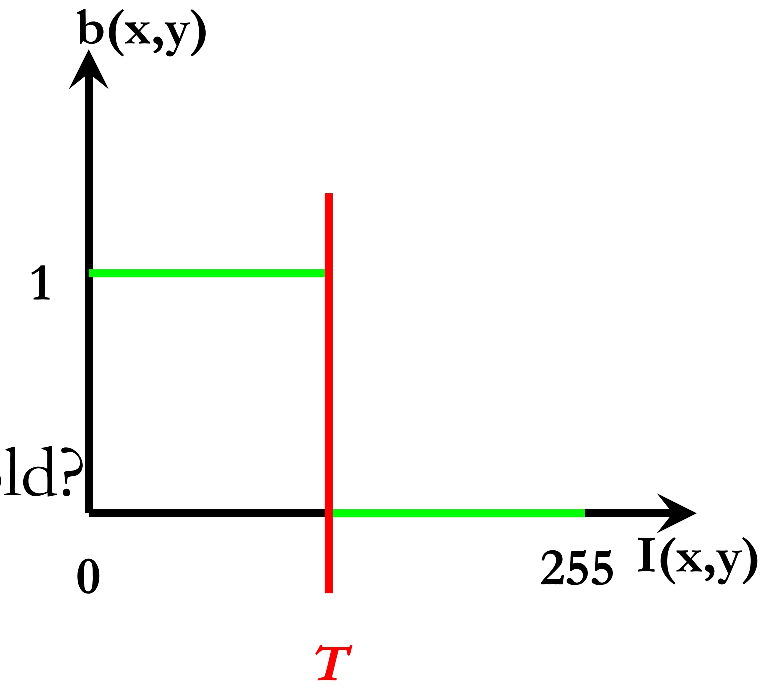


What is the discriminatory feature of the pupil? How would we extract it?

Pupil Boundary Extraction

- Pupil extraction involves image thresholding or the so called binarization.
- We want to find a gray level (threshold) T such that:

$$b(x,y)=\begin{cases}1 & ;I(x,y)<T\\ 0 & ;I(x,y)\geq T\end{cases}$$

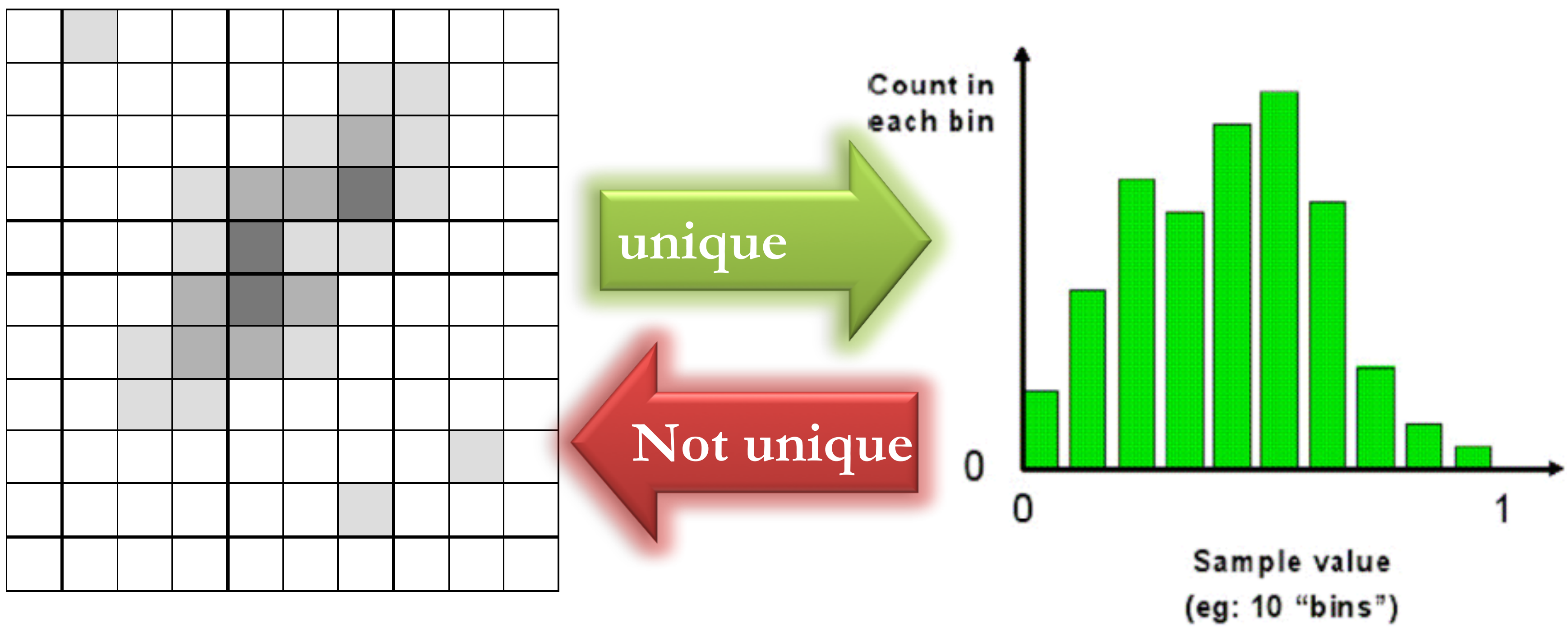


- But, how can we find this threshold?
  - Fixed !!!
  - Function of the input image !!!

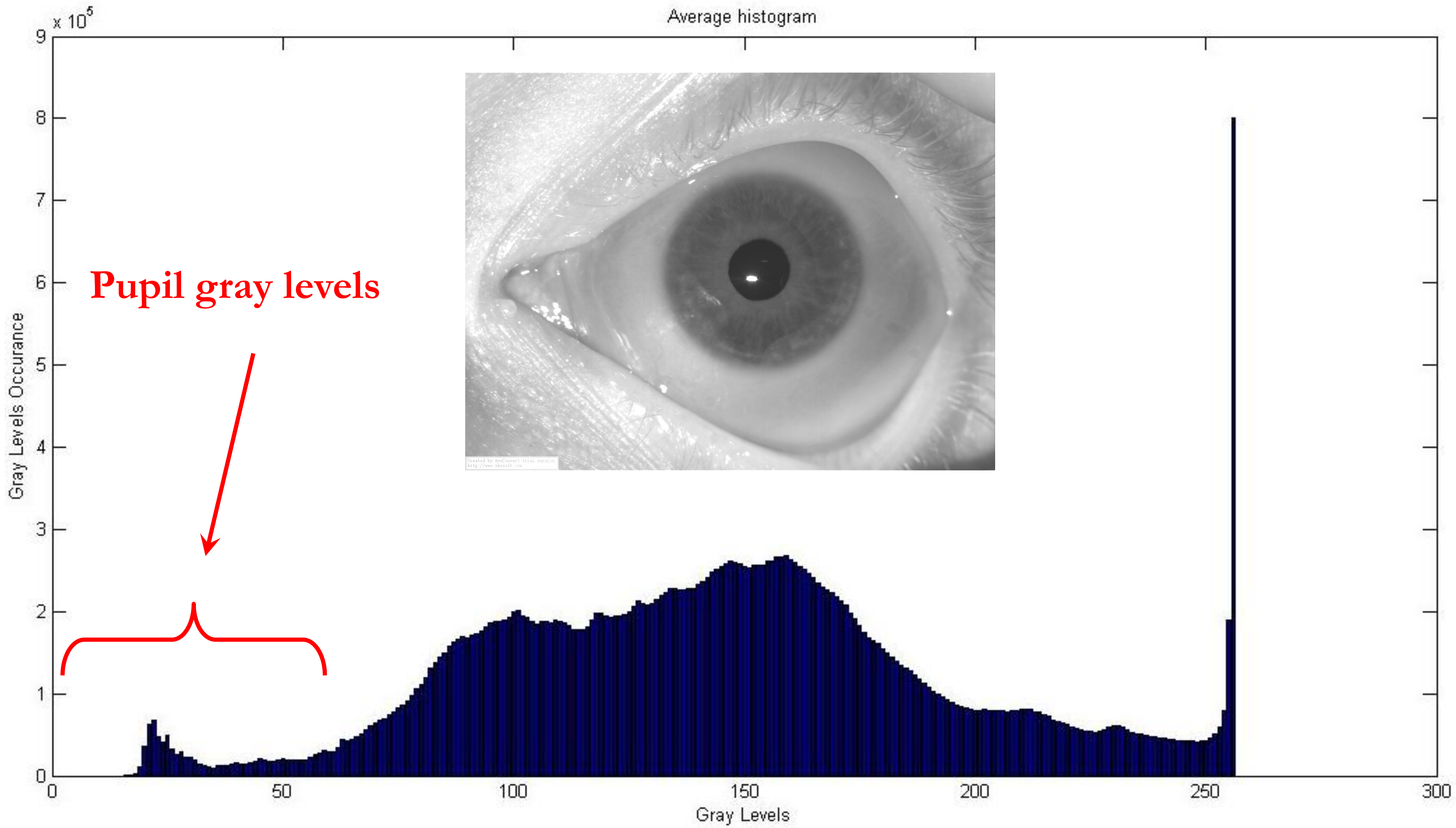
Pupil Boundary Extraction

Image Histogram:

- $h(i)$ is the number of pixels in $I(x,y)$ having the intensity i.

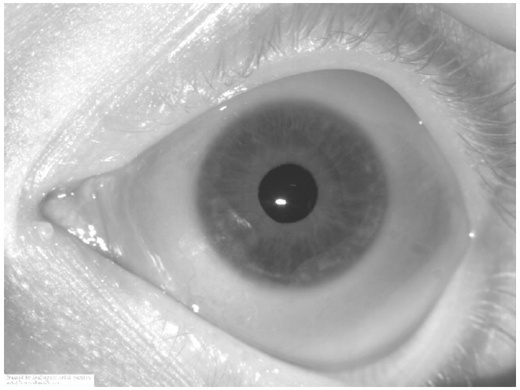


Pupil Boundary Extraction

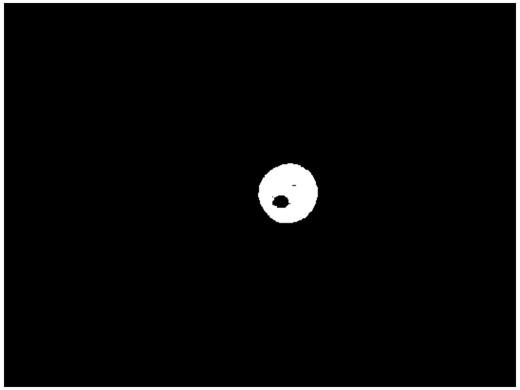


Pupil Boundary Extraction

In Matlab



```
I = imread('1.jpg');

figure
imshow(I);

% pupil extraction
% histogram generation
[img_hist,img_bins] = hist(double(I(:)),5);

% threshold determination
T = img_bins(1);

% image binarization/thresholding
b = I < T ;

% visualizing the result
figure
imshow(b);
```



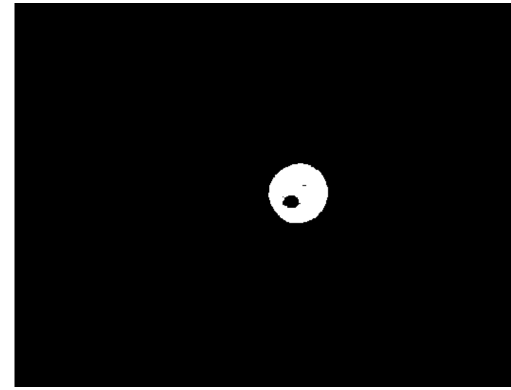
Pupil Boundary Extraction

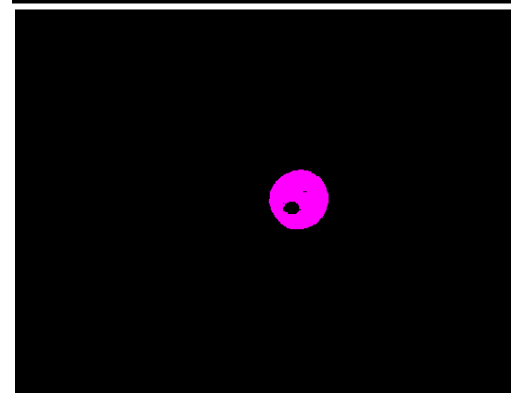
How to grab hold of the pupil from the image ?

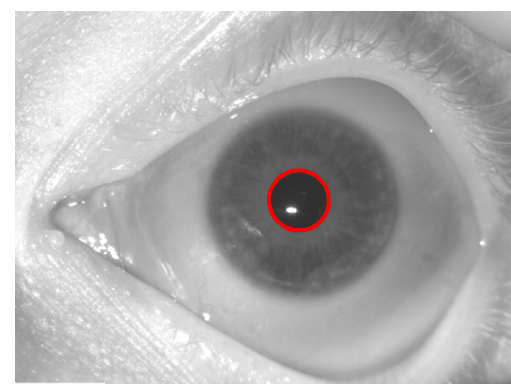
- The solution is **connected component labeling**
- Connected Components algorithm is used to extract "regions" from an image.
- A region in an image is a set of pixels with similar intensity values which are neighbours to each other.
- Once the regions are extracted they are labelled with different numbers/colors.

Pupil Boundary Extraction

```
% connected component labeling
labeled = bwlabel(b,8);
rgb = label2rgb(labeled,'spring',[0 0 0]);

figure, imshow(rgb)

% getting pupil candidates
candidate_pupil = regionprops(labeled,'Area', ...
                        'Eccentricity','Centroid','BoundingBox');
maxArea = 0;
for i = 1 : length(candidate_pupil)
    if(candidate_pupil(i).Area > maxArea) &&...
            (candidate_pupil(i).Eccentricity <= 0.7)
        maxArea = candidate_pupil(i).Area;
        m = i;
    end
end

% getting the centroid and radius of the pupil
Pupil.Cx = round(candidate_pupil(m).Centroid(1));
Pupil.Cy = round(candidate_pupil(m).Centroid(2));
Pupil.R = round(max(candidate_pupil(m).BoundingBox(3)/2,candidate_pupil(m).BoundingBox(4)/2));

% visualizing pupil contour
% pupil contour points
nPoints = 500;
theta = linspace(0,2*pi,nPoints);
rho = ones(1,nPoints)* Pupil.R;
[X,Y] = pol2cart(theta,rho);
X = X + Pupil.Cx;
Y = Y + Pupil.Cy;

figure, imshow(I); hold on
plot(X,Y,'r','LineWidth',3);
```

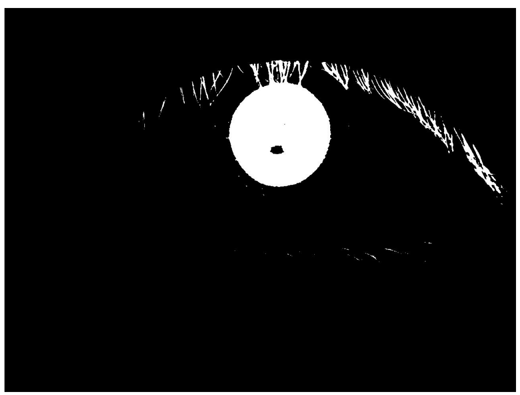


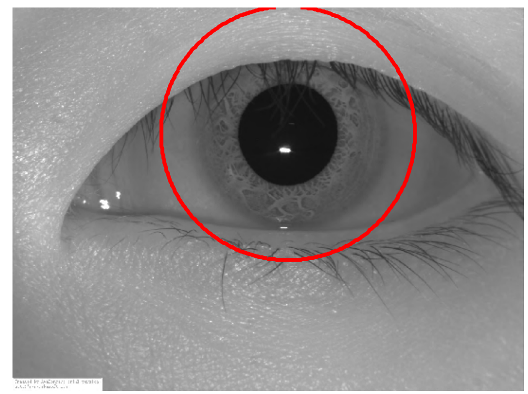




Pupil Boundary Extraction

- Nothing is easy ☹
- You might have eyelashes connected to the pupil, and both will have low gray level.





- Good news is: pupil region will be the dominant region, eyelashes can be considered as noise, which can be removed by **median filtration**.

Pupil Boundary Extraction

Median filtration

- Median filter is a semi-low-pass filter that attempts to remove noisy pixels while keeping the edges intact.
- The value of the pixels in the window are sorted and the median--the middle value in the sorted list--is chosen.

Example: Noise removal with a 3x3 median filter

Image

1	1	1	1	1
1	1	1	1	1
1	1	1	1	1
1	1	6	1	1
1	1	1	1	1
1	1	1	1	1
1	1	1	1	1

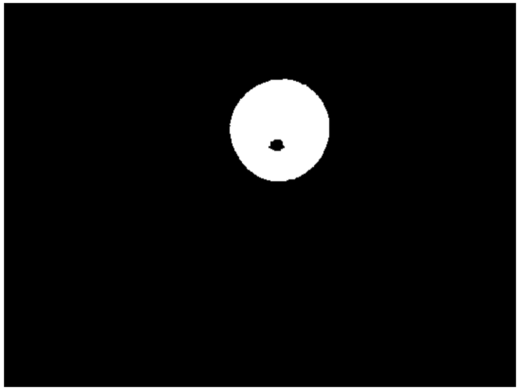
Output

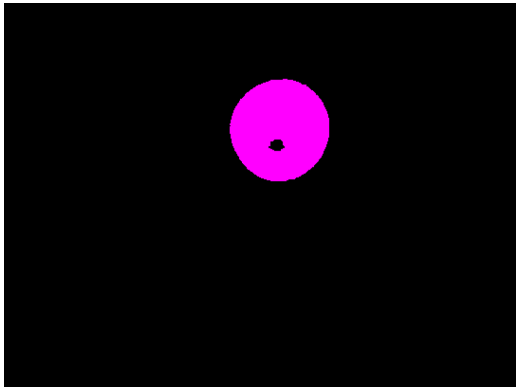
1	1	1
1	1	1
1	1	1
1	1	1
1	1	1

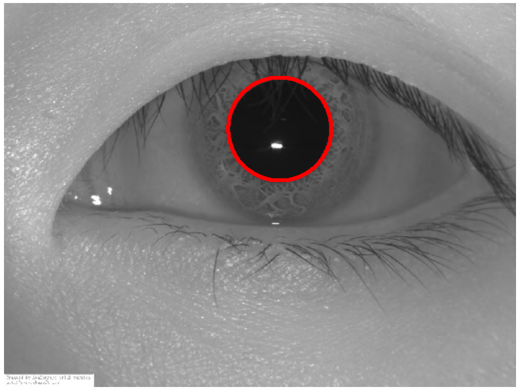
Pupil Boundary Extraction

In Matlab

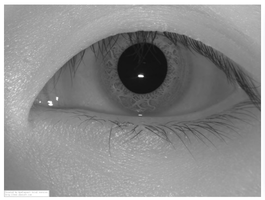
```
b = medfilt2(b,[5 5]);
```



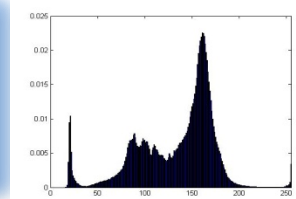




Pupil Boundary Extraction



Histogram Generation



Threshold Determination

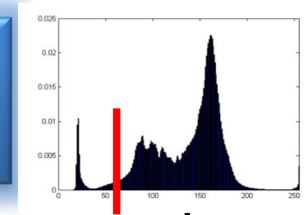
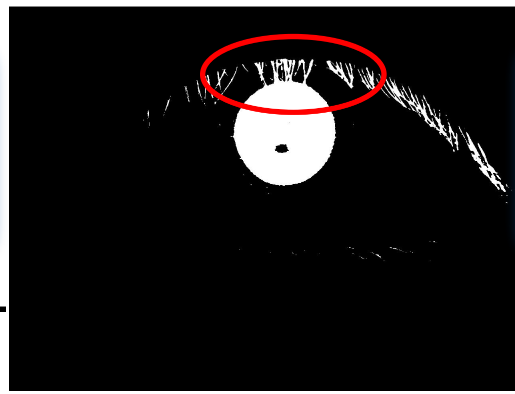
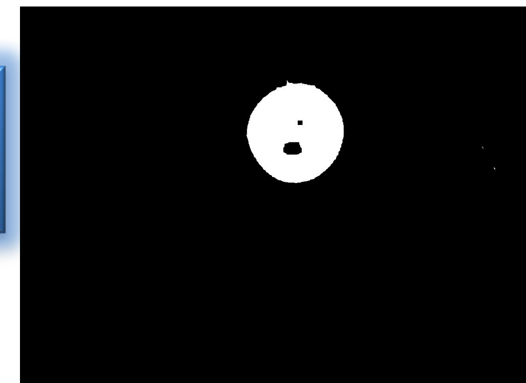


