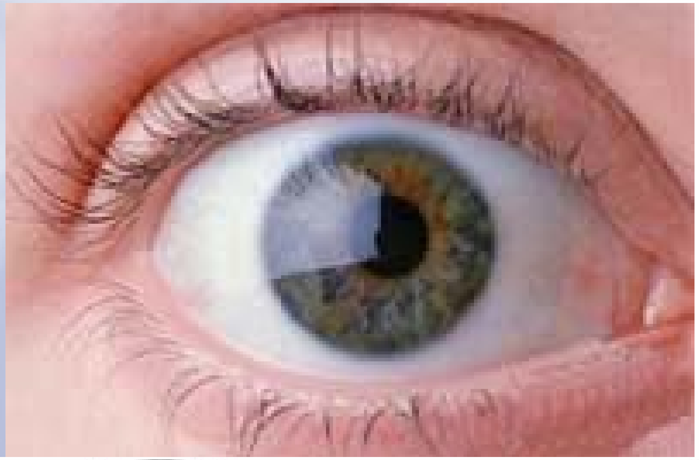
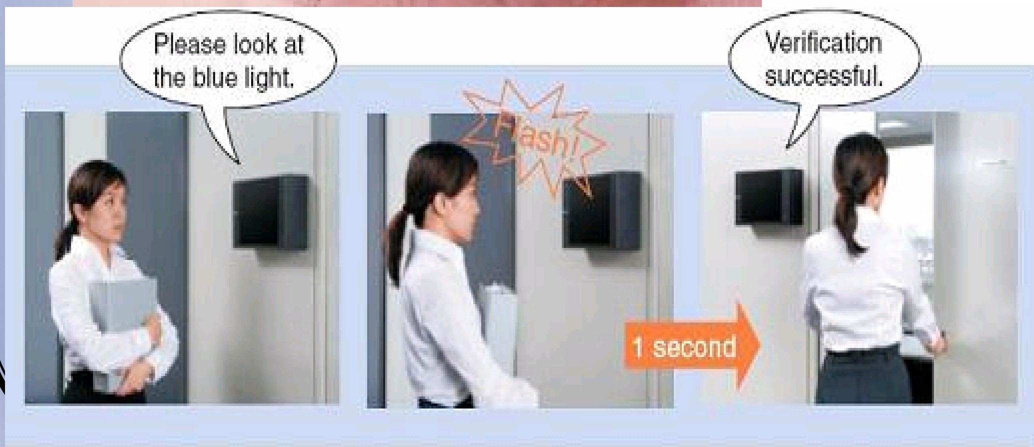
Biometric Authentication

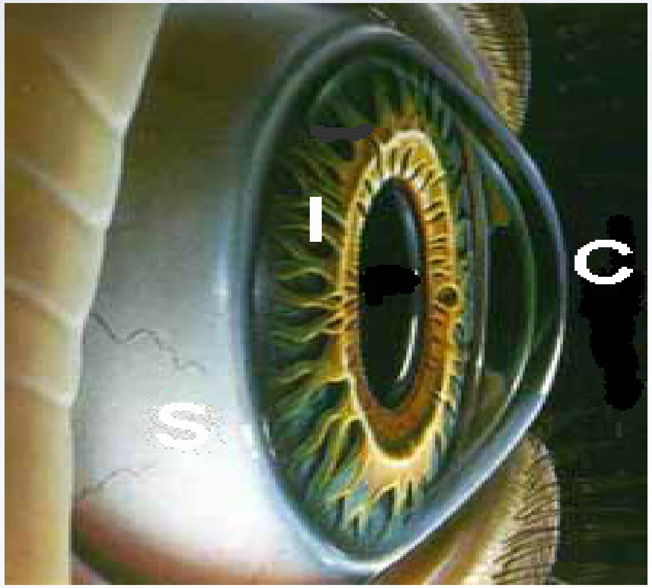


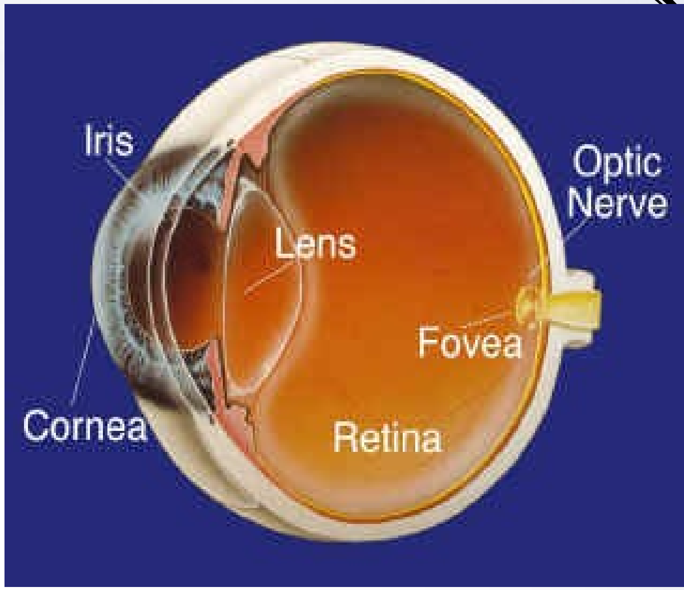
Lecture 9

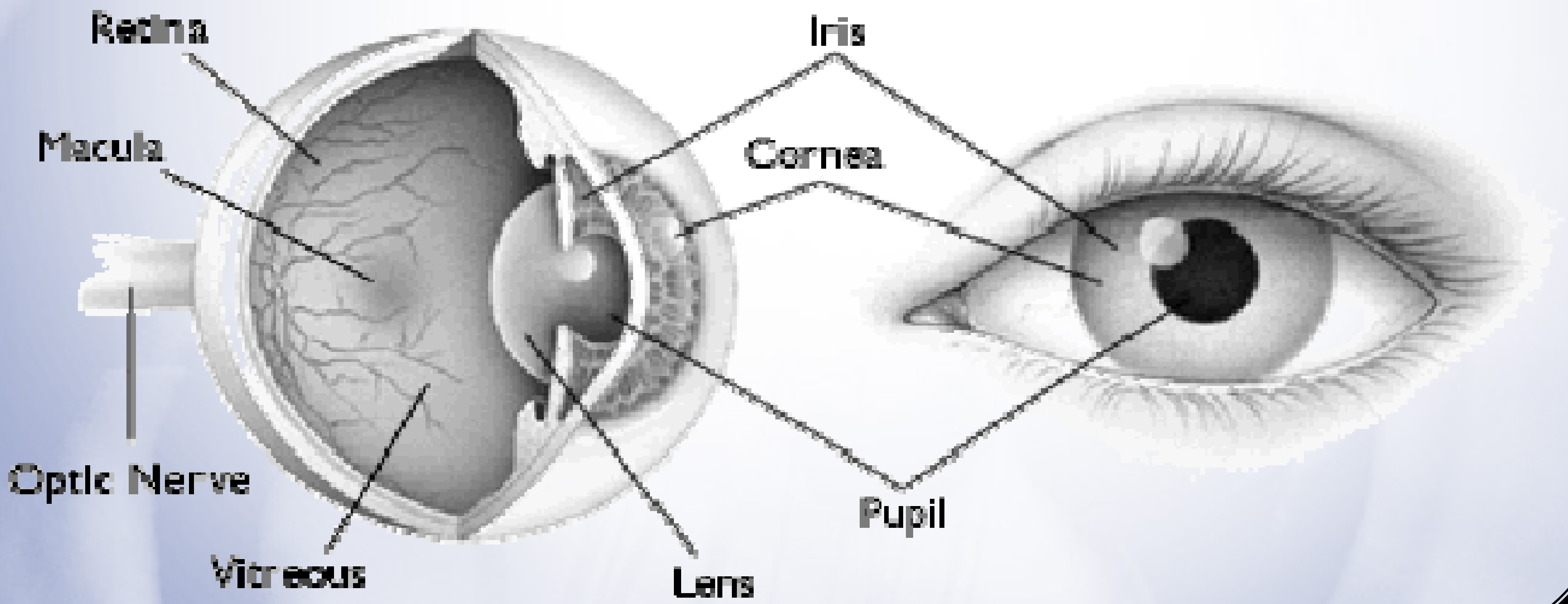


Traditional Uni-Modal Retina/Iris Recognition