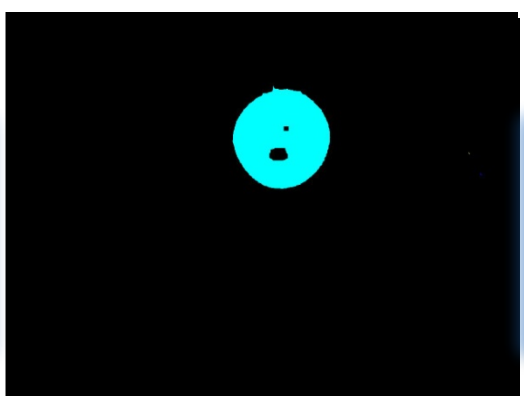
Image Binarization



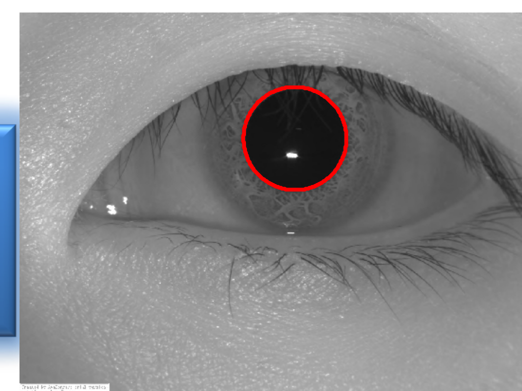
Median Filtration



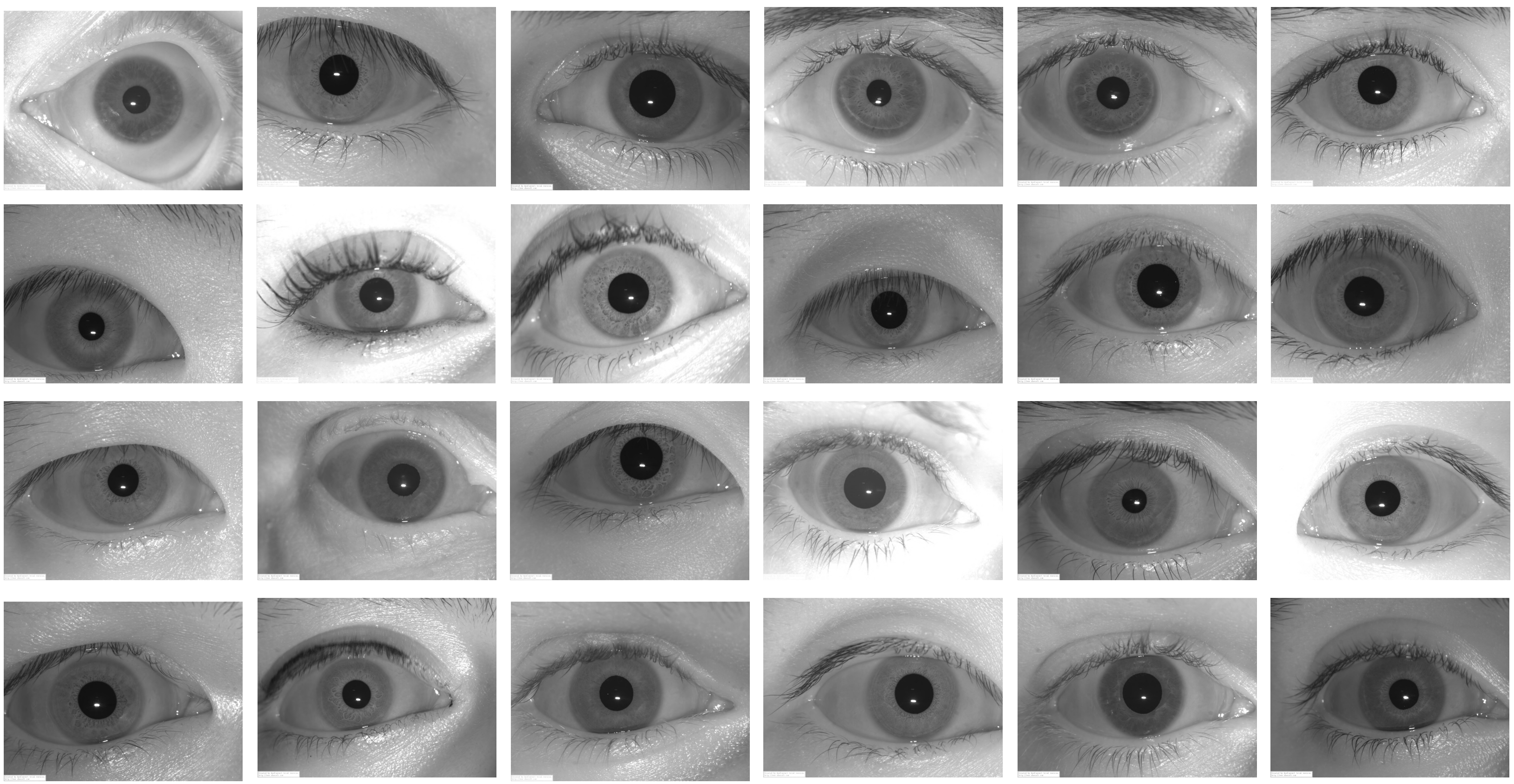
Connected Component Labeling



Centroid-Radius Calculation

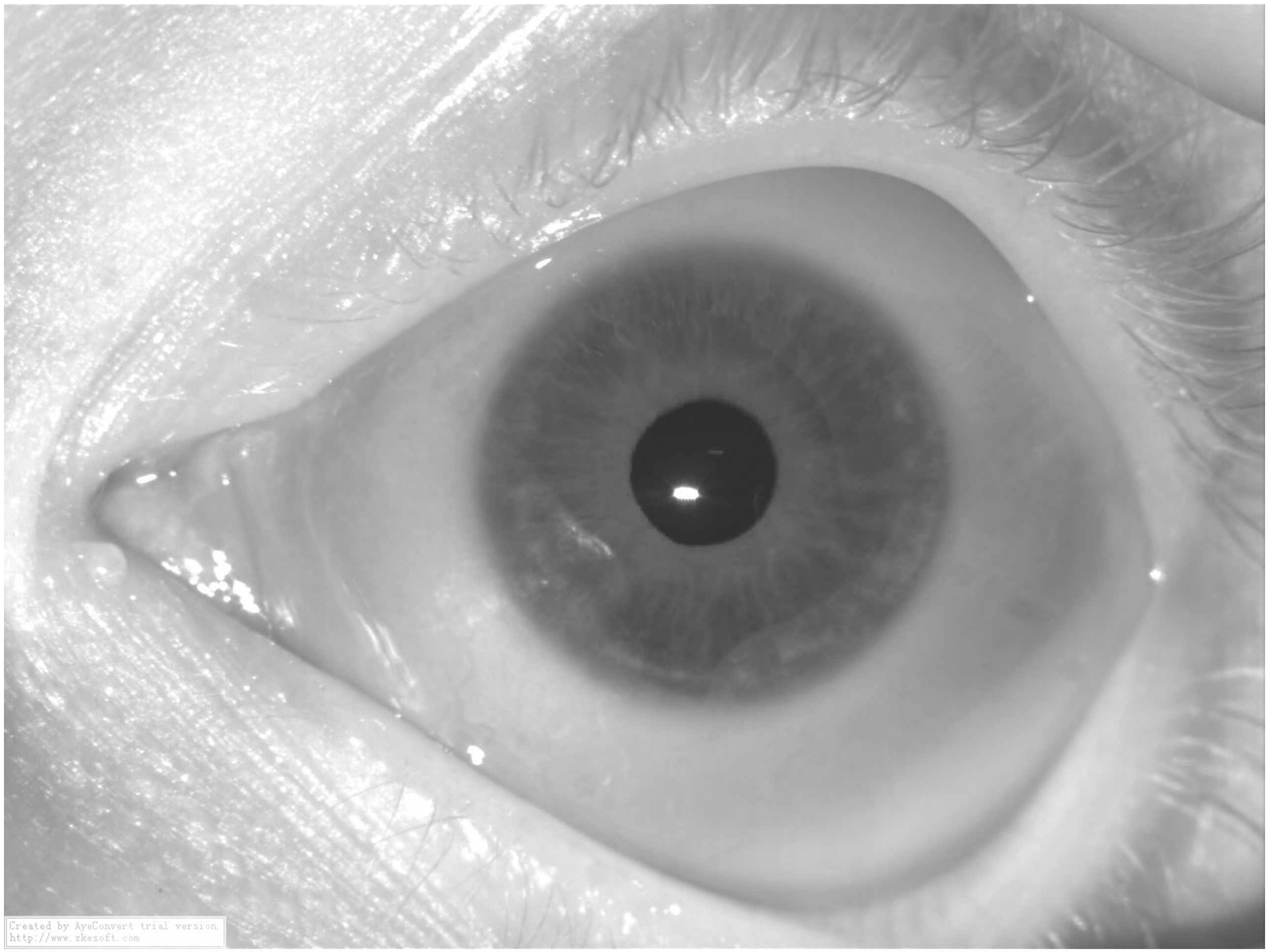


Iris Boundary Extraction



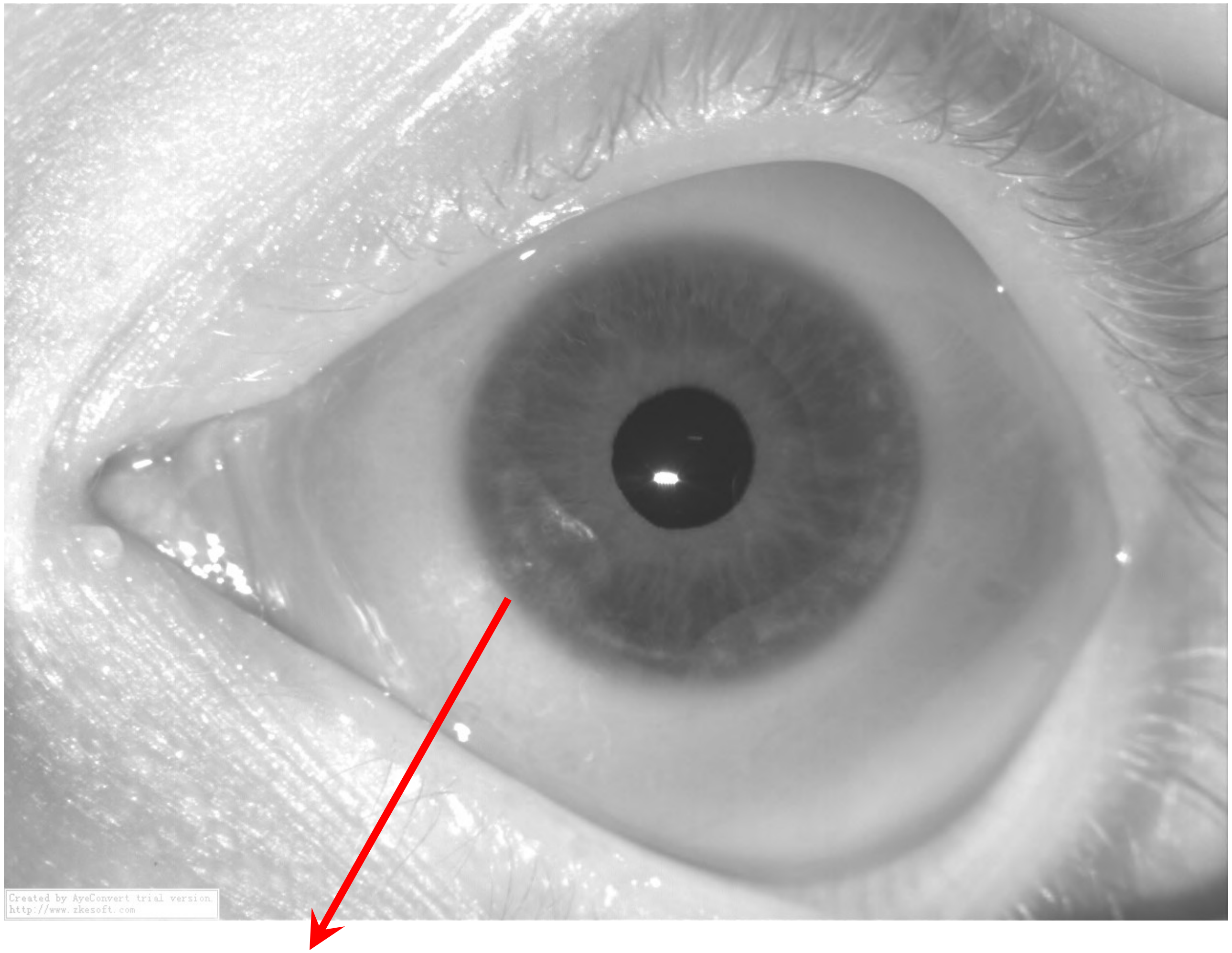
What is the **discriminatory feature of the iris**? How would we extract it?

Iris Boundary Extraction



A closer LOOK !!!

Iris Boundary Extraction



Edge separating the iris region and the sclera !!!

Iris Boundary Extraction

Edge detection:

- Edges characterize boundaries.

- Edges in images are areas with strong intensity contrasts – a jump in intensity from one pixel to the next.

- There are many ways to perform edge detection. However, the majority of different methods may be grouped into two categories, gradient and Laplacian.

- The **gradient method** detects the edges by looking for the maximum and minimum in the first derivative of the image.

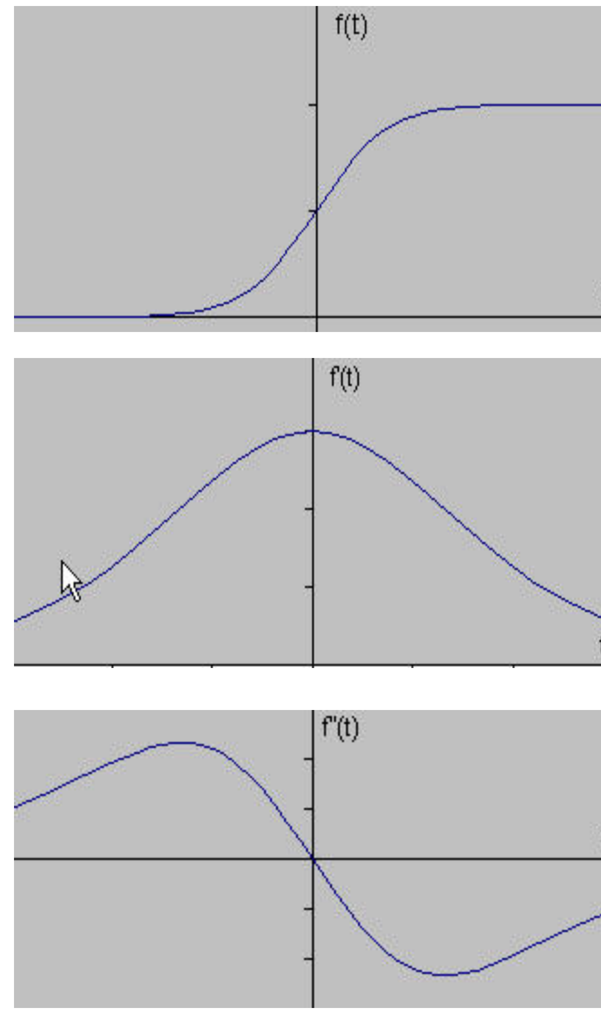
- The **Laplacian method** searches for zero crossings in the second derivative of the image to find edges.

- An edge has the one-dimensional shape of a ramp and calculating the derivative of the image can highlight its location. Suppose we have the following signal, with an edge shown by the jump in intensity below:

Iris Boundary Extraction

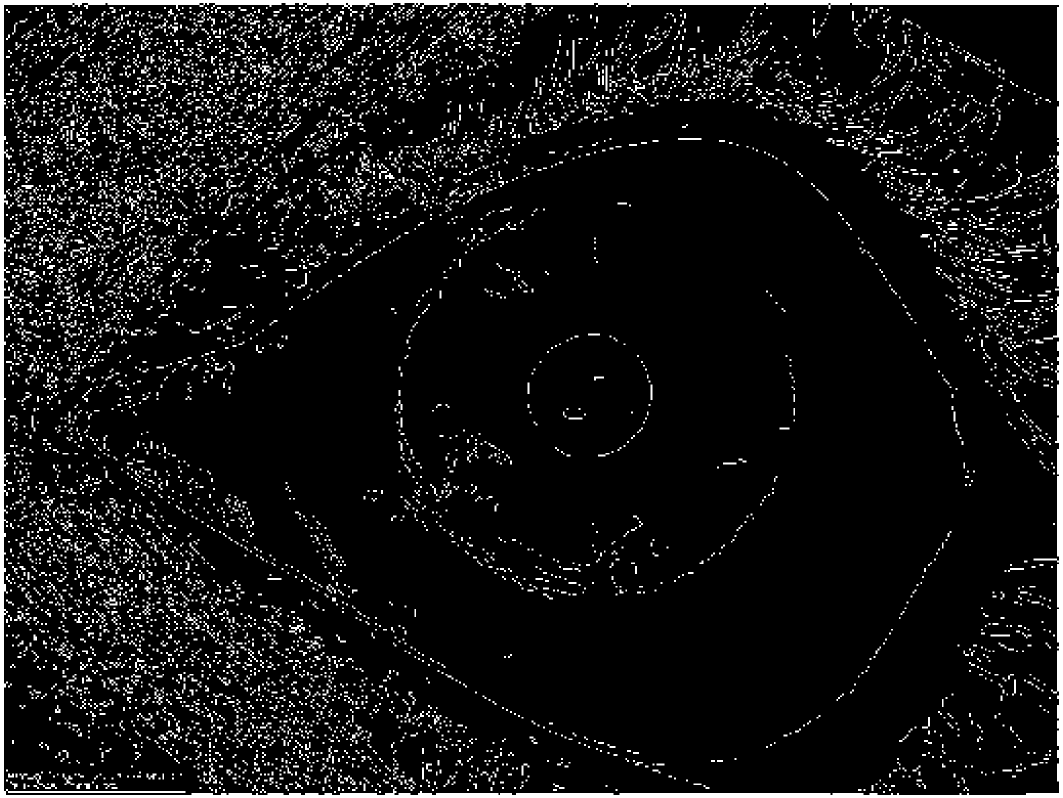
Edge detection:

- Suppose we have this signal, with an edge shown by the jump in intensity.
- Clearly, the derivative shows a maxima located at the center of the edge in the original signal. This method of locating an edge is characteristic of the "gradient filter" family of edge detection filters.
- A pixel location is declared an edge location if the value of the gradient exceeds some threshold. i.e. edges will have higher pixel intensity values than those surrounding it.
- Furthermore, when the first derivative is at a maximum, the second derivative is zero. As a result, another alternative to finding the location of an edge is to locate the zeros in the second derivative. This method is known as the Laplacian.



Iris Boundary Extraction

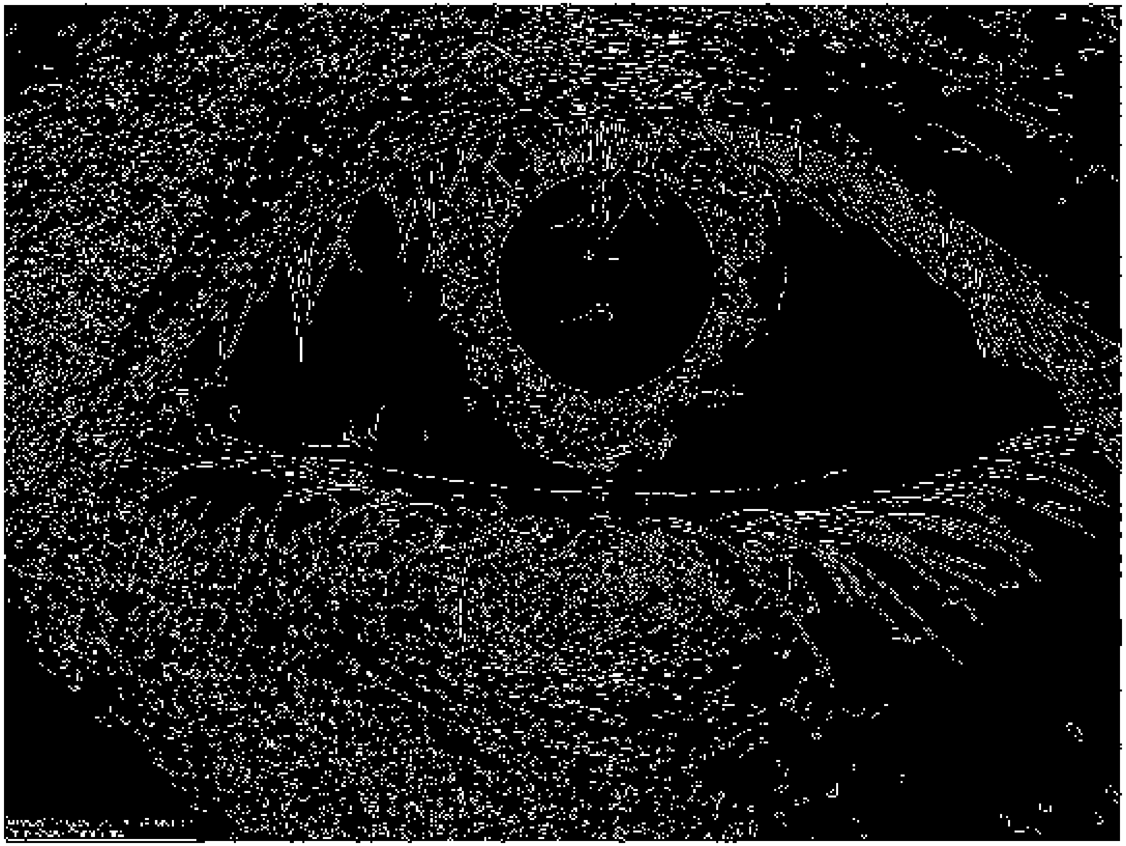
```
% edge detection
edge_map = edge(I,'canny');
```