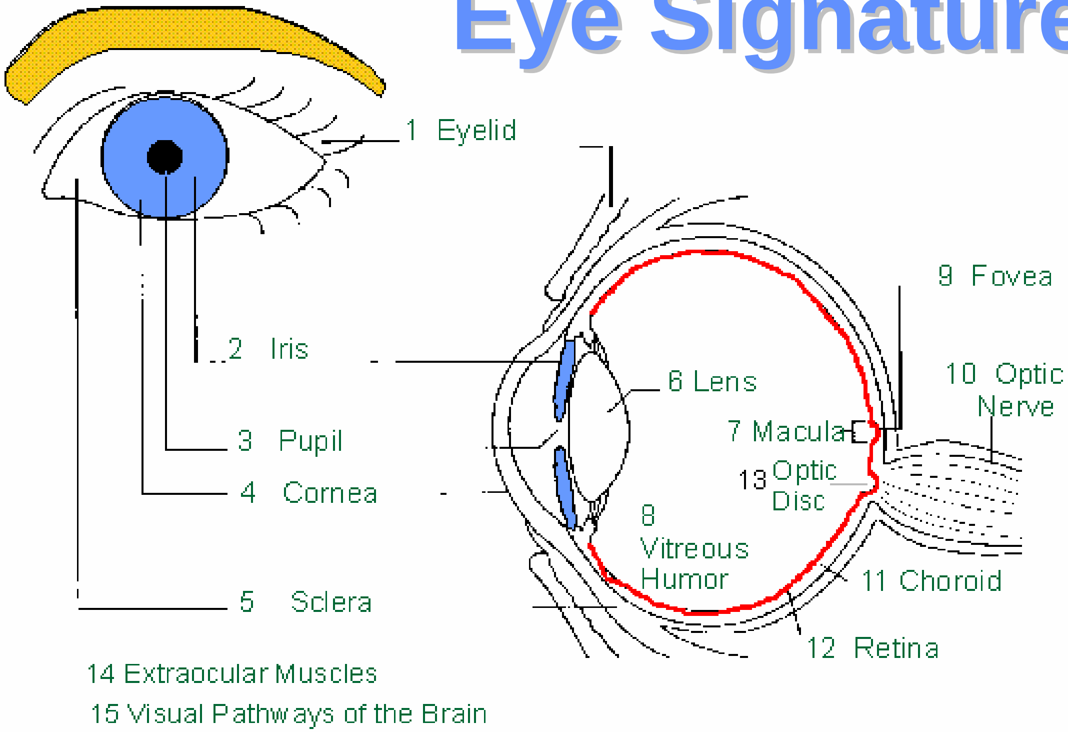
Eye Structure

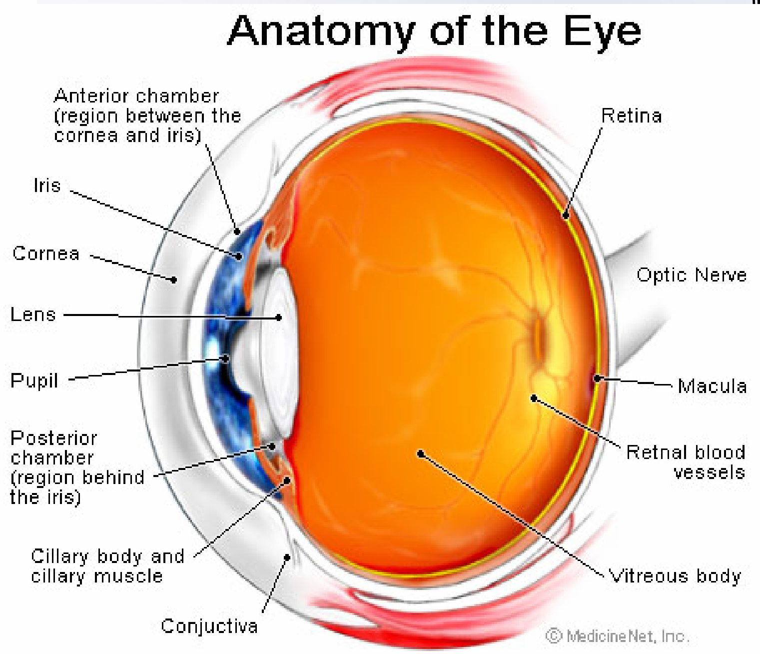




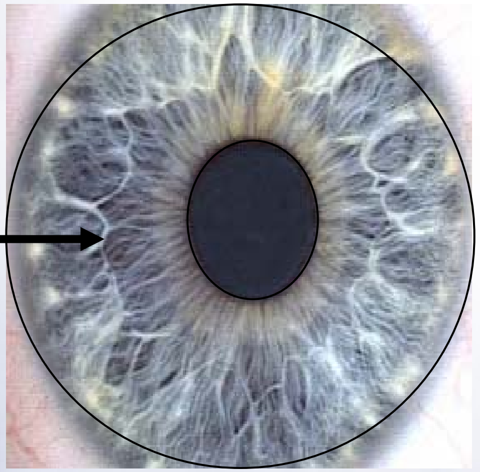


Eye Signature: Retina & Iris

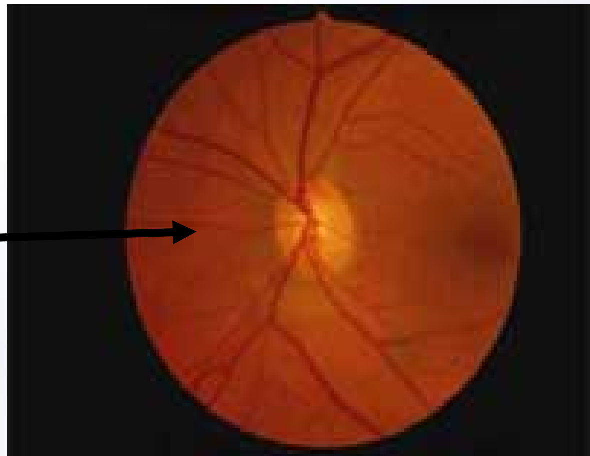




Iris: An annular region between the pupil and the white sclera.

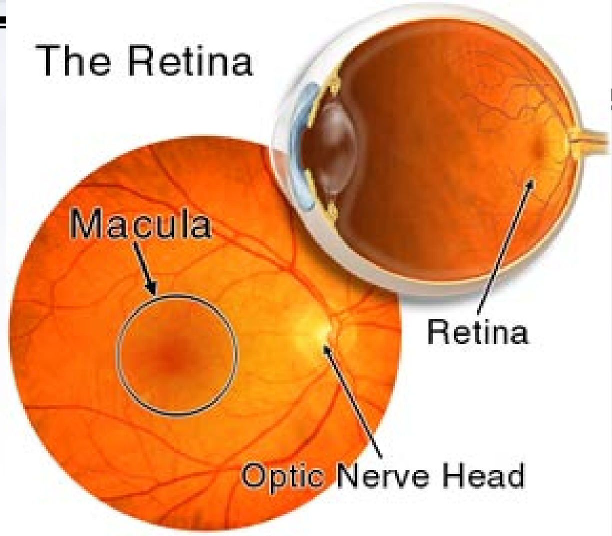


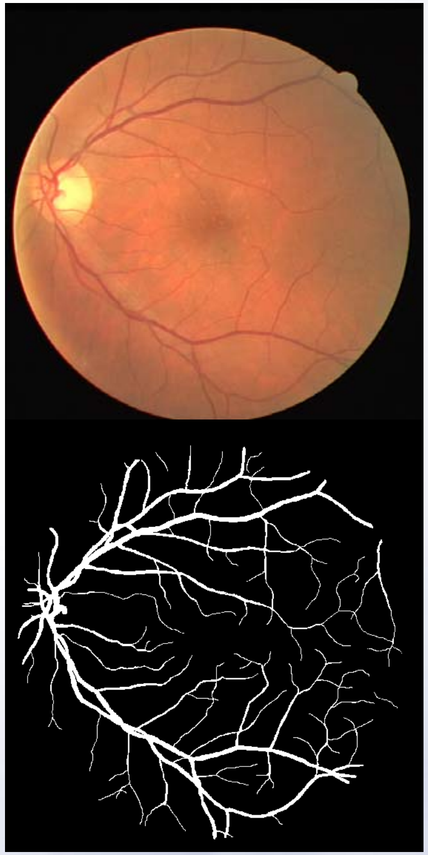
Retina: Blood vessels at the back of the eye.