Where is the iris ?!!! ☹

Iris Boundary Extraction

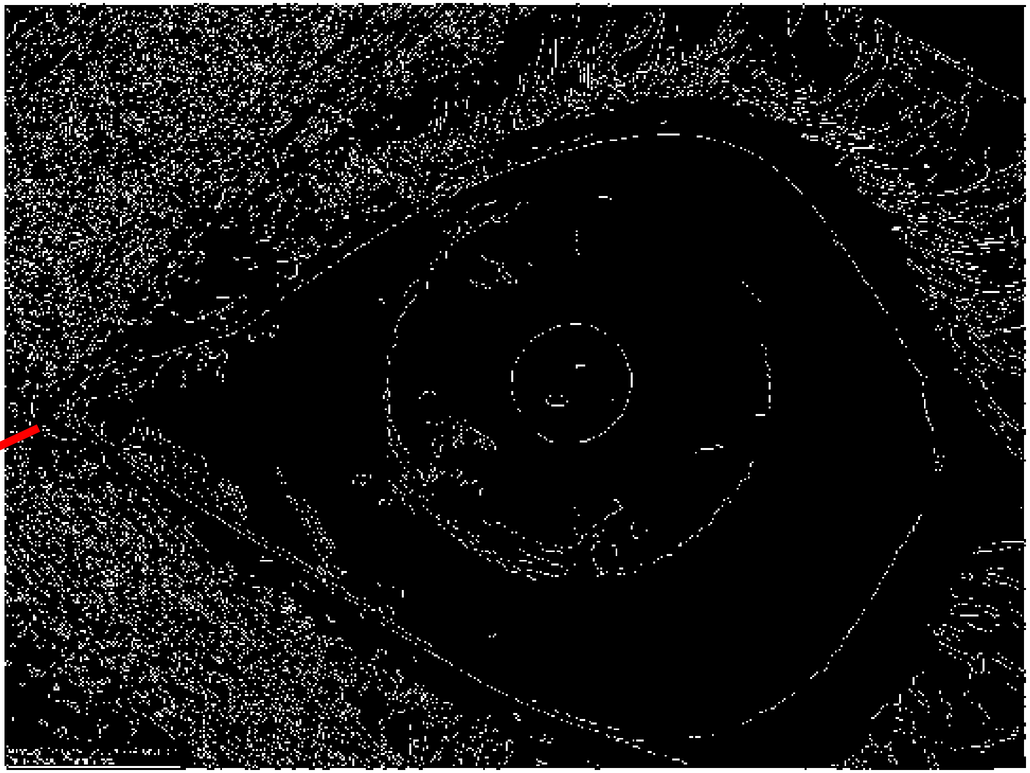
```
% edge detection
edge_map = edge(I,'canny');
```



Where is the iris ?!!! ☹

Iris Boundary Extraction

```
% edge detection
edge_map = edge(I,'canny');
```

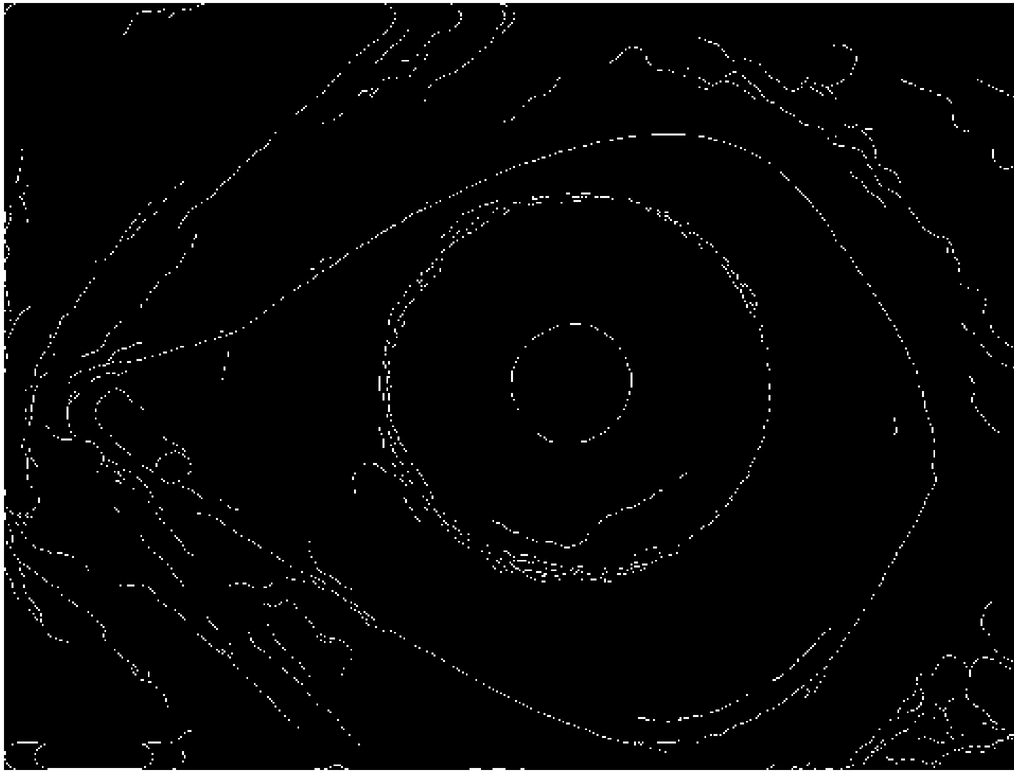


Noisy edge map

We need smoothing …

Iris Boundary Extraction

```
% image smoothing
Smoothed_I = I;
for i = 1 : 200
    Smoothed_I = medfilt2(Smoothed_I,[7 7]);
end
% edge detection
edge_map = edge(Smoothed_I,'canny');
```

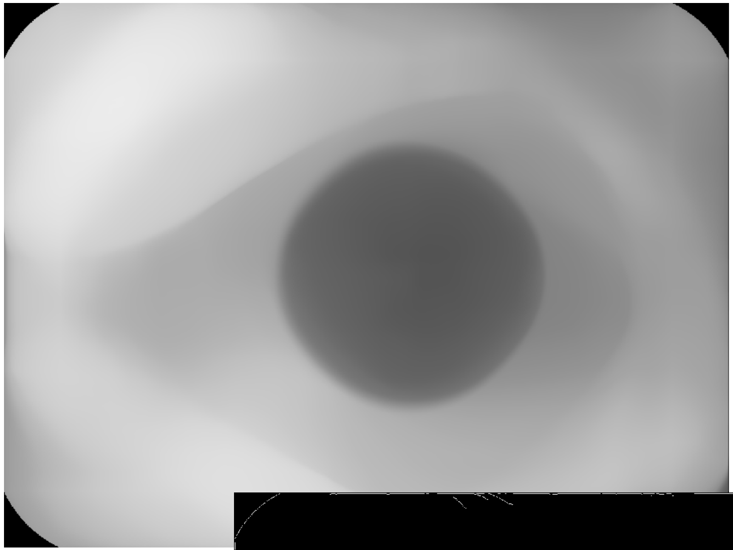


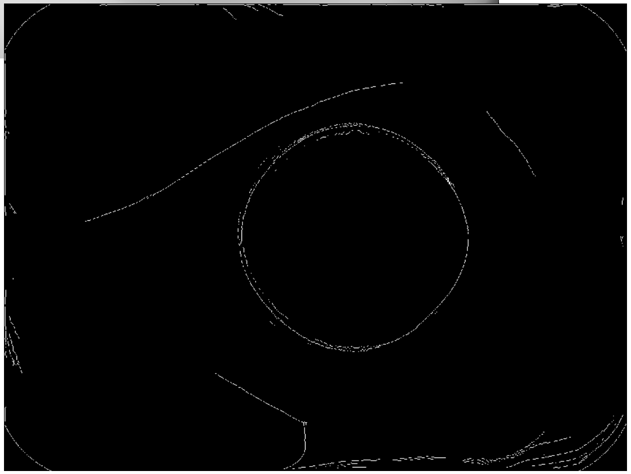
Iris Boundary Extraction

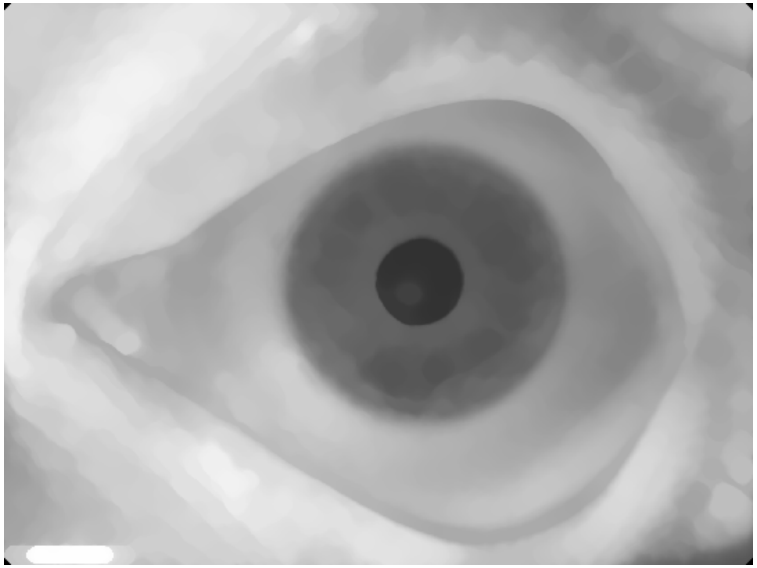
Do it one time with a very big filter size

Compare

Iterative median filtration with small sized filter





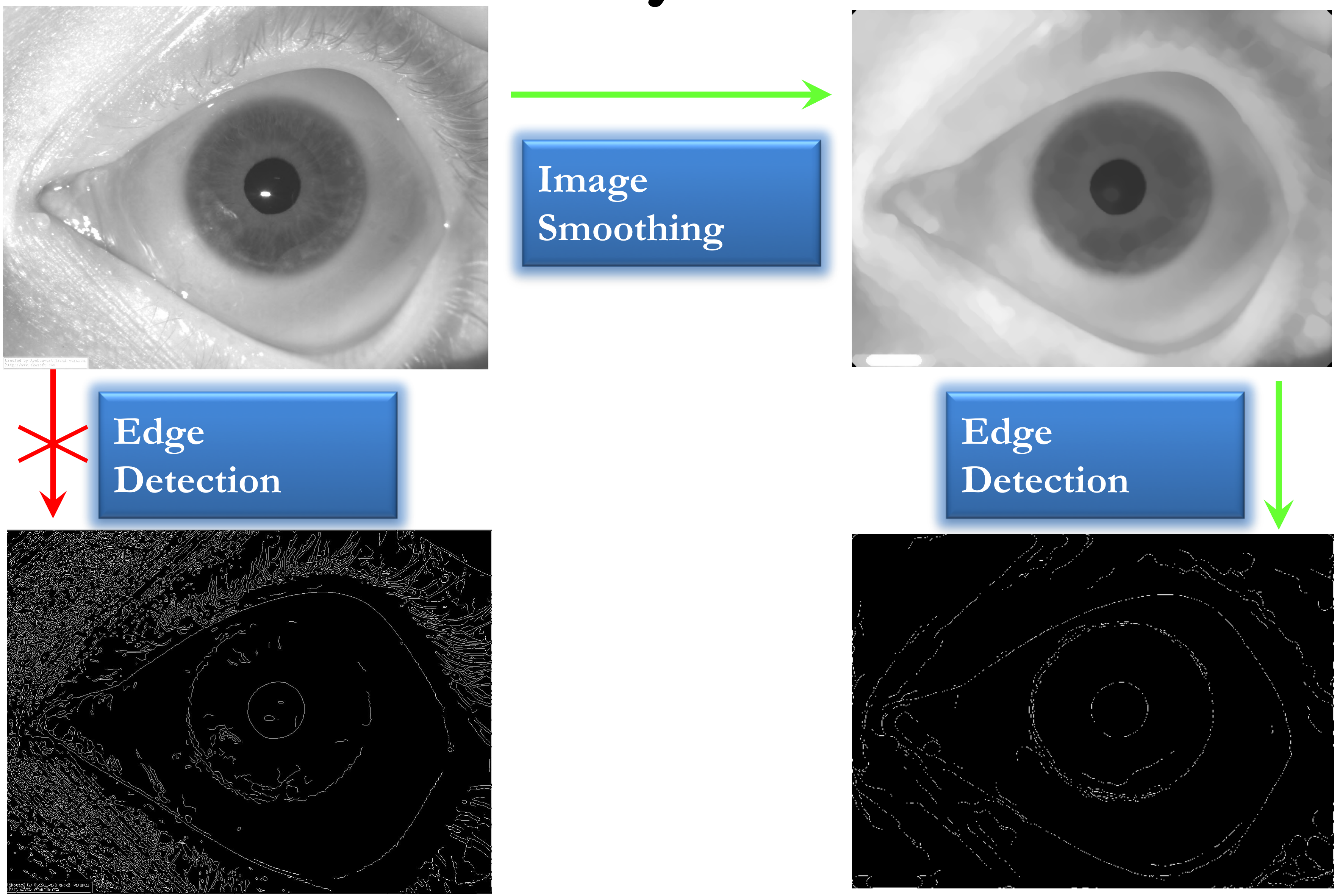


But …

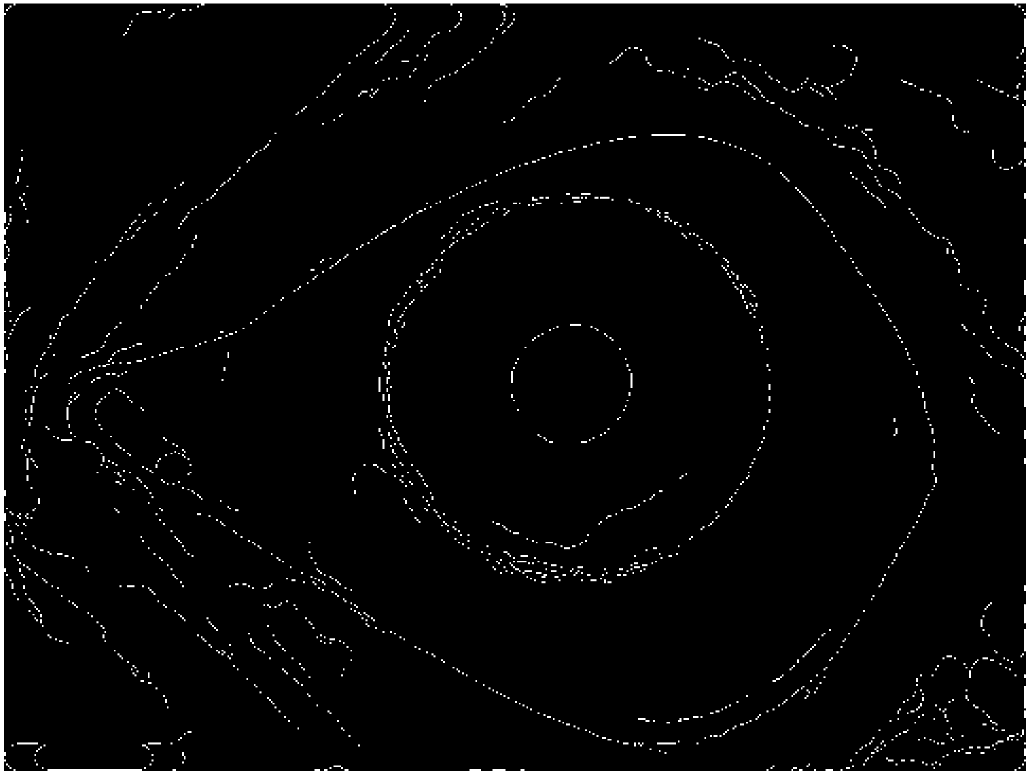
Would it work for other irises, in particular light ones?

You have to check this out !!!

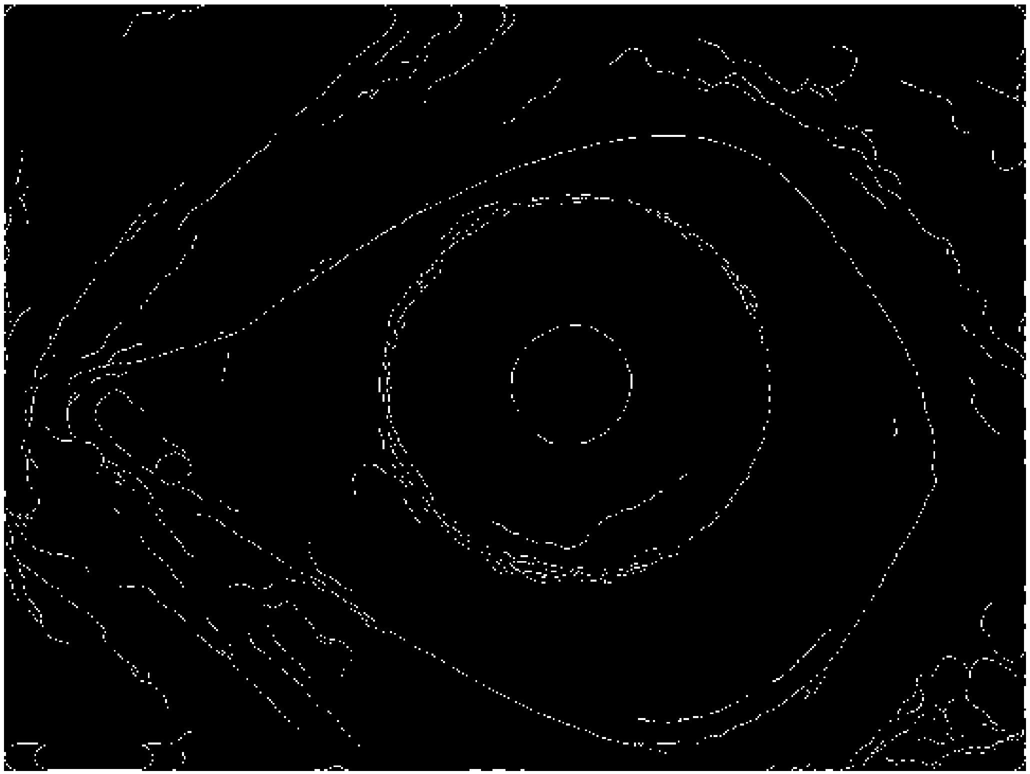
Iris Boundary Extraction

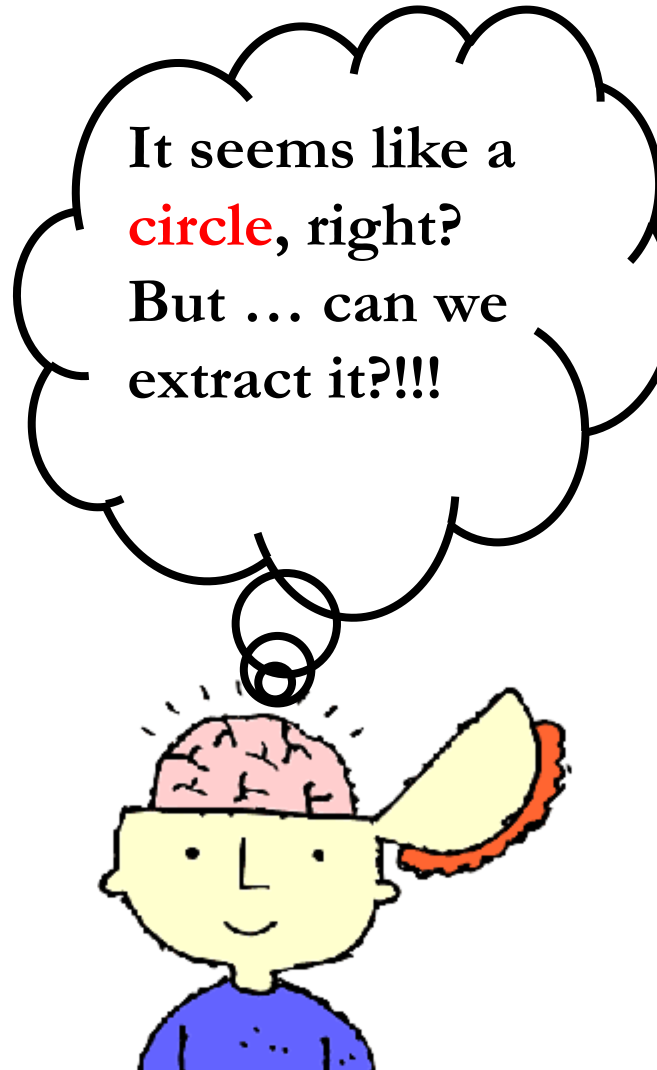


Iris Boundary Extraction



Iris Boundary Extraction





Iris Boundary Extraction

Hough Transform

- Procedure to find occurrences of a "shape" in an image.
- Basic idea: transform the pattern detection problem into a **parametric space** via Hough transforms and perform the easier pattern detection problem (e.g., peak detection) in the parametric space
- Used for detecting parametric patterns such as lines (linear hough transform), circles (circular hough transform), i.e. any pattern (object) which can be mathematically formulated as an equation.

Iris Boundary Extraction

Hough Transform

- Find all the desired (edge) feature points in an image
- Transform each feature point into a parameter space
- The transformed feature point (e.g., could be a line, a circle) "votes" in the parameter space
- The votes are accumulated and the local maxima are extracted.
- *Note*: The parameter space is called the **accumulator** which needs to be discretized to accumulate votes.