Retina Verification

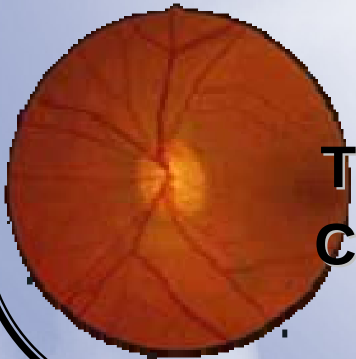
- Retinal scanning analyses the layer of blood vessels at the back of the eye.
- Scanning involves using a low-intensity light source and an optical coupler to scan the unique patterns of the retina
- It can read the patterns at a great level of accuracy.
- It does require the user to remove glasses, place their eye close to the device, and focus on a certain point.
- Whether the accuracy can outweigh the public discomfort is yet to be seen.



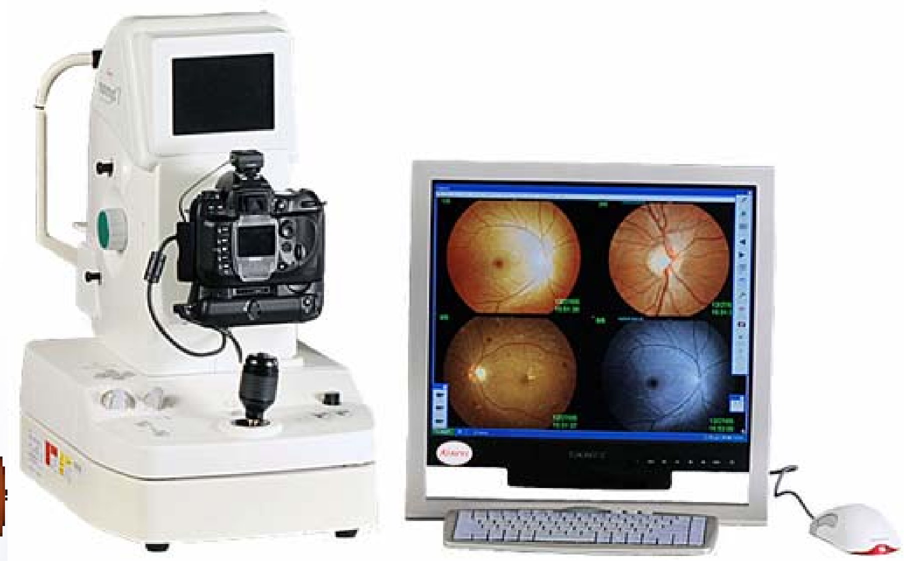


Retina: Background

- Uniqueness of the retinal vascular pattern discover by Dr. Carleton Simon and Isodore Goldstein in 1935. Every eye has its own totally unique pattern of blood vessels
- In 1950, Dr. Paul Tower study showed that of all the factors compared twins, retinal vascular patterns showed the least similarity
- Stable
  - eye diseases
  - cases of severe head trauma