Iris Boundary Extraction

Hough Transform – Parametric Space

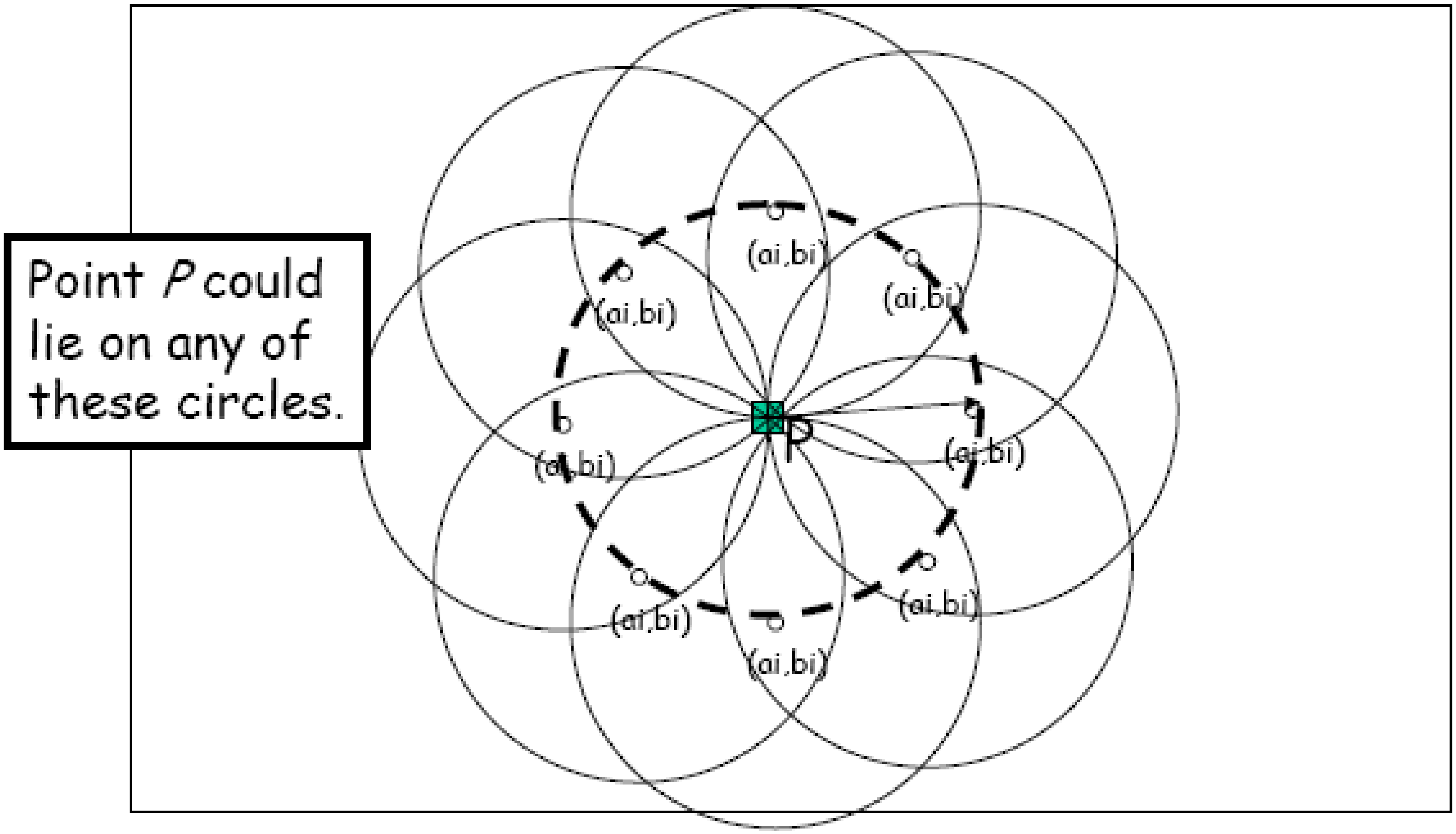
- Consider 2D circle:
- It can be parameterized as:

$$r^2 = (x-a)^2 + (y-b)^2$$

- Assume an image point was part of a circle, it could belong to a unique family of circles with varying parameters: a, b, r

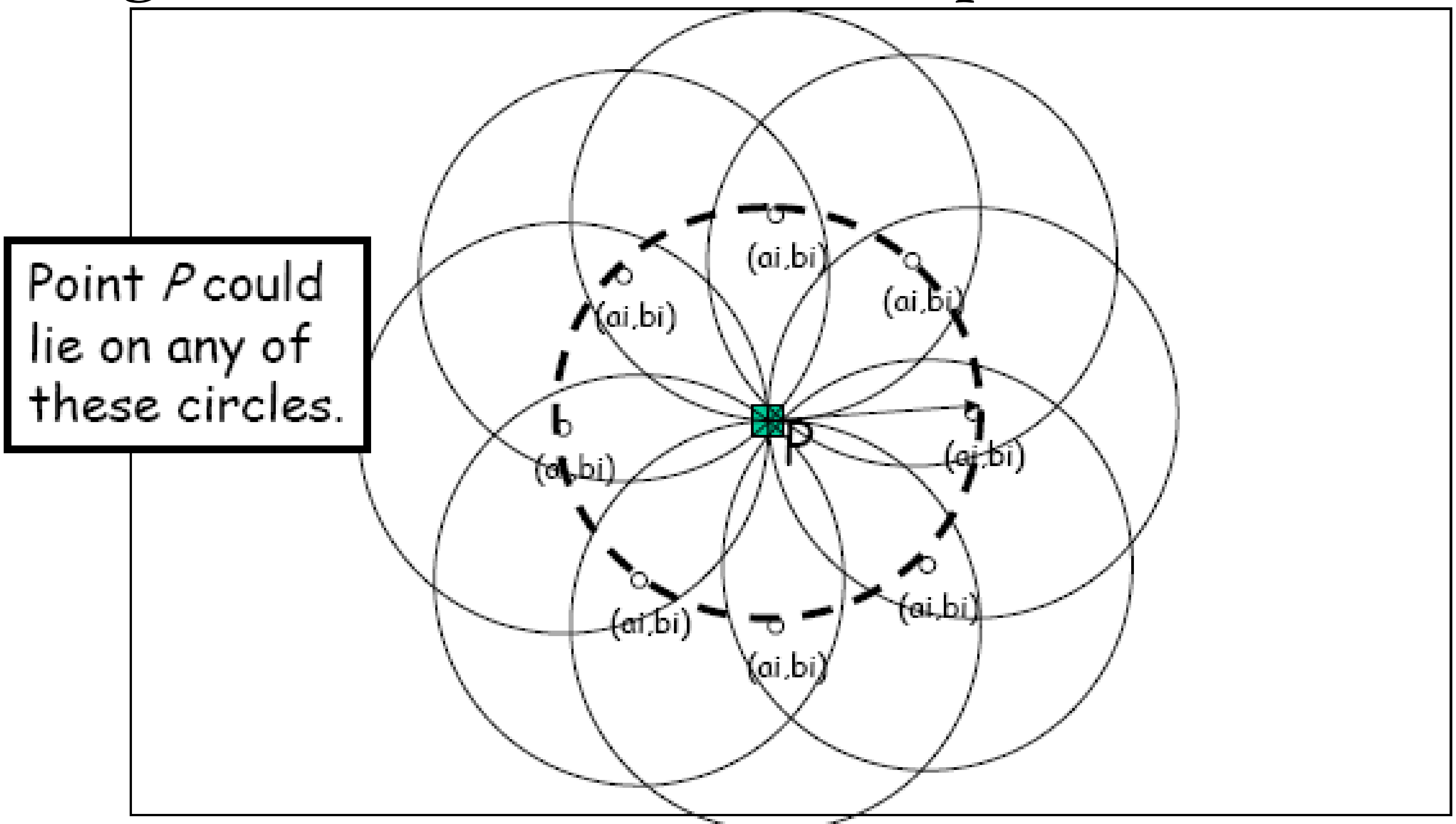
Iris Boundary Extraction

Hough Transform – Parametric Space



Iris Boundary Extraction

Hough Transform – Parametric Space



- For simplicity, lets assume we are searching for a circle with a fixed radius, r. Therefore, we only have two parameters (a,b)

Iris Boundary Extraction

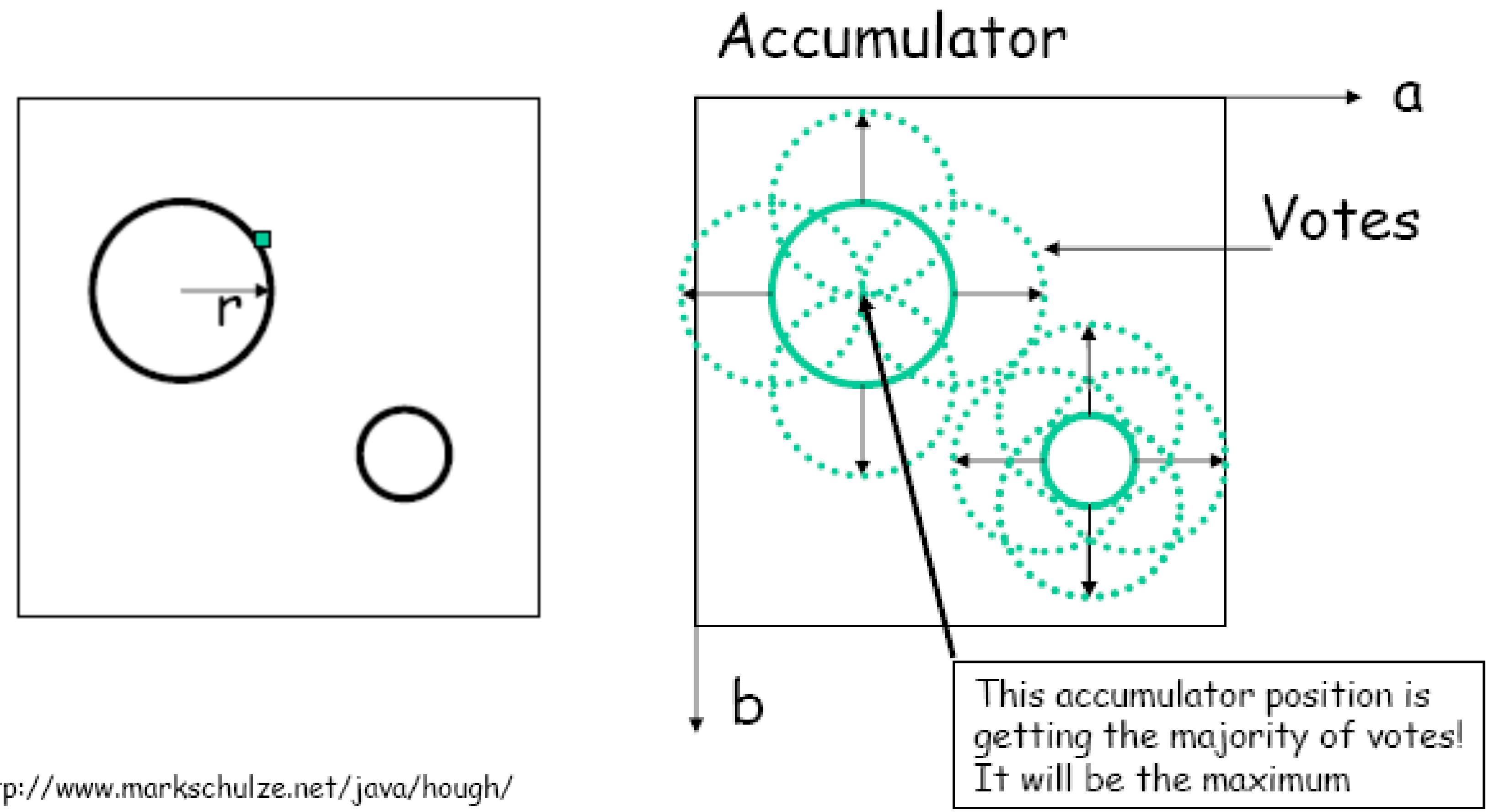
Hough Transform – Procedure

- Create an accumulator whose axis are the parameters (a,b)
  - Set all values to zero
  - We “discretize”/”quantize” the parameter space
- For each edge point, votes for appropriate parameters in the accumulator
  - Increment this value in the accumulator

Iris Boundary Extraction

Hough Transform – Procedure

- Assume we are looking for a circle with radius *r*.

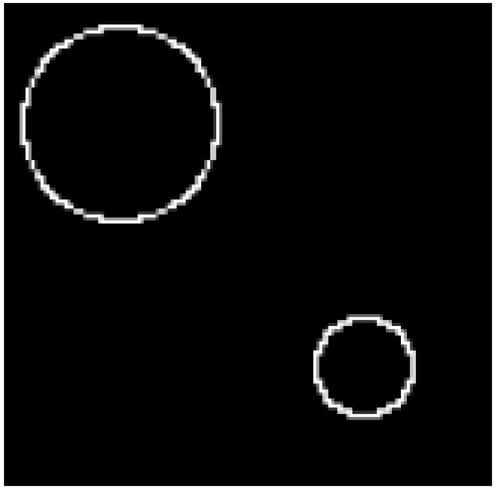


Example: http://www.markschulze.net/java/hough/

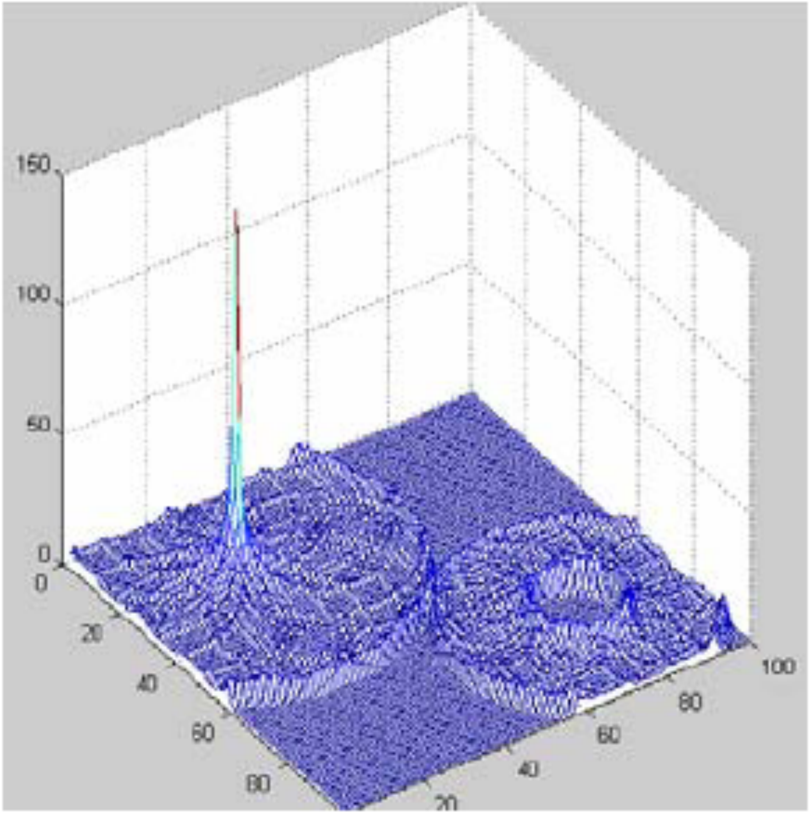
Iris Boundary Extraction

Hough Transform – Procedure

- Accumulator space:



Input



Accumulator/Parameter Space

Example: http://www.markschulze.net/java/hough/

Iris Boundary Extraction

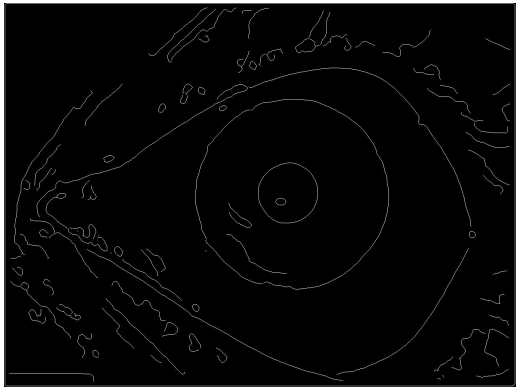
Hough Transform – Procedure

- Same procedure will be used to search for circles with different radii, the only difference is that we will have 3D parameter space instead of 2D.

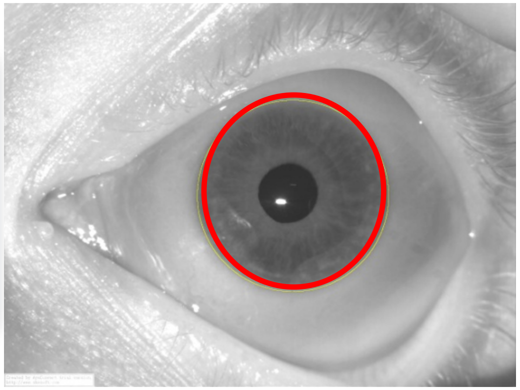
Iris Boundary Extraction

```
% circular hough transform
[M,N] = size(edge_map);
[X,Y] = find (edge_map >0);

% possible centers (within the pupil)
a = Pupil.Cx - Pupil.R : 5 : Pupil.Cx + Pupil.R;
b = Pupil.Cy - Pupil.R : 5 : Pupil.Cy + Pupil.R;
% possible radii
maxR = Pupil.R * 10;
R = Pupil.R+10 : 1 : maxR;

Accumalator = zeros(length(a),length(b),length(R));

for f = 1 : length(X)
    x = X(f);
    y = Y(f);
    for i = 1:length(a)
        for j = 1:length(b)
            r = round(sqrt((x-a(i))^2+(y-b(j))^2));
            fr = find(R == r);
            if(~isempty(fr))
                Accumalator(i,j,fr(1)) = Accumalator(i,j,fr(1)) + 1;
            end
        end
    end
end
```

Iris Boundary Extraction

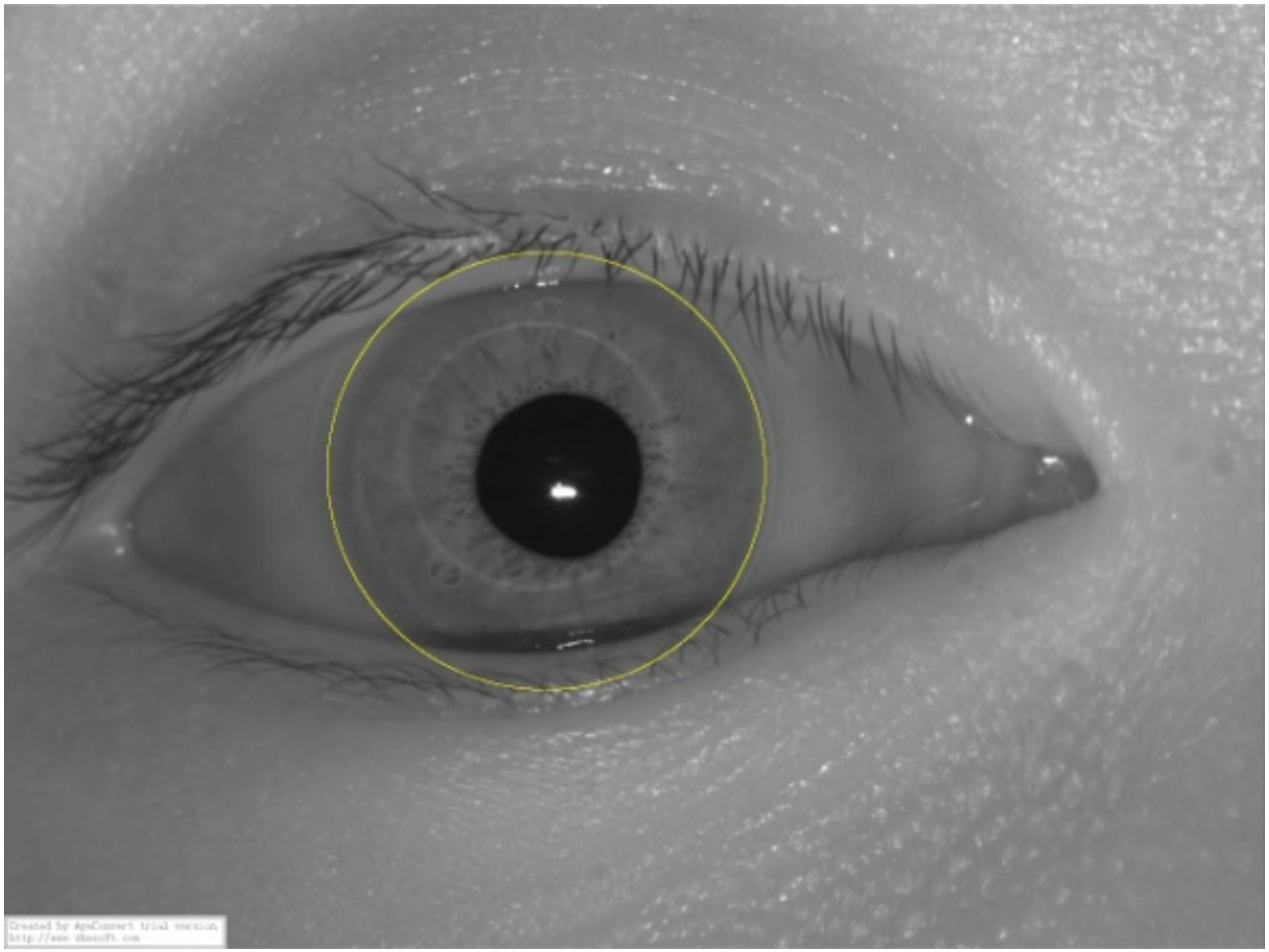


Circle Fitting
Using
Hough Transform



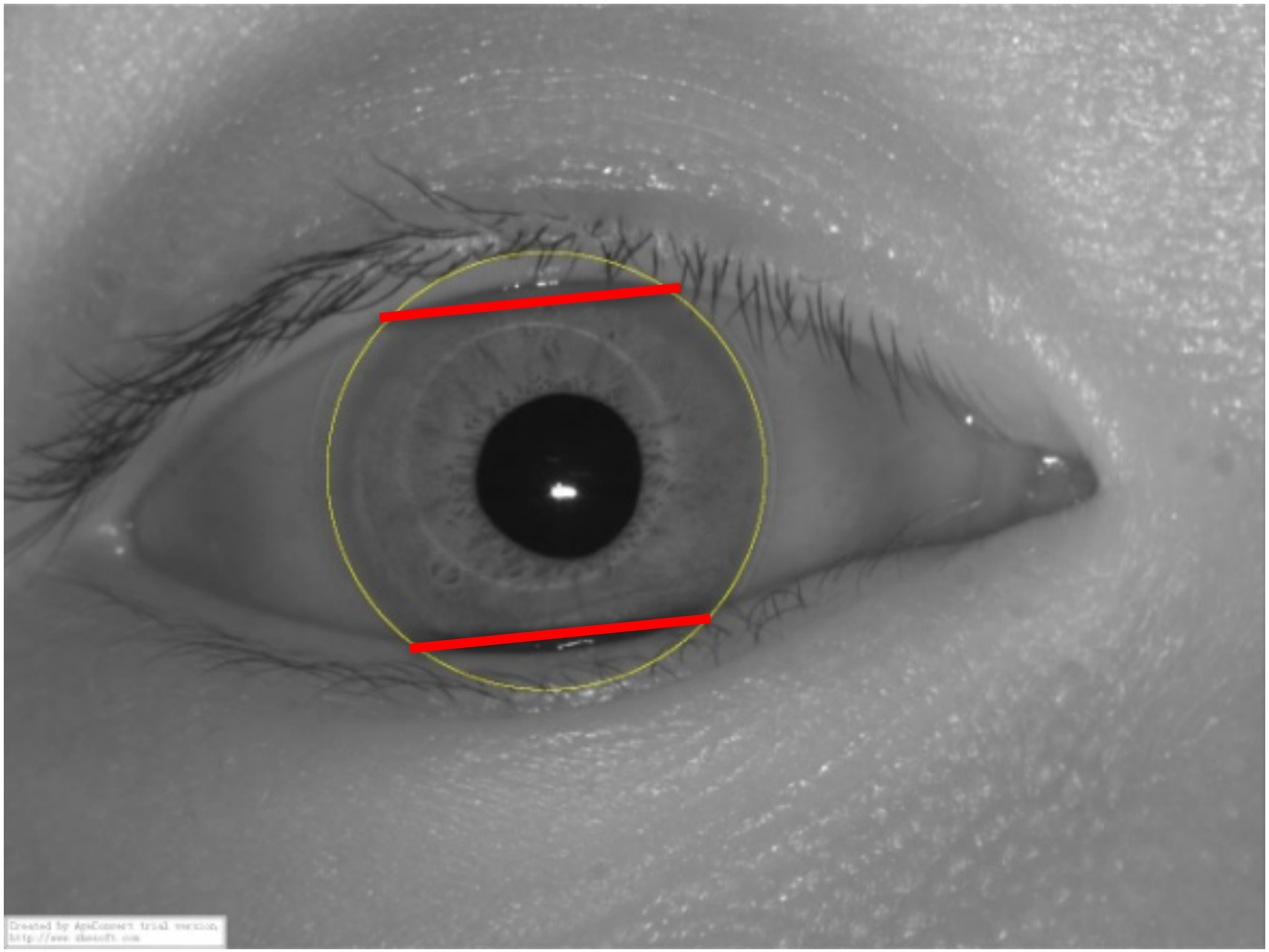
Finding the circle parameters (center and radius) which best describes the scattered edge points

Iris Boundary Extraction



Something interesting ?!!!

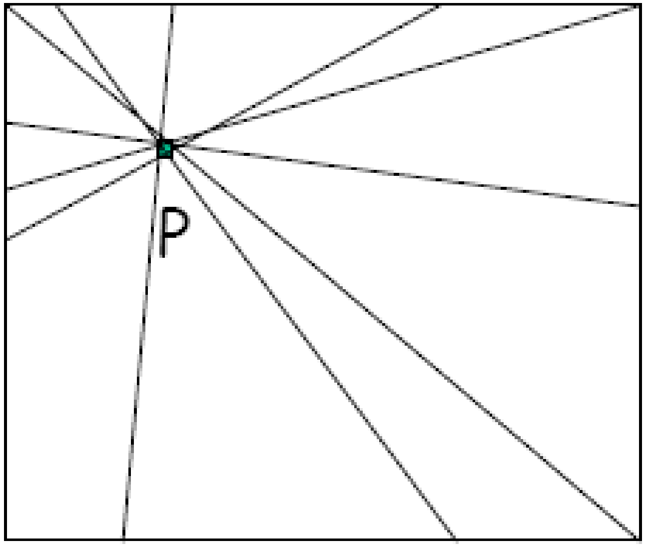
Eyelid Extraction



Eyelids can be approximated as lines, parabolas …

Eyelid Extraction

Hough Transform for Lines



All possible lines
going through P

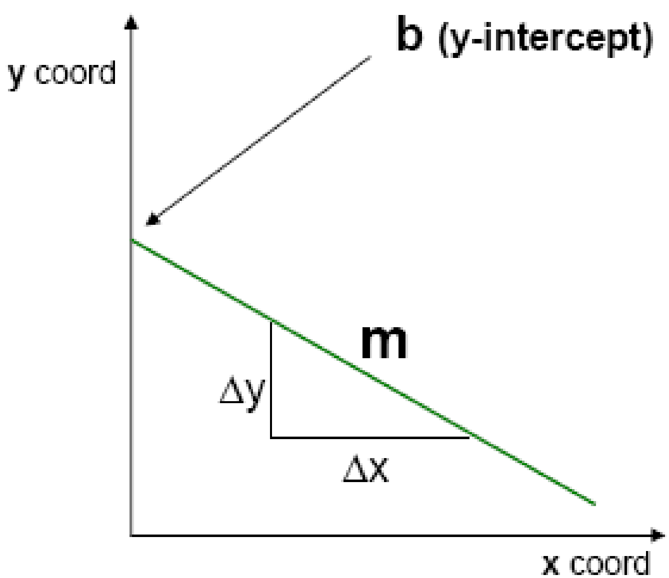
Parametric Form

$y = \boxed{m}\,x + \boxed{b}$

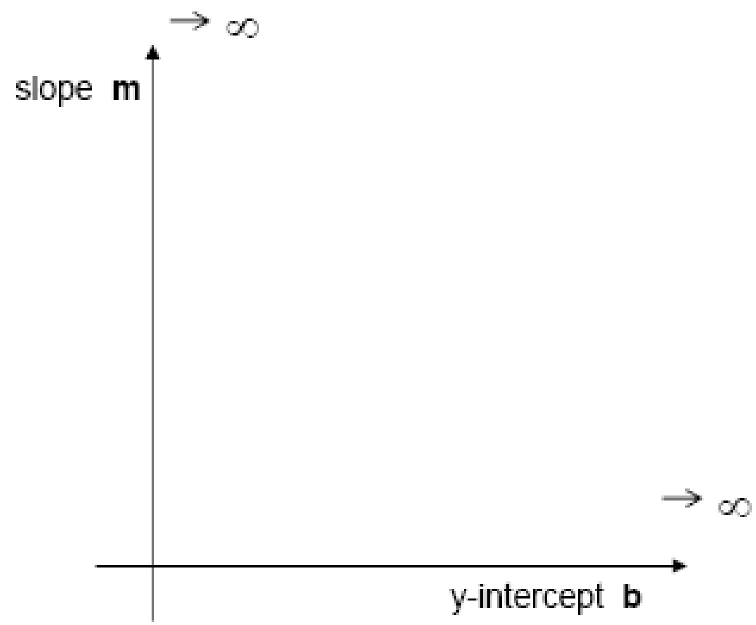
Is there a problem with this parameterization?!!!

Eyelid Extraction

Hough Transform for Lines



Edge Image

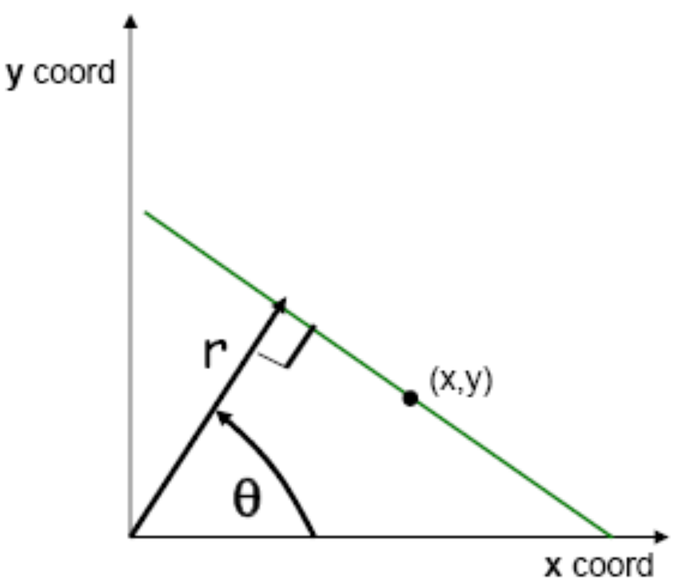


Parameter space

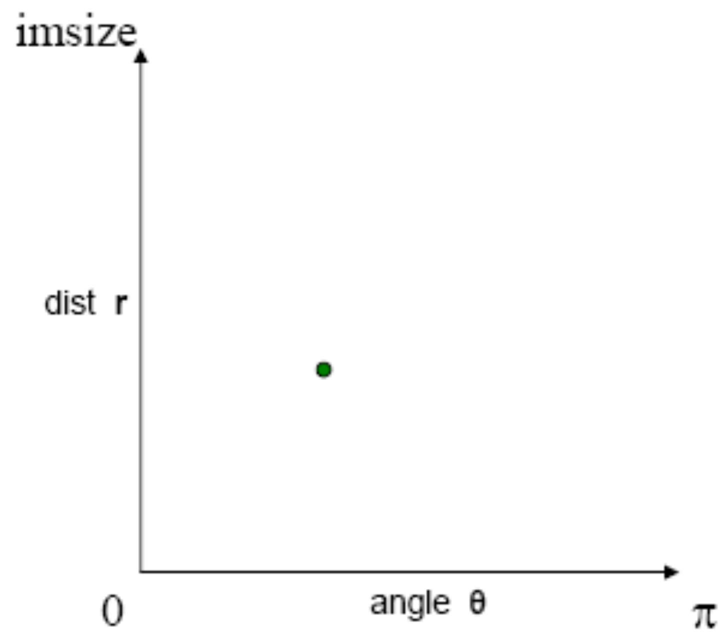
Eyelid Extraction

Hough Transform for Lines

$\mathbf{r} = x \cos\theta + y \sin\theta$ "normal" form

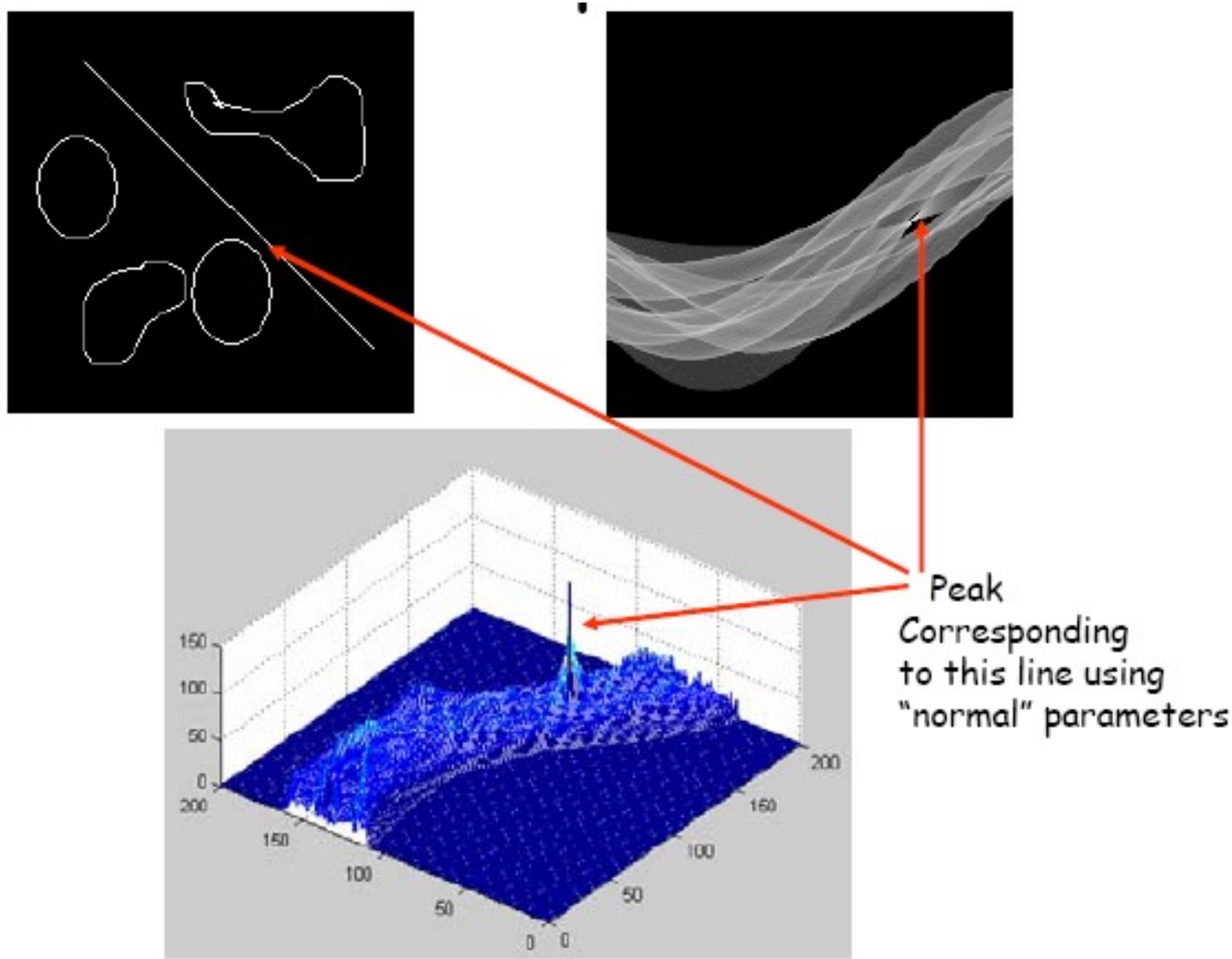


Edge Image



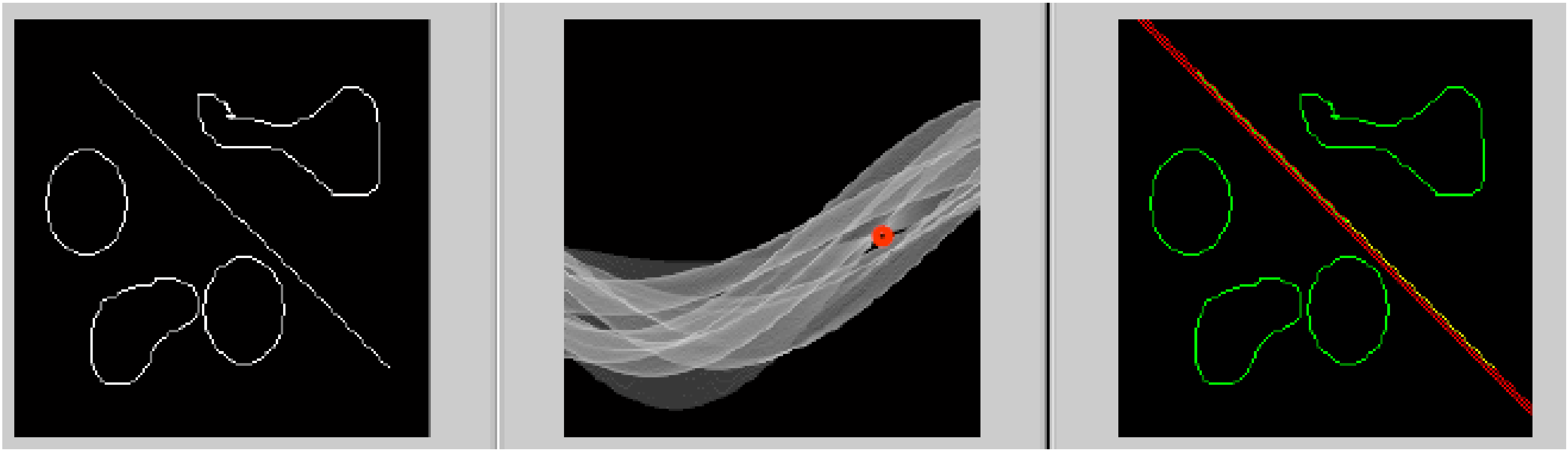
Parameter space

Eyelid Extraction

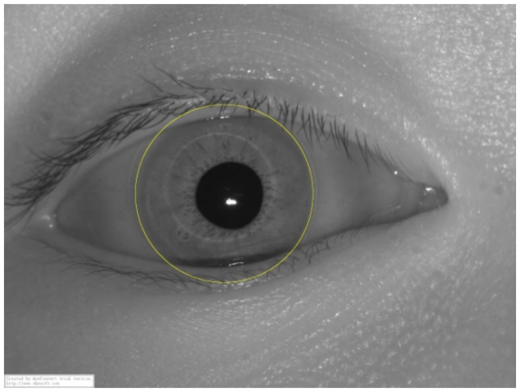


Eyelid Extraction

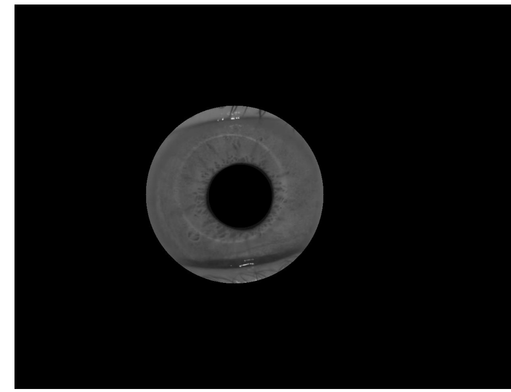
- Note: the parametric solution represents the whole line and not the segment!!!