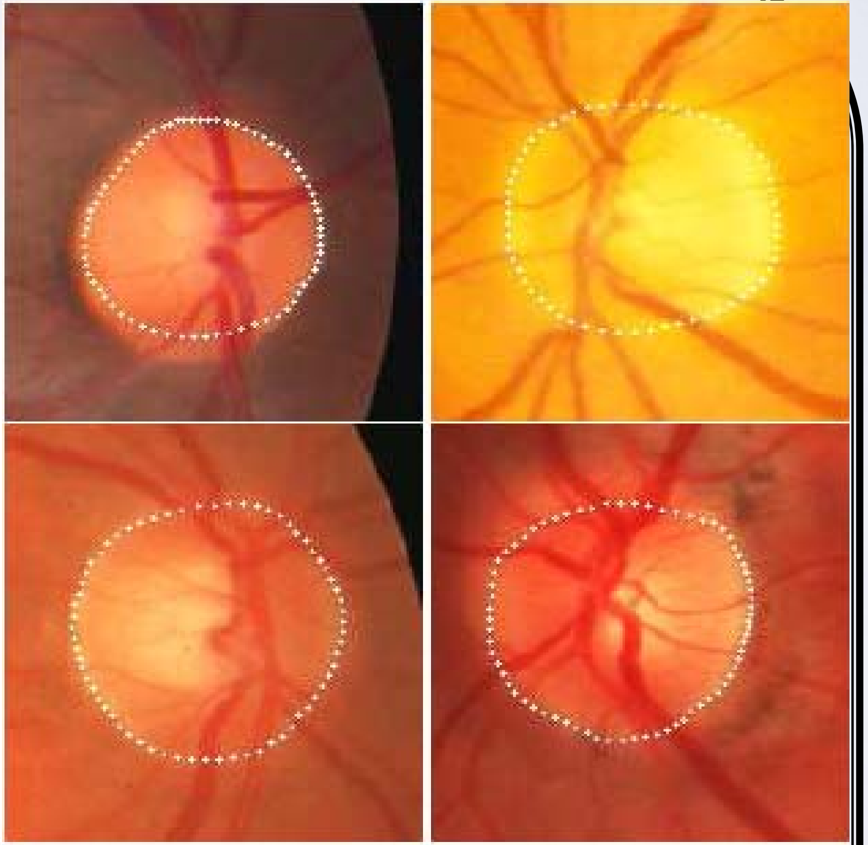
Twin Retina Comparison

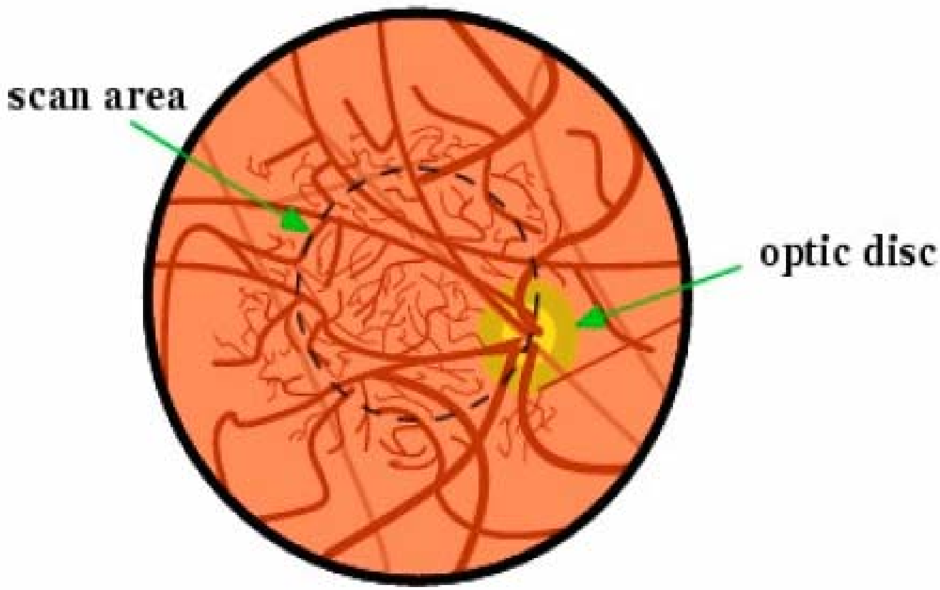


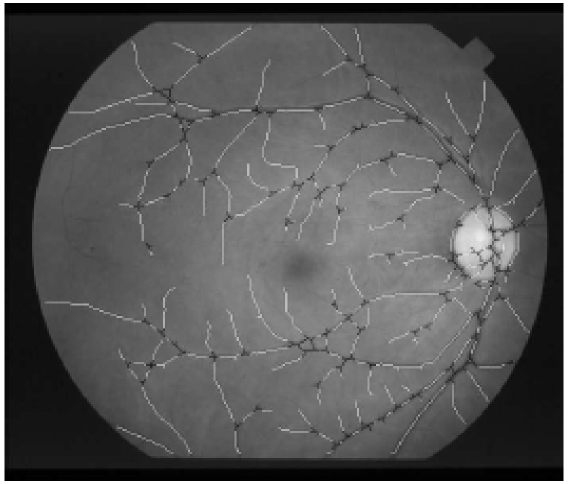
► **Retina Scanner**

Retina Location and Features

- ⇒ Blood vessel pattern stable enough for whole life
- ⇒ Also, no need to update frequently







1-pixel wide vascular tree with intersections and crossovers (overlaying on grayscaled image.)