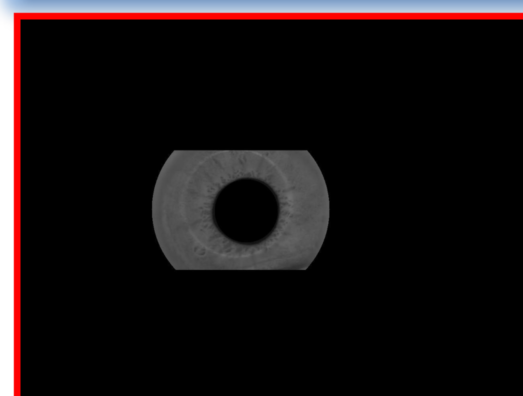
Eyelid Extraction

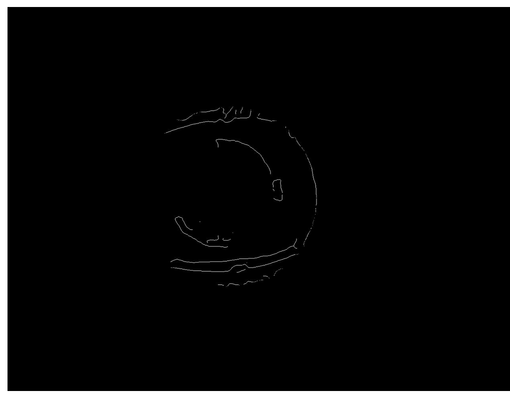


Iris Region Extraction

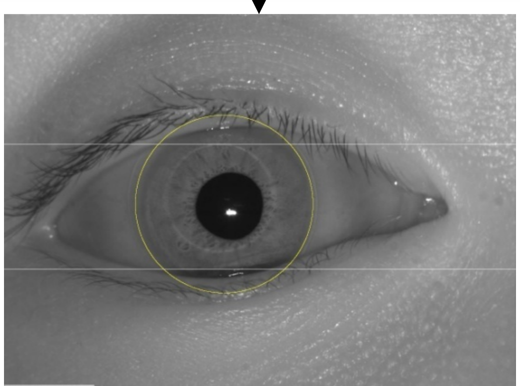


Edge Detection Within Iris Region



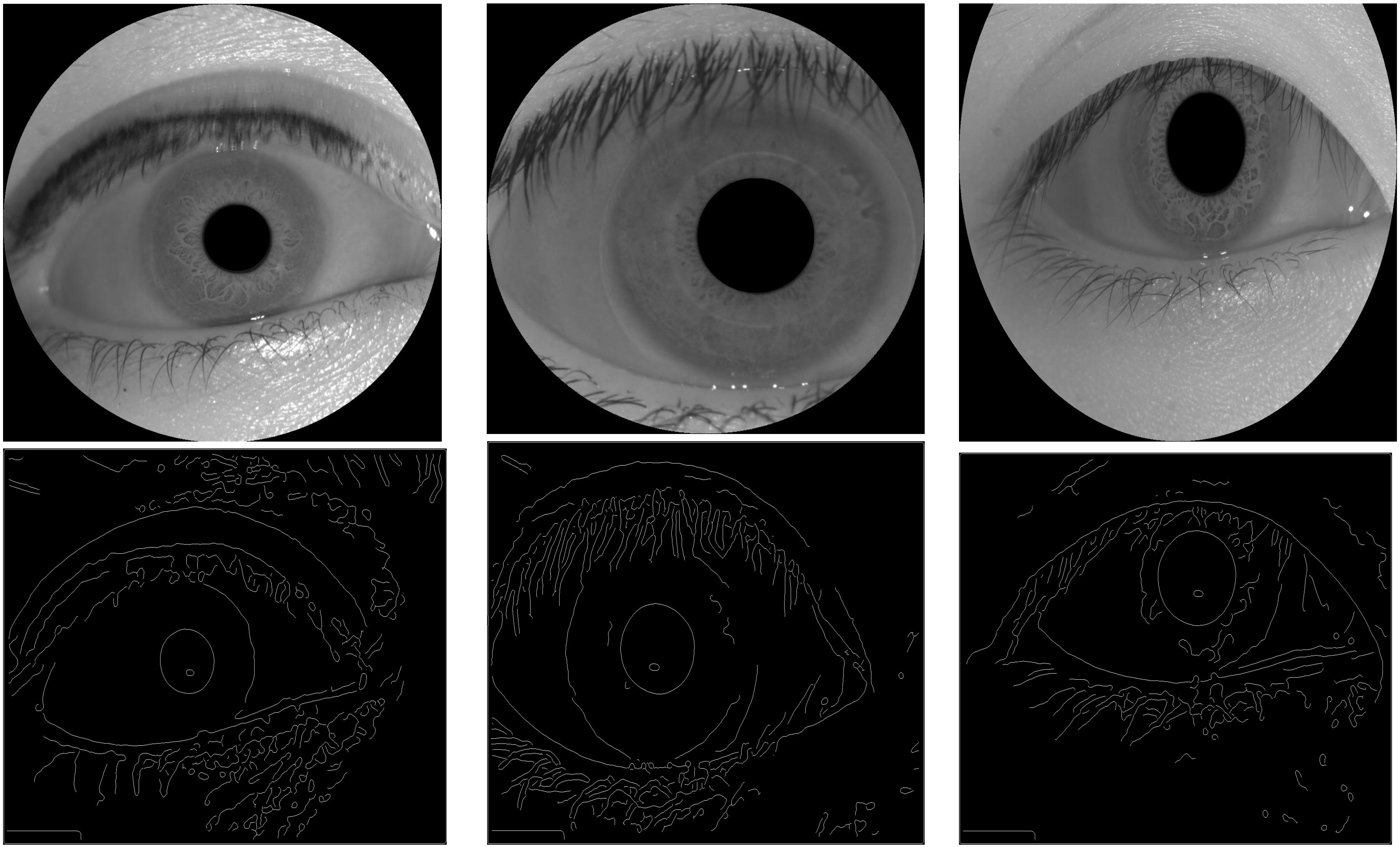


Line Fitting Using Hough Transform

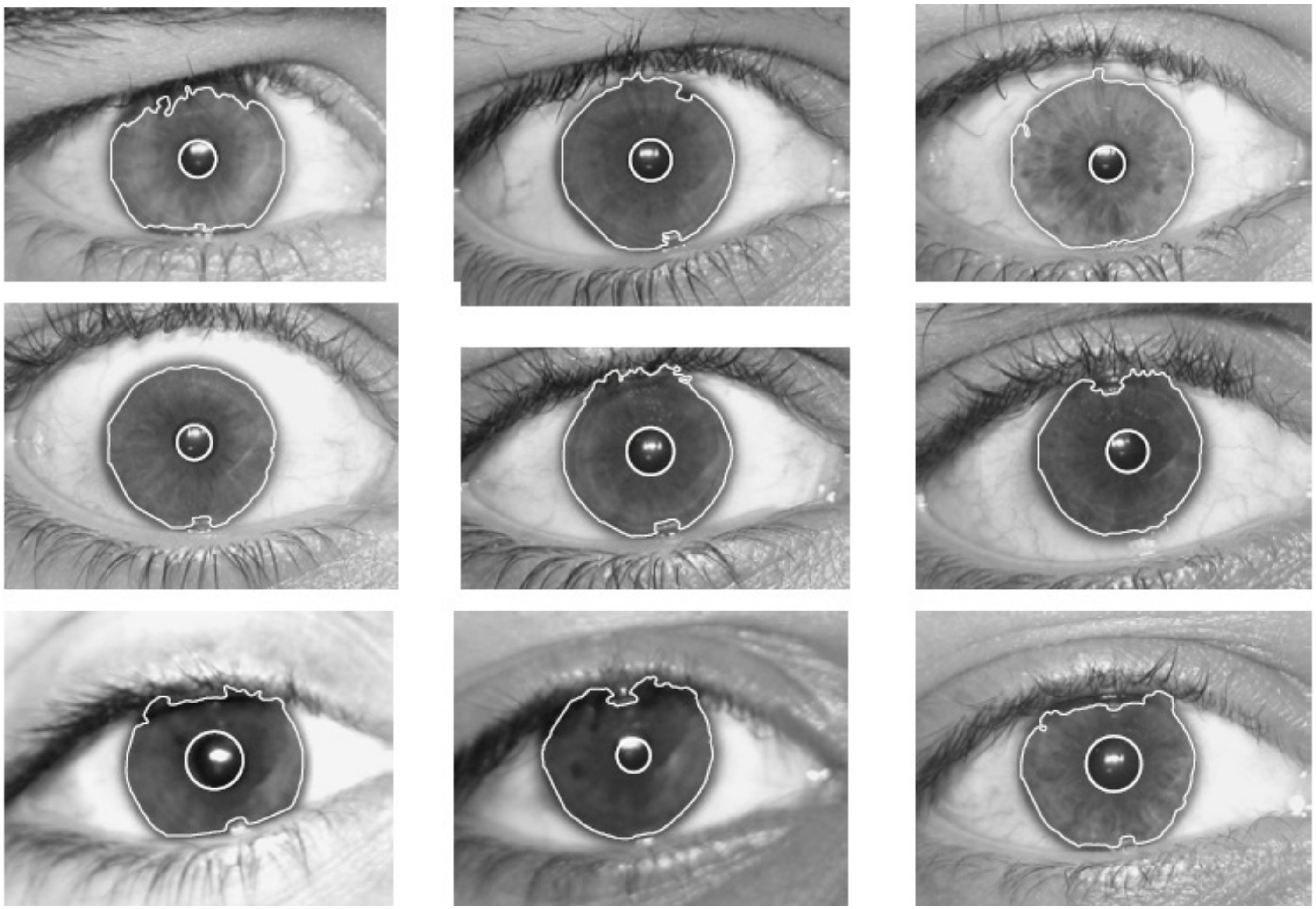


Finding the line parameters which best describes the scattered edge points

Limitations



Active Contours



Results reported by Arun Ross and Samir Shah, *"Segmenting Non-ideal Irises Using Geodesic Active Contours",* West Virginia University, www.citer.wvu.edu

References

- Li. Ma, Y. Wang, and T. Tan, "Iris recognition using circular symmetric filters," in *Proc. 16th Int. Conf. Pattern Recognition, vol. II, 2002, pp. 414-417*
- Li. Ma, Y. Wang, and T. Tan, "Iris recognition based on multi-channel Gabor filtering," in *Proc. 5th Asian Conf. Computer Vision, vol. I, 2002, pp. 279-283*
- Daugman, J. 2004. How iris recognition works. *IEEE Trans, CSVT 14, 21—30*
- Daugman, J. The importance of being random: Statistical principles of iris recognition. *Pattern Recognition, vol. 36, num. 2, pp. 279-291, 2003*
- Ma Li, Tan T., Wang Y. and Zhang, D. (2004): Efficient Iris Recognition by characterizing Key Local Variations, *IEEE Trans. Image Processing, vol 13,* no.6, pp. 739-750
- A. Poursaberi, B. N. Araabi, "A Novel Iris Recognition System Using Morphological Edge Detector and Wavelet Phase Features", *ICGST International Journal on Graphics, Vision and Image Processing, P1150517004, June* 2005

Iris Recognition

Q3 :

(a) How to normalize the iris region?

(b) How to extract features from the iris region?

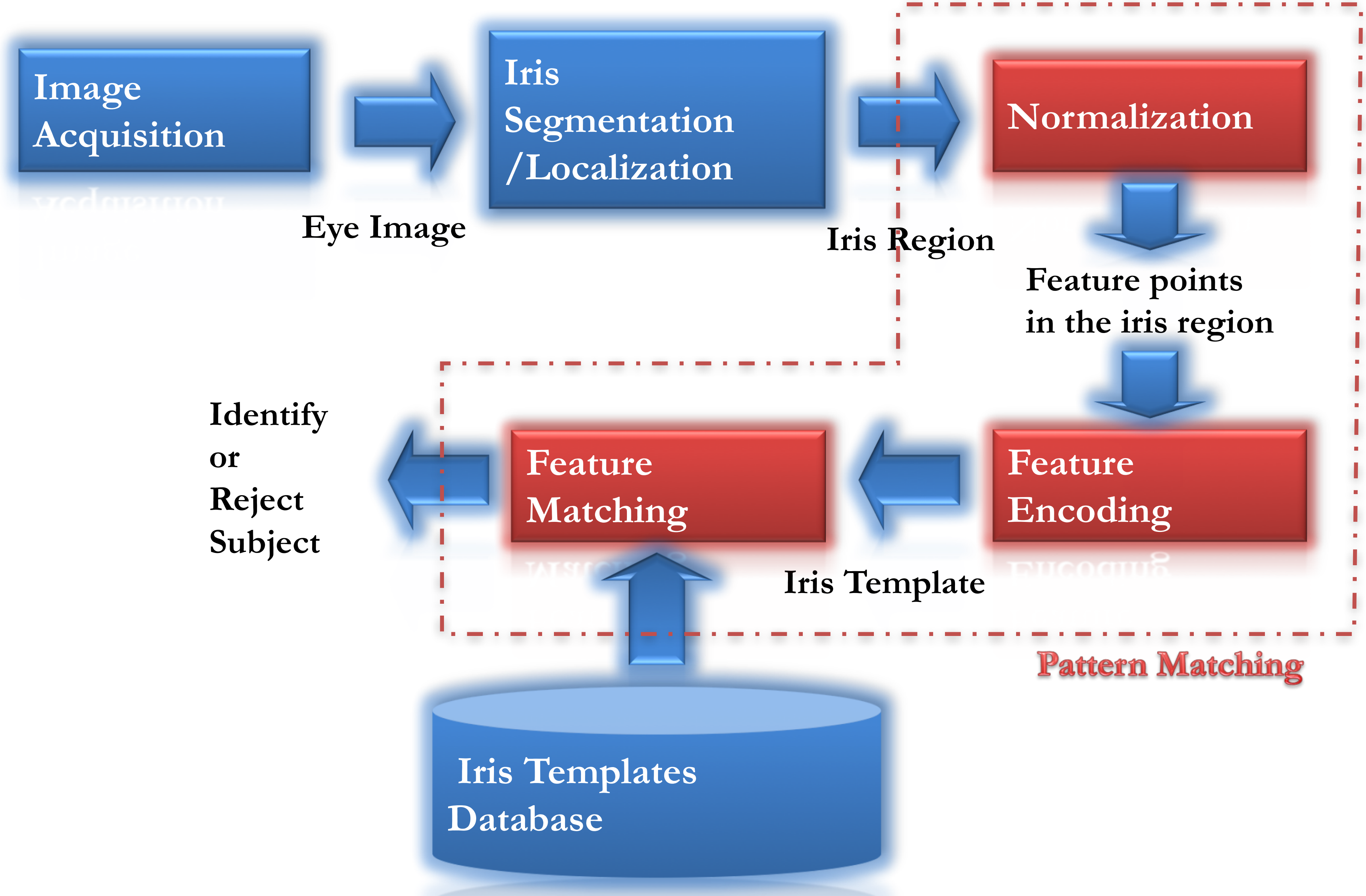
(c) How to match iris features?

By

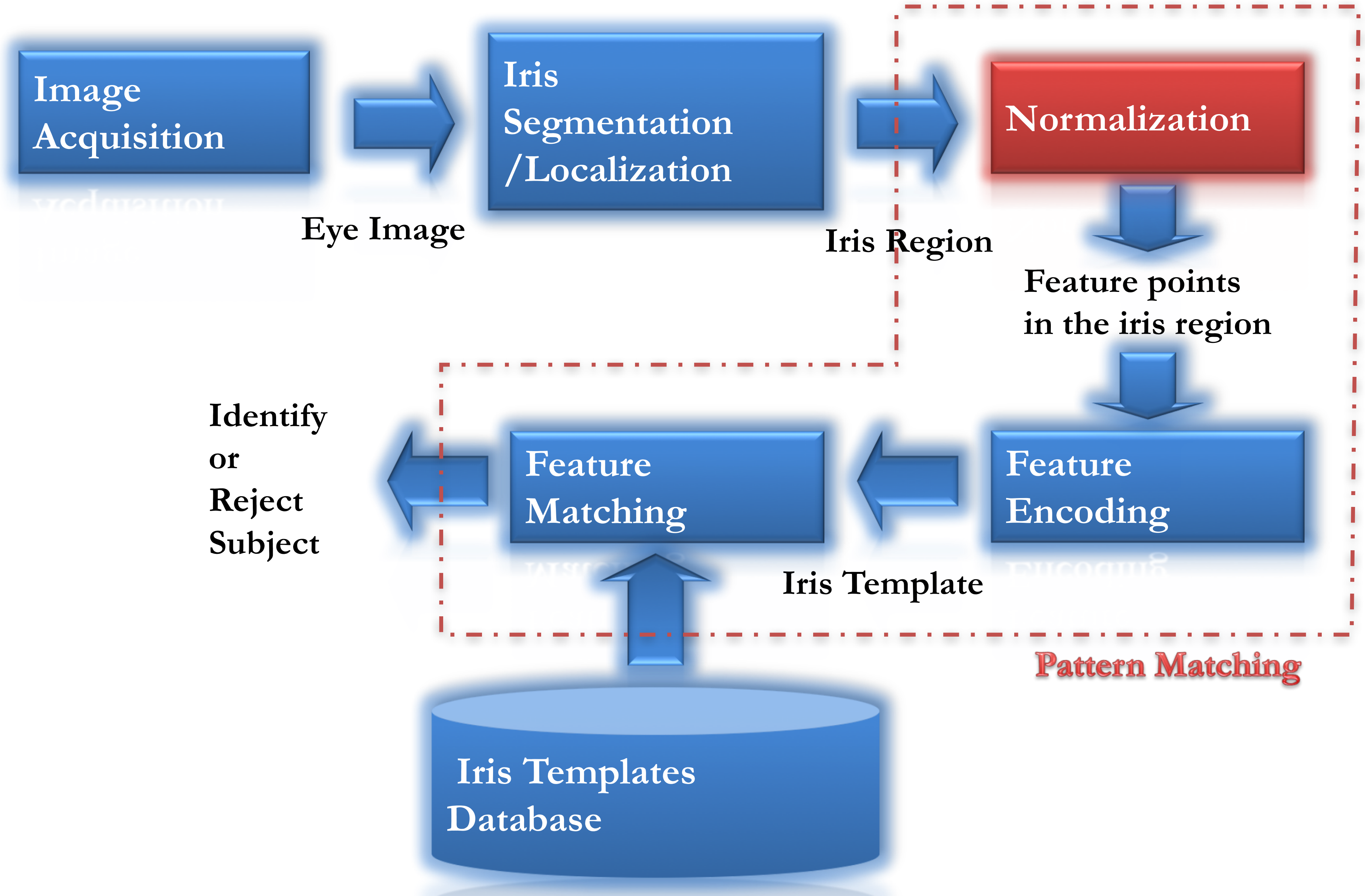
Shireen Y. Elhabian

University of Lousiville, CVIP Lab

Daugman Model for Iris Recognition

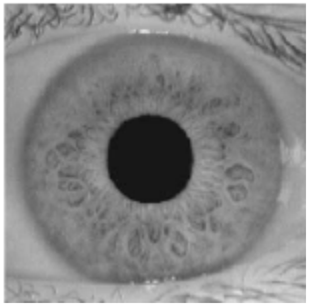


Daugman Model for Iris Recognition



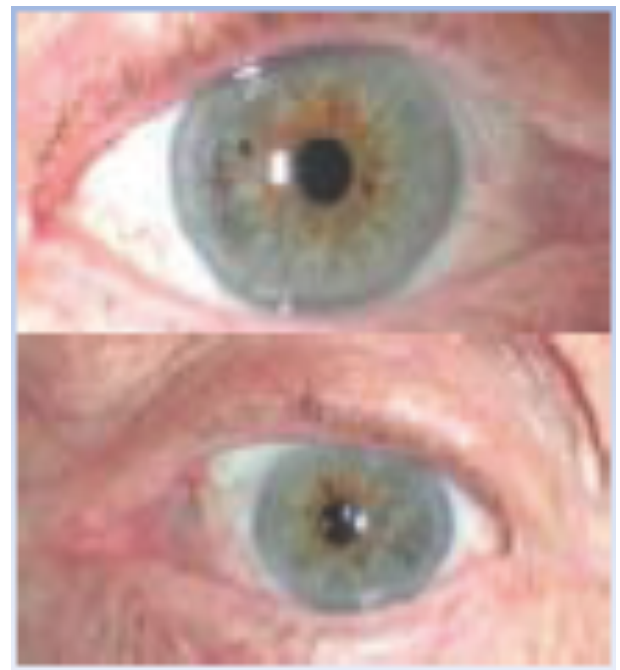
Why do we need normalization?

- Given an iris region, it is required to extract fixed number of features from this region regardless its spatial resolution, i.e. number of pixels.



- Hence we need to map any iris region to a fixed reference, or coordinate system.

Normalization Handles Variation



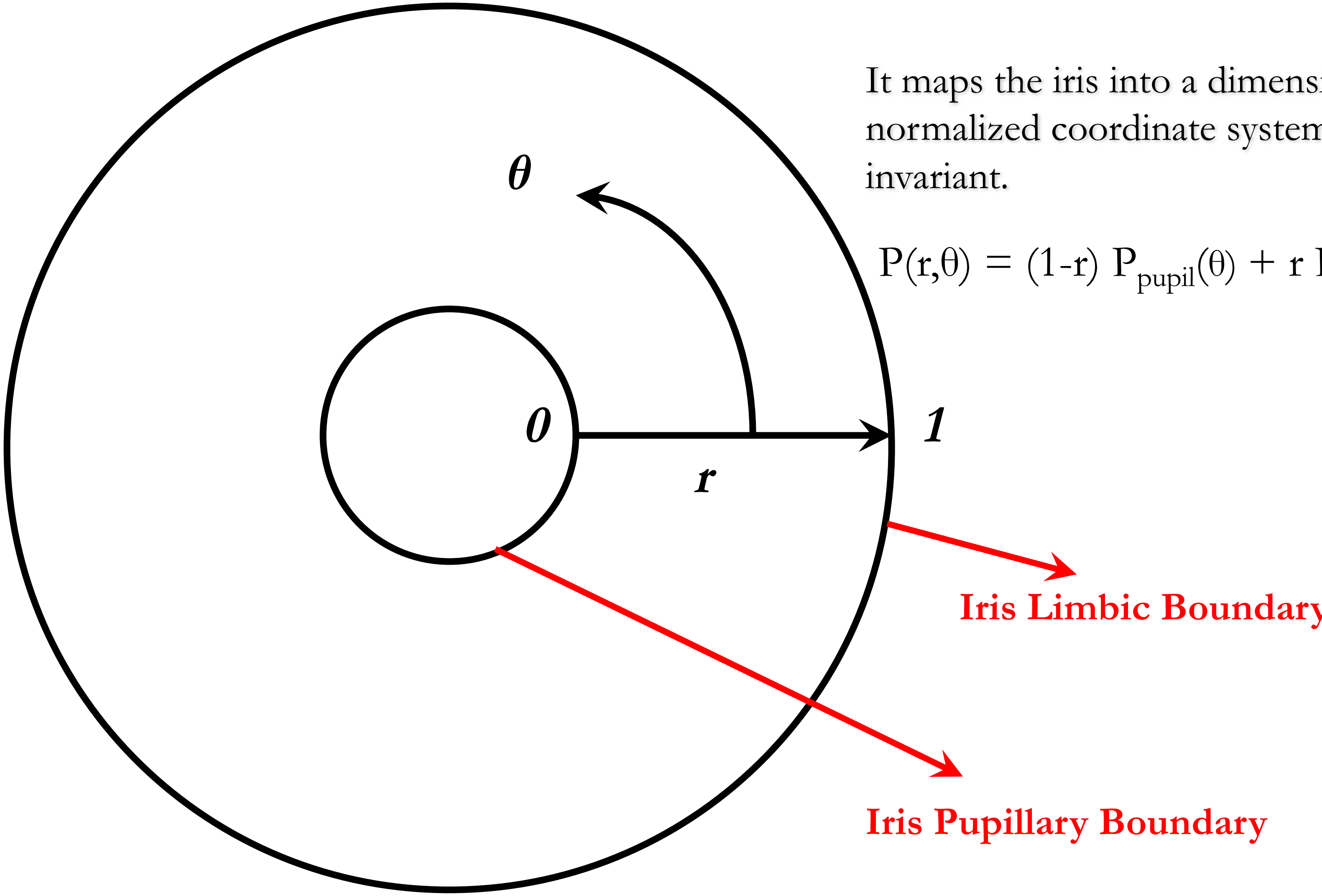
Pupil dilation
(Lighting changes)

Inconsistent iris sizes
(Distance from camera)

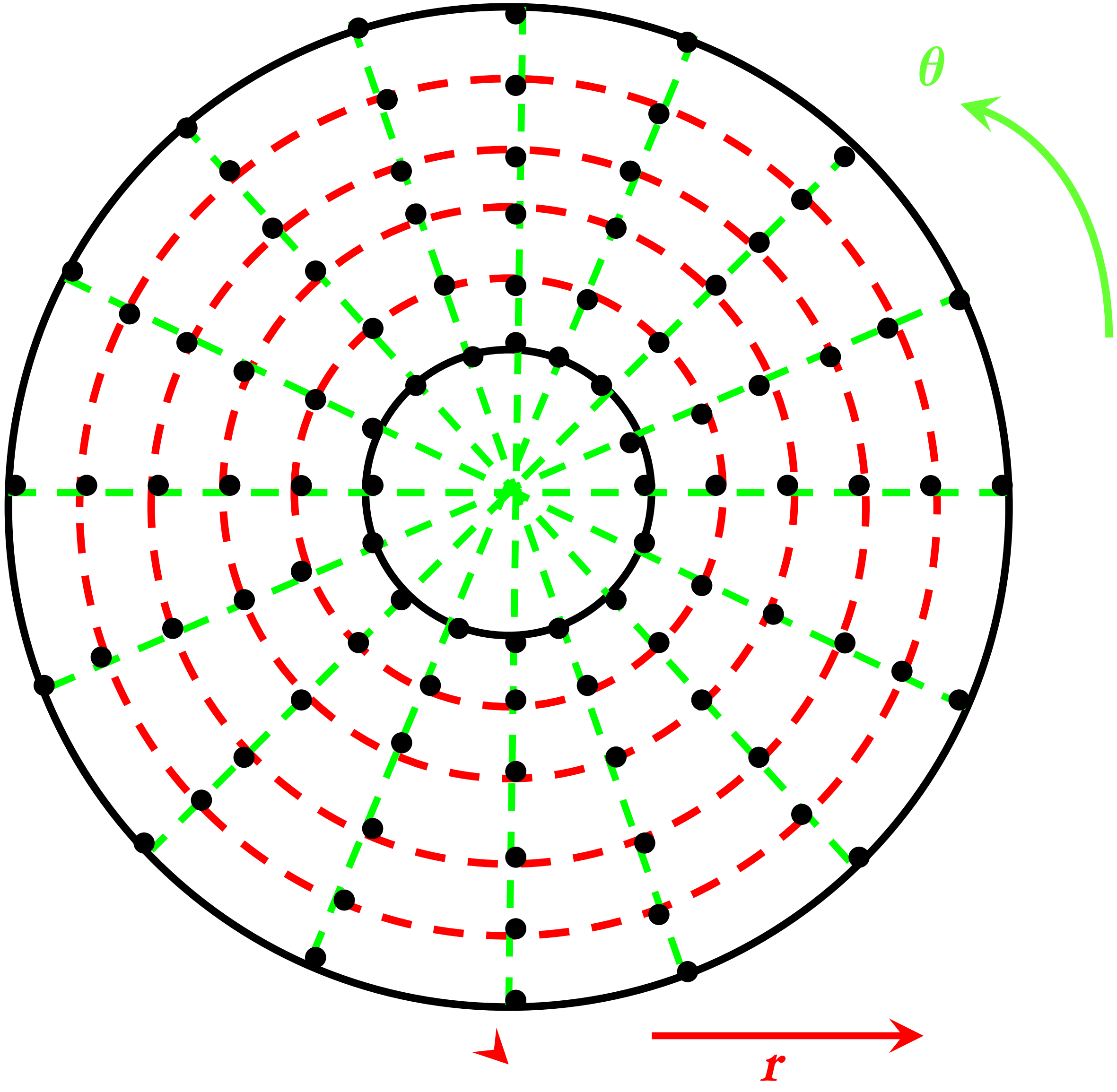
Daugman Rubber Sheet Model

It maps the iris into a dimensionless, normalized coordinate system that is size-invariant.

$$P(r,\theta) = (1-r)\, P_{pupil}(\theta) + r\, P_{limbic}(\theta)$$

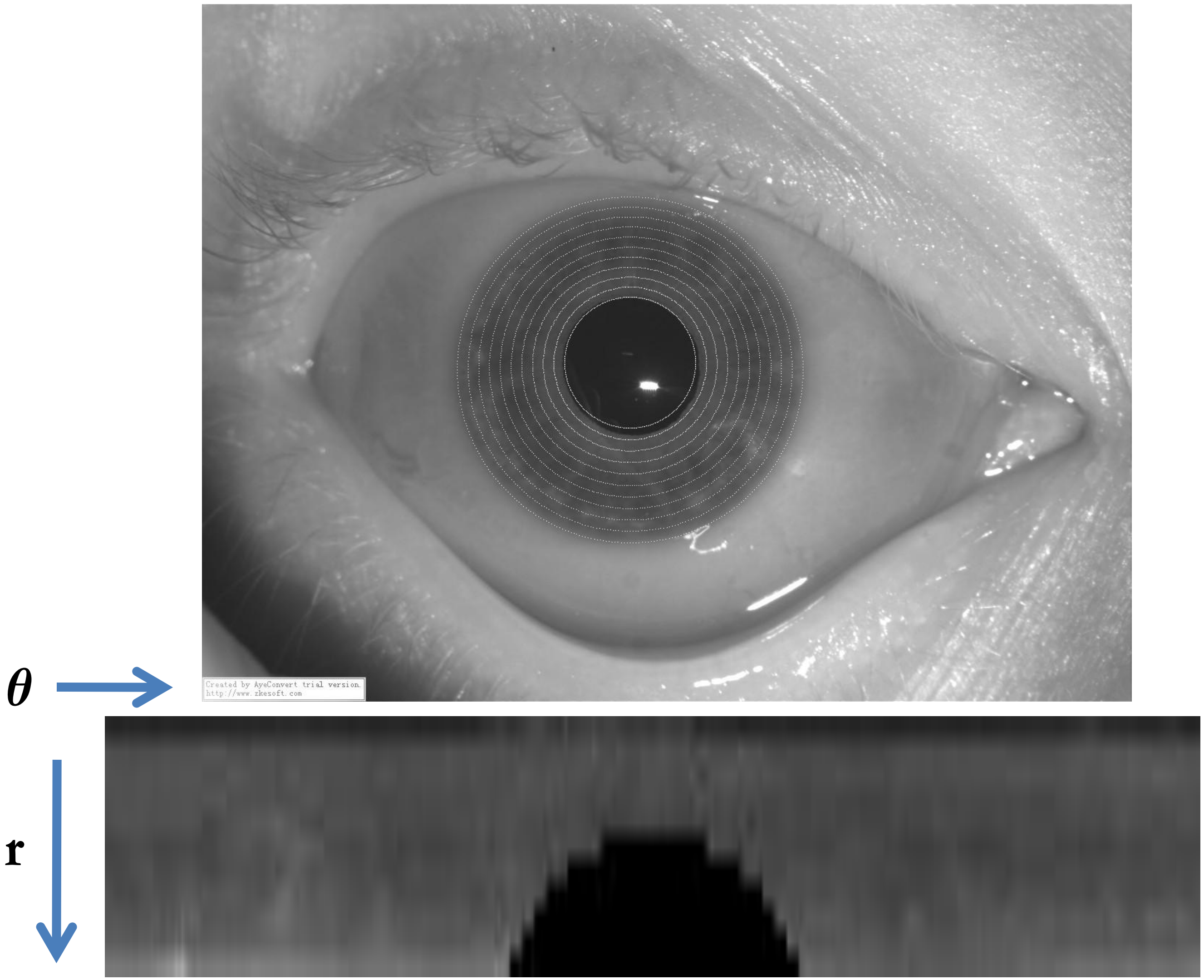


Daugman Rubber Sheet Model



Daugman Rubber Sheet Model

Unwrap the Iris region onto a rectangular block of size 64x512

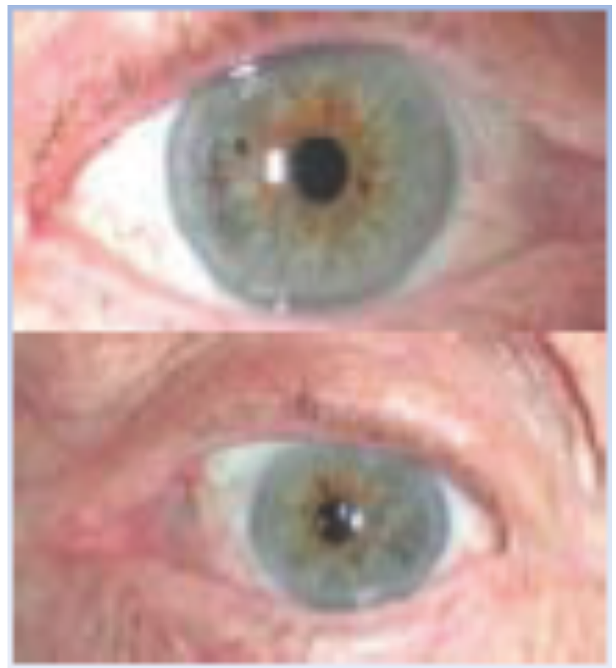


Normalization do and don't

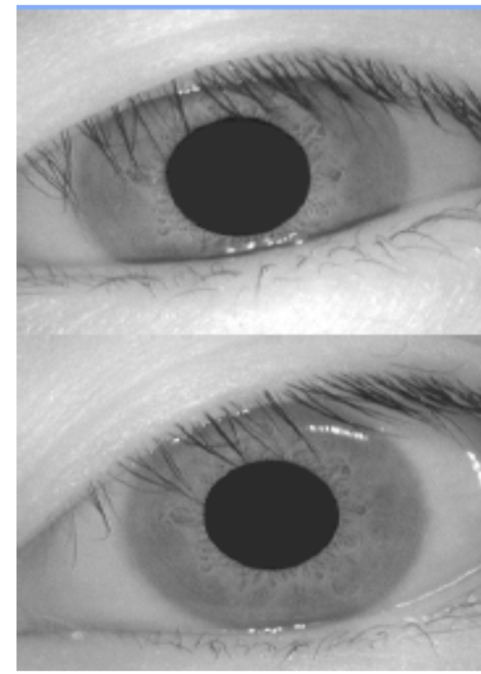
- The model remaps each point within the iris region to a pair of polar coordinates (r,θ) where r is in the interval [0,1] and θ is angle in $[0,2\pi]$
- The model compensates **pupil dilation** and **size inconsistencies** by producing a size-and translation-invariant representation in the polar coordinate system.
- The model **does not** compensate for **rotational inconsistencies**, which is accounted for **during matching** by shifting the iris templates in the θ direction until two iris templates are aligned

Normalization do and don't

Pupil dilation
(Lighting changes)



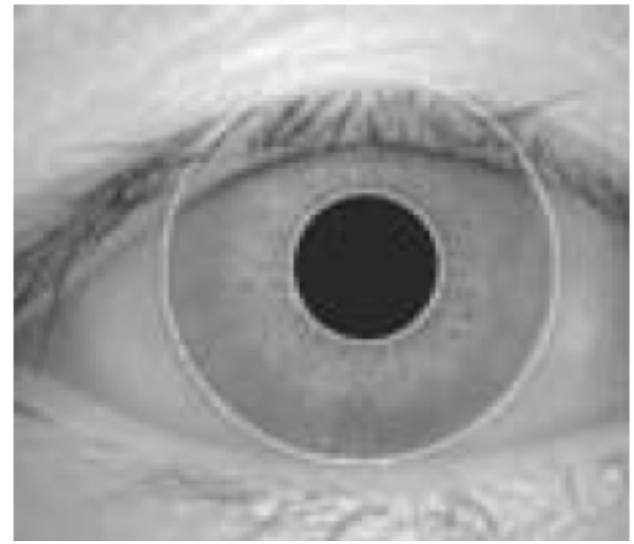
Inconsistent iris sizes
(Distance from camera)

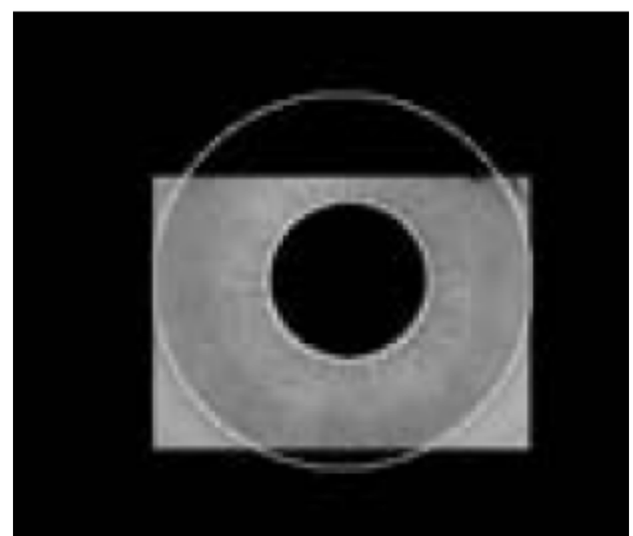


Eye rotation
(Head tilt)

Noise Removal

- Linear Hough transform is used to fit a line on lower and upper eyelid
- A horizontal line is then draw intersecting the first line on the iris edge which is closest to the pupil



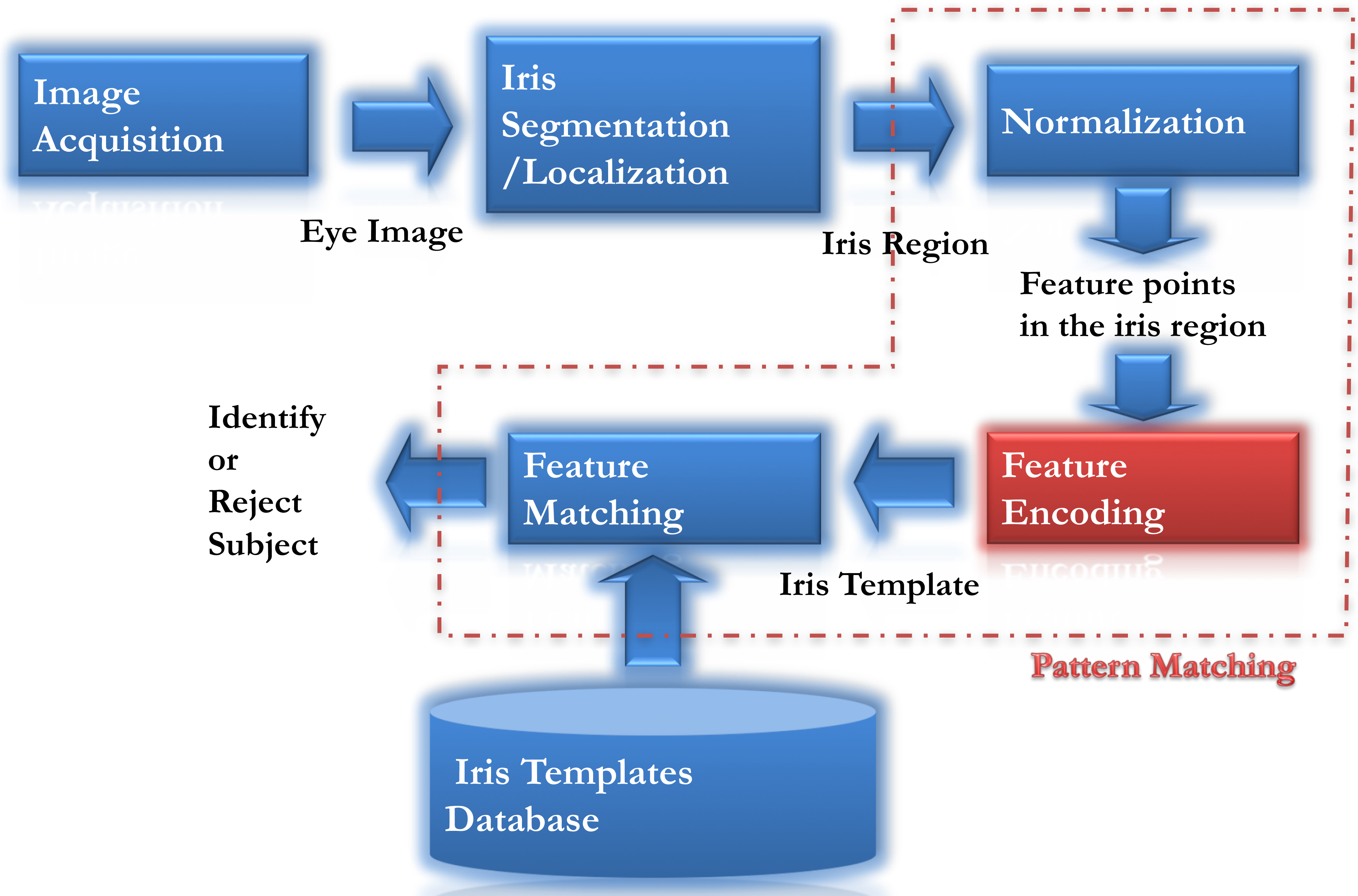


Noise Removal

Normalized Iris

Normalized Iris after noise removal (Eyelash)

Daugman Model for Iris Recognition



Iris Features

- Any given iris has a unique **texture** that is generated through a random process before birth.

Phase Information

- It has been shown by Oppenheim and Lim[1] that phase information, rather than amplitude information provides the most significant information within an image.
- Taking only the phase will allow encoding of discriminating information in the iris, while discarding redundant information such as illumination, which is represented by the amplitude component.
- Therefore, it is required to transform the iris feature points to a domain where phase information is available, i.e. real and imaginary parts for each feature point.
- What about using Fourier Transform?!!

[1] A. Oppenheim, J. Lim. The importance of phase in signals. *Proceedings of the IEEE 69*, 529-541, 1981.

Space vs Frequency

- We know two bases for images:
  - Pixels are localized in space.
  - Fourier are localized in frequency.
- We need a domain which is
  - a little of both.
  - good for measuring frequency locally.

Gabor Filters

- Gabor filters are the products of a Gaussian filter with oriented complex sinusoids.

- Gabor filters come in pairs, each consisting of a symmetric filter and an anti-symmetric filter.

$$G_{Symmetric}(x, y) = \cos(k_x x + k_y y)\exp\left\{-\frac{x^2 + y^2}{2\sigma^2}\right\}$$

$$G_{Antisymmetric}(x, y) = \sin(k_x x + k_y y)\exp\left\{-\frac{x^2 + y^2}{2\sigma^2}\right\}$$

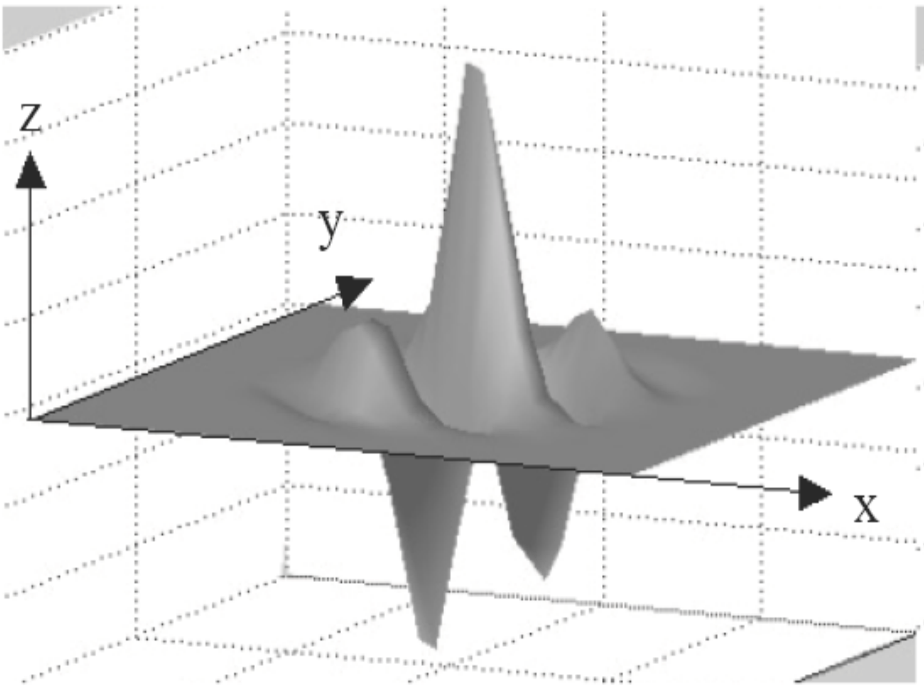
- (k_x, k_y) determines the spatial frequency and the orientation of the filter and σ determines the scale of the filter

- A filter bank is formed by varying the frequency, the scale, and the filter orientation.

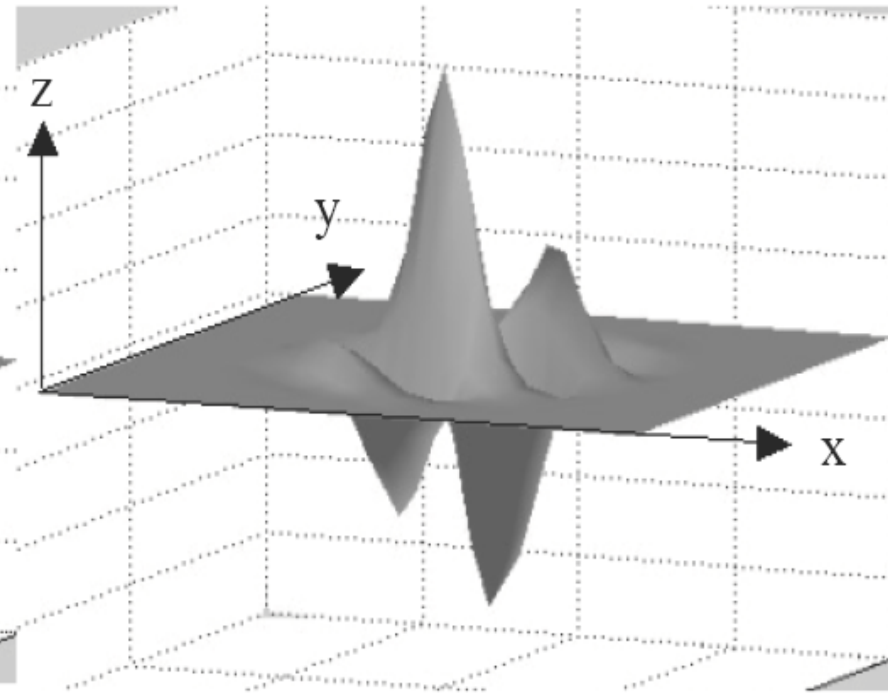
Gabor Filters

- Modulating a sine/cosine wave with a Gaussian.
- It provides conjoint localization in both space and frequency.
- Decomposition of a signal is accomplished using a quadrature pair of Gabor filters.
- The real part specified by a cosine modulated by a Gaussian.
- While the imaginary part is specified by a modulated sine.
- The real and imaginary filters are also known as the even symmetric and odd symmetric components respectively.
- The centre frequency of the filter is specified by the frequency of the sine/cosine wave.
- The bandwidth of the filter is specified by the width of the Gaussian.

Gabor Filters



Real component or even symmetric filter characterized by a cosine modulated by a Gaussian



Imaginary component or odd symmetric filter characterized by a sine modulated by a Gaussian

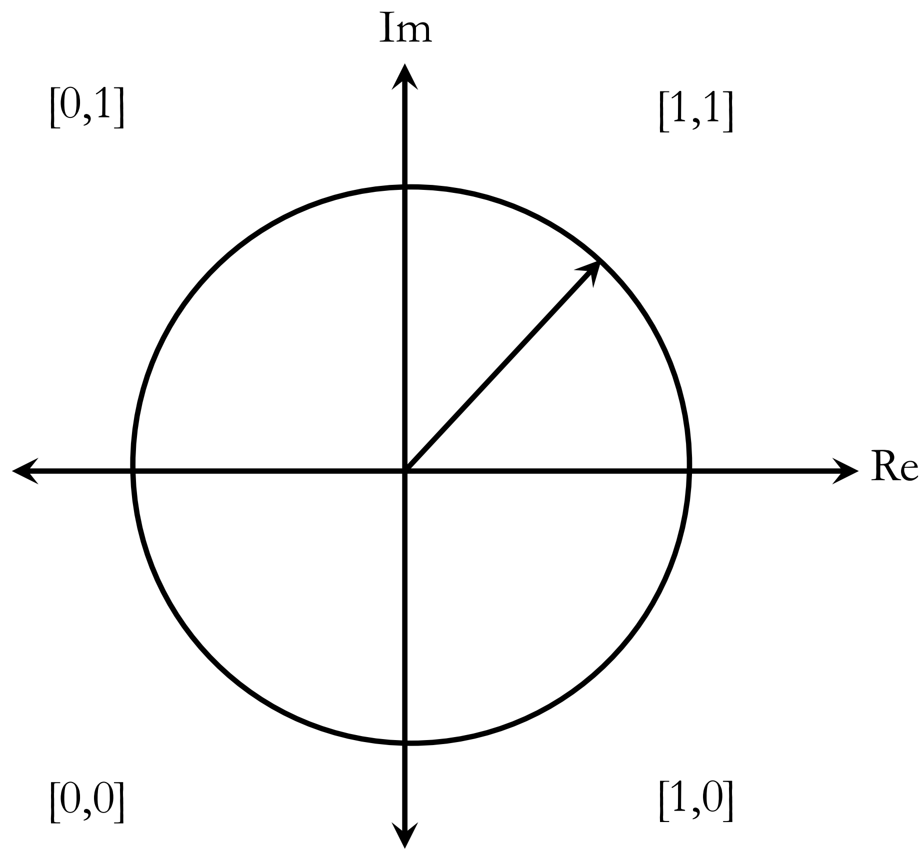
Daugman Iris Codes

$$h_{\{\mathrm{Re},\mathrm{Im}\}}(r,\theta) = \mathrm{sgn}_{\{\mathrm{Re},\mathrm{Im}\}} \int_\rho \int_\phi I(\rho,\phi) e^{-i\omega(\theta-\phi)} e^{-\frac{(r-\rho)^2}{\alpha^2}} e^{-\frac{(\theta-\phi)^2}{\beta^2}} \rho d\rho d\phi$$

- Daugman makes use of a 2D version of Gabor filters in order to encode iris pattern data.
- Where:
  - $h_{\{Re,Im\}}(r,\theta)$ is the iris code at a feature point (iris point) with r distance from the pupil boundary and θ degrees from the horizontal axis.
  - $I(\varrho,\phi)$ is the raw iris image in the dimensionless coordinate system.
  - α, β is the width of the Gaussians used in modulation.

Daugman Iris Codes

- Daugman demodulates the output of the Gabor filters in order to compress the data.
- This is done by quantising the phase information into four levels, for each possible quadrant in the complex plane.



For Gabor filter toolbox - refer to http://www.it.lut.fi/project/simplegabor/

Code Guide

bank = sg_createfilterbank(N, f, m, n)

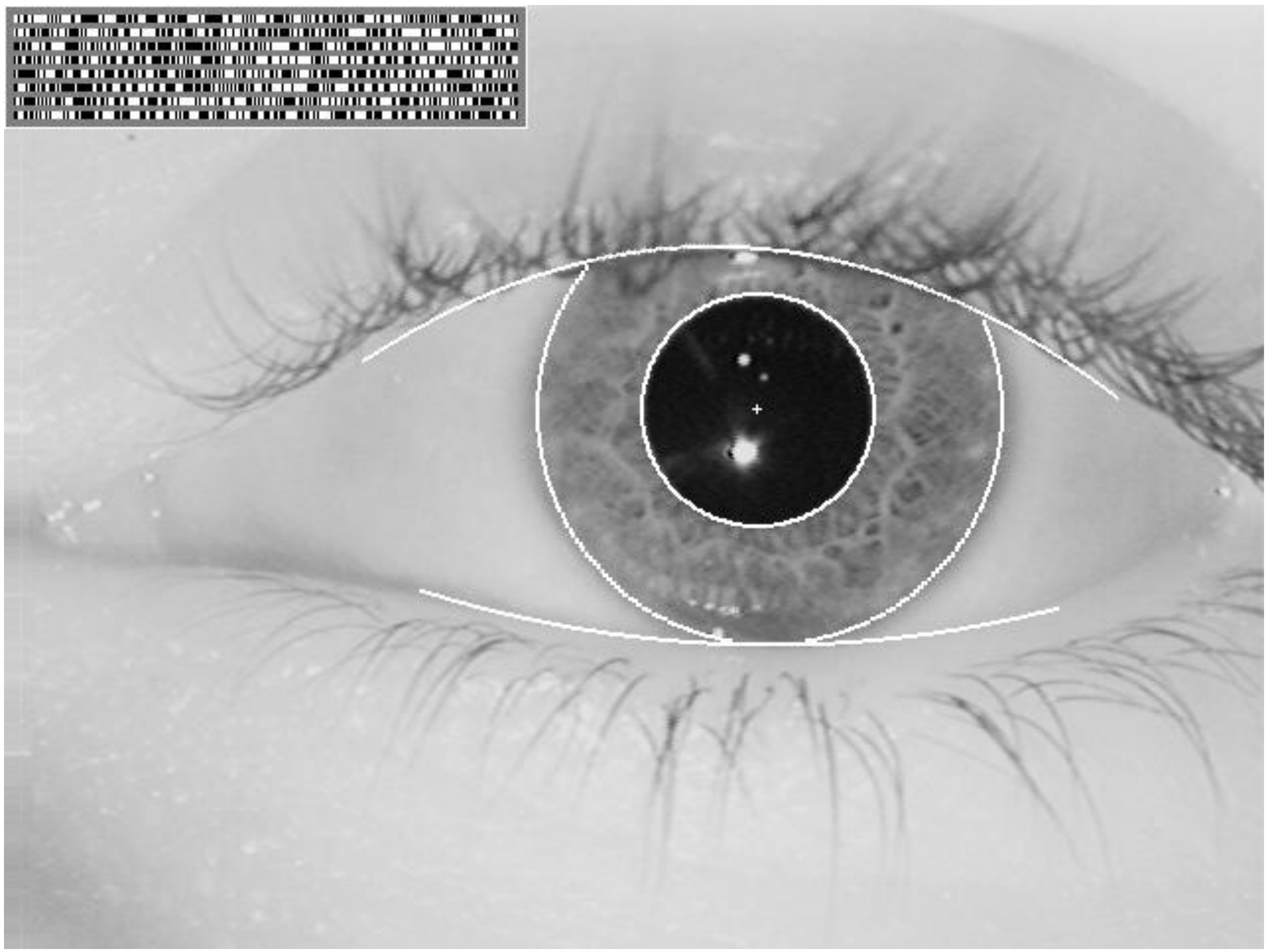
Creates filterbank with specified frequencies and orientations.
N - size of the image, [height width].
f – max frequency allowed for the filters
m - number of filter frequencies.
n - number or filter orientations.

```
IrisRubberSheet = IrisRubberSheet ./ 255 ; % convert it to 0 to 1

% creating a filter bank

bank = sg_createfilterbank(size(IrisRubberSheet), 0.6 , 8, 8,'verbose',1);

% filter the image

r = sg_filterwithbank(IrisRubberSheet,bank,'method',1);

% converting to a 3d matrix: Converting response structure returned by sg_filterwithbank
to a matrix more suitable for e.g. using with classifiers.

m = sg_resp2samplematrix(r);

% summing the output of the filter

all = sum(m,3);

% getting the real and imaginary parts

Re = real(all);

Im = imag(all);
```

Code Guide

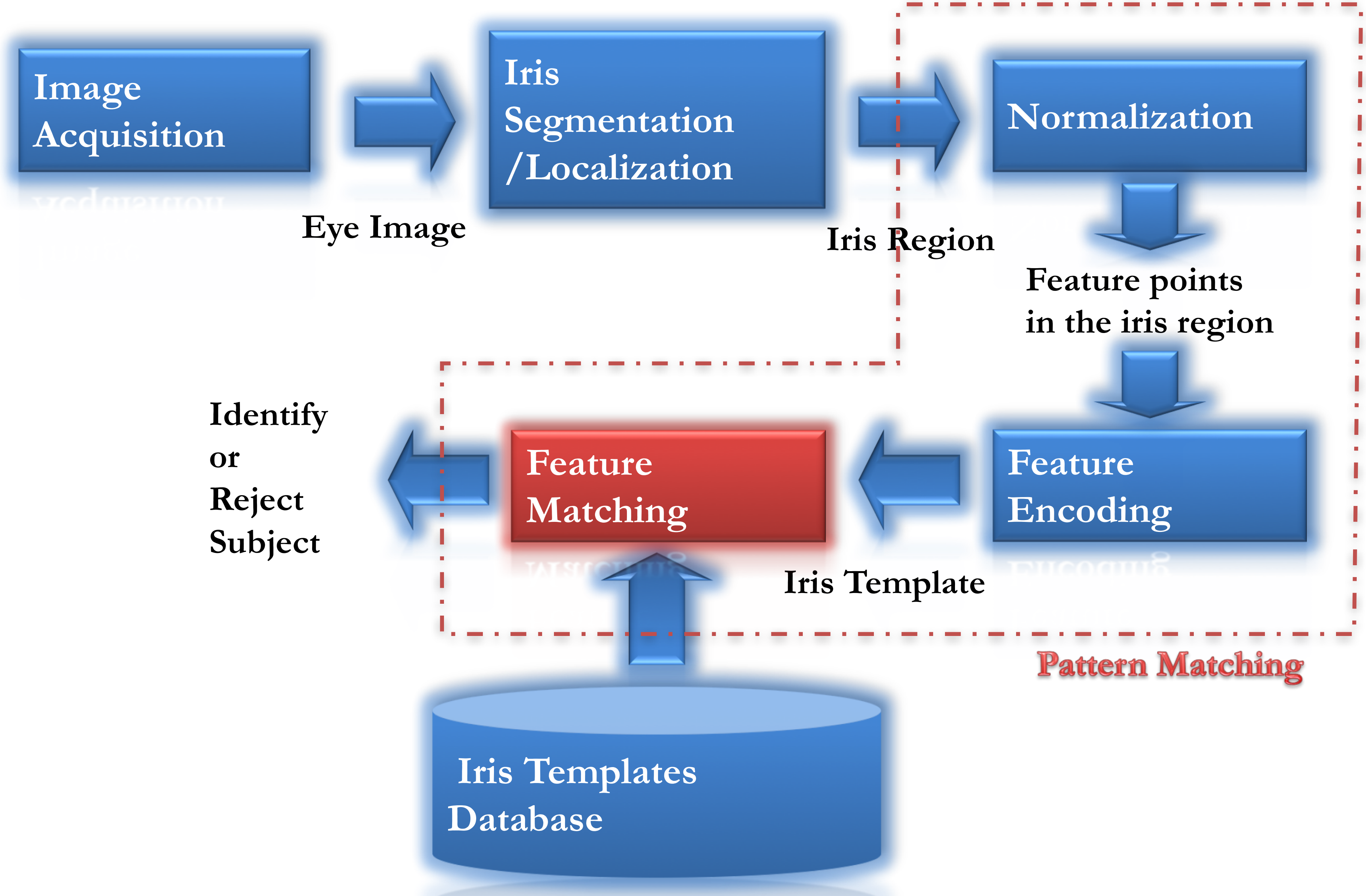
```
% generating the iris code

[R,T] = size(IrisRubberSheet)

IrisCodes = zeros(R, 2*T); % two bits for each feature point

for r = 1 : R

     tt = 0;

     for t = 1 : 2:2*T

        tt = tt + 1;

        % the real part

        if(Re(r,tt) >= 0 ) IrisCodes(r,t) = 1;

        else IrisCodes(r,t) = 0; end

        % the imaginary part

        if(Im(r,tt) >= 0 ) IrisCodes(r,t+1) = 1;

        else IrisCodes(r,t+1) = 0; end

     end

end
```

Daugman Iris Codes



http://www.cl.cam.ac.uk/~jgd1000/iris_recognition.html

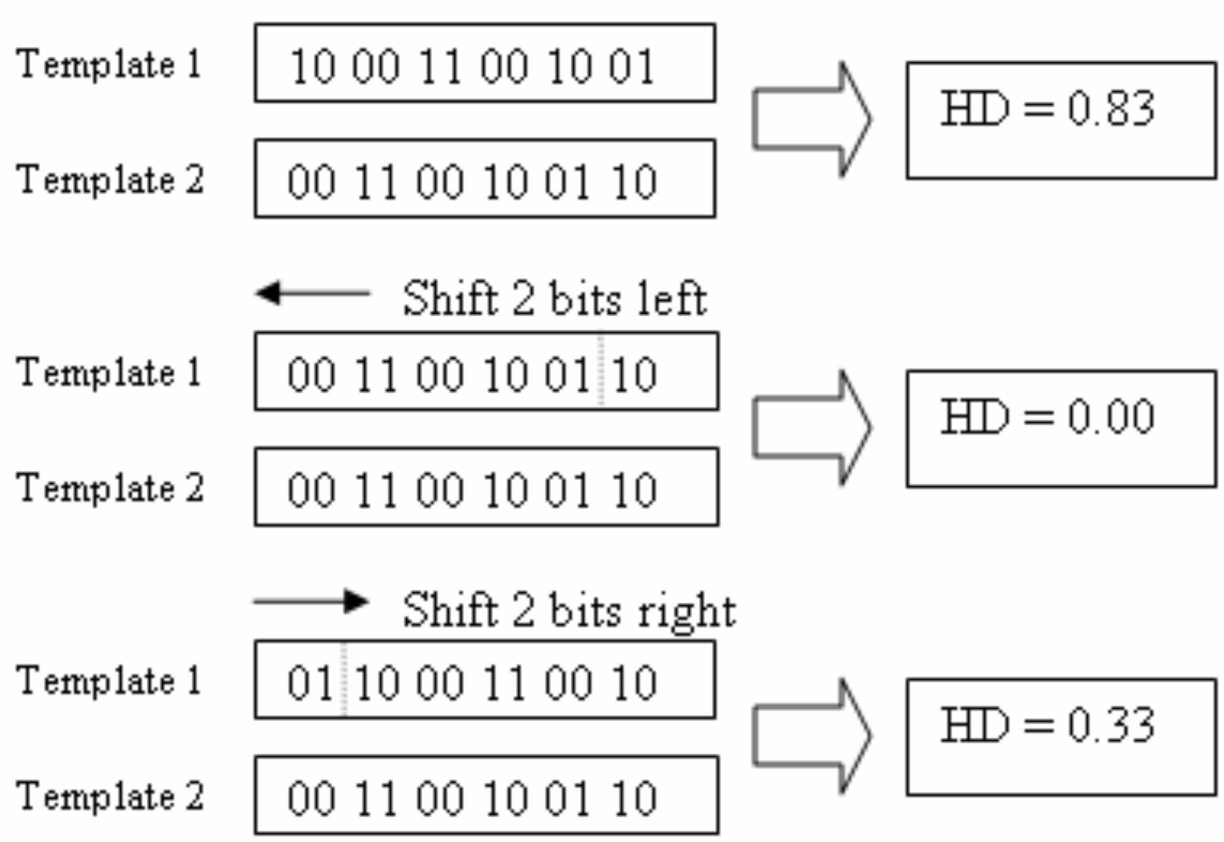
Daugman Model for Iris Recognition



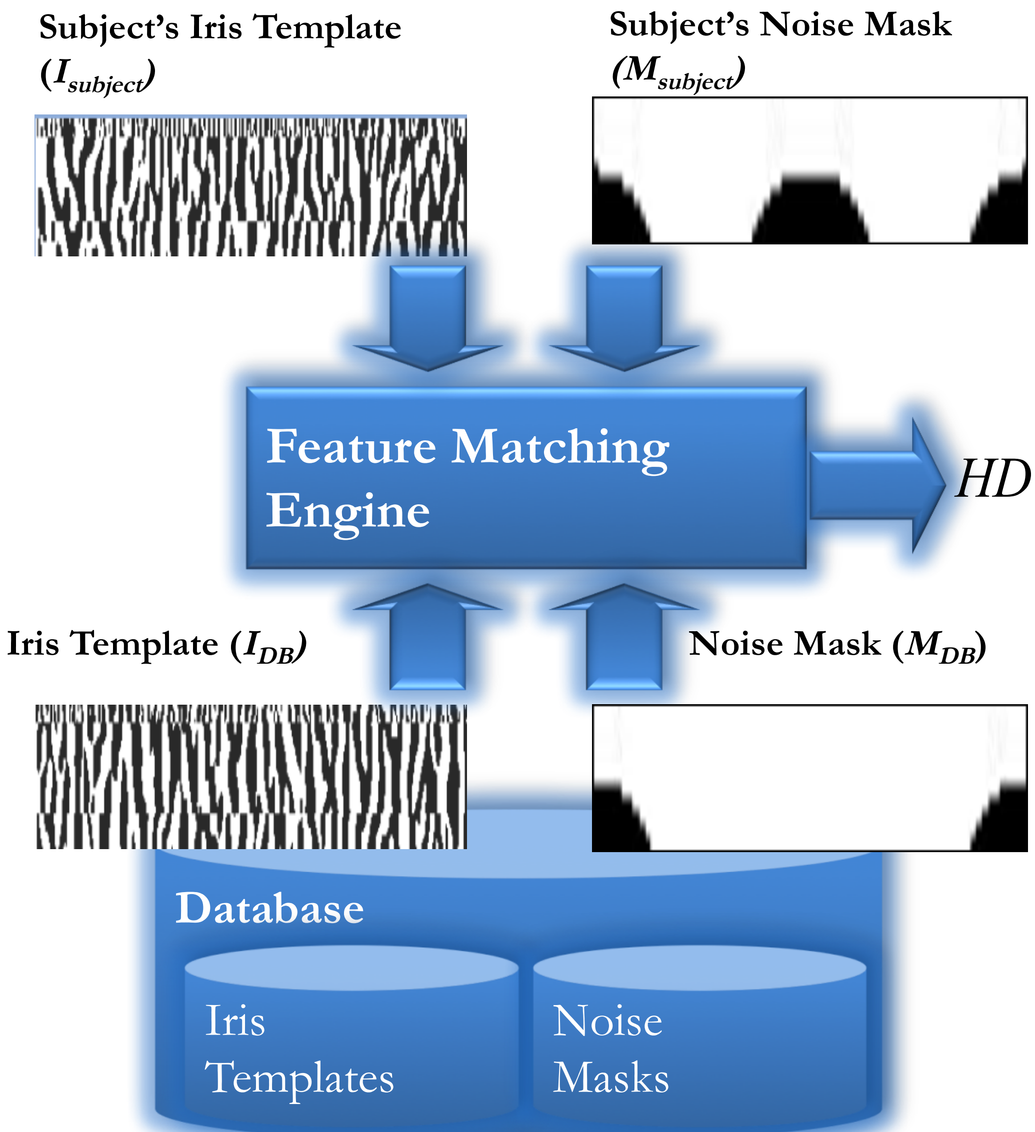
Hamming Distance

- Given two patterns X and Y, it is the sum of disagreeing bits (sum of the exclusive-OR between) divided by N, the total number of bits in the pattern
- If two patterns are derived from the same iris, the Hamming distance between them will be close to 0.0 due to high correlation
- In order to account for rotational inconsistencies, one template is shifted left and right bit-wise and a number of Hamming distance values are calculated from successive shifts.
- The smallest Hamming distance is selected as it corresponds to the best match between two templates.

Illustration: Shifting Process



Iris Codes Comparison



Feature are matched through the normalized hamming distance, which mainly rely on XOR operation, when both codes will disagree.

Matching Score

$$HD = \frac{\left\| \left(I_{subject} \otimes I_{DB} \right) \cap M_{subject} \cap M_{DB} \right\|}{\left\| M_{subject} \cap M_{DB} \right\|}$$

So, the distance will be summing up when both codes disagree, yet we have to take into account iris region only with no noise.

Then we divide by the number of iris feature points taken into consideration for normalization, after ruling out the noisy regions.

Code Guide

```
Codes_xor = bitxor(IrisCode_subject , IrisCode_db);

% get the anding of the masks

Masks_and = bitand(Mask_subject , Mask_db);

total = sum(sum(Masks_and)) ; % number of pixels to be taken into consideration

hd = sum(sum(bitand(Codes_xor,Masks_and)))/total;
```

In Words …

- We have presented the general framework of an automated iris recognition system as proposed by J. Daugman.
- Daugman model consists of four phases; iris segmentation, normalization, feature encoding and feature matching.
- The iris region can be segmented using numerous methods such as Hough Transform (Circular, Linear and Parabolic), active contour models and template matching.
- Normalization is used to extract fixed number of feature points from the iris region in order to handle iris images variability.
- Iris features are encoded using their phase information, Daugman used 2D Gabor filter, while there are other filter which also used such as 1D Gabor filter and wavelets.
- Hamming distance, based on XORing, is used as a similarity measure between the phase information of two irises.

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- Li. Ma, Y. Wang, and T. Tan, "Iris recognition based on multi-channel Gabor filtering," in *Proc. 5th Asian Conf. Computer Vision, vol. I, 2002, pp. 279-283*

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- Ma Li, Tan T., Wang Y. and Zhang, D. (2004): Efficient Iris Recognition by characterizing Key Local Variations, *IEEE Trans. Image Processing, vol 13,* no.6, pp. 739-750

- A. Poursaberi, B. N. Araabi, "A Novel Iris Recognition System Using Morphological Edge Detector and Wavelet Phase Features", *ICGST International Journal on Graphics, Vision and Image Processing, P1150517004, June* 2005