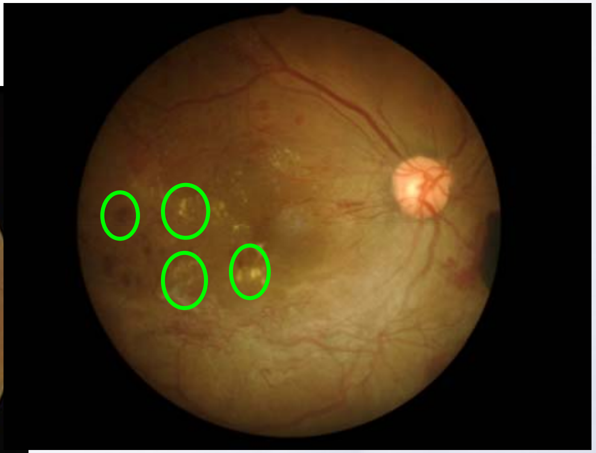
Major Retinal Features

- Physical features
  - ◆Vessels: Blood transfer;
  - ◆Optic Disk: The nerves of eye connected to brain;

→The deformation of vessels can be a sign of some diseases such as hypertension and diabetes. The optic disk is used to describe the position of the deformation.

- Pathological features
  - ◆Red Lesion
  - ◆Bright Lesion

→Red lesion and bright lesion on the retina are signs of some diseases, such as hypertension and diabetes



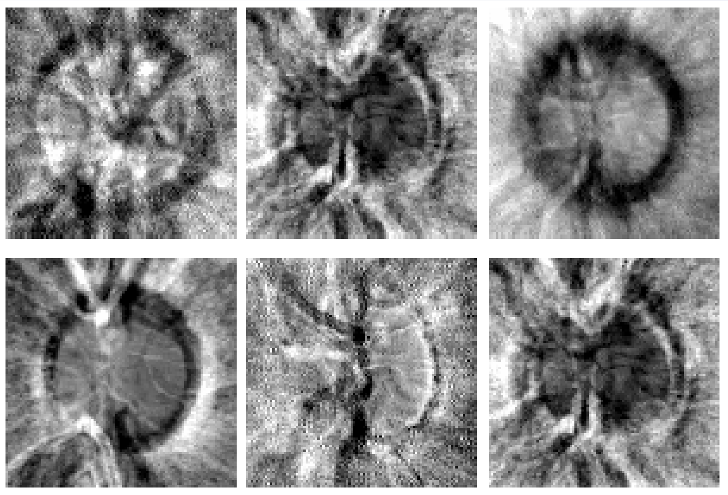
- A healthy retina and an unhealthy retina.

How to extract Optic Disk?

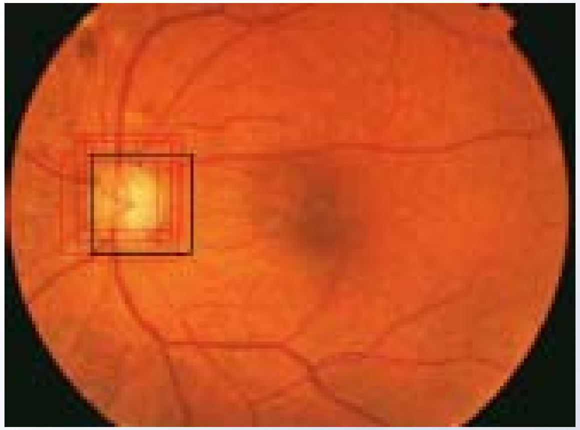
❑ PCA-based Method

1) Some optic disks of the images are manually cut to obtain the training data.

2) The eigen vectors of the covariance matrix of the training data can be calculated, which may be named as eigen optic discs.



The first 6 Eigen vectors



3) A square window is moved iteratively on the retinal image. The sub-image inside the square window is projected onto the optic disc space and the reconstruction error is calculated. The sub-image with the minimum reconstruction error will be classified as the optic disk.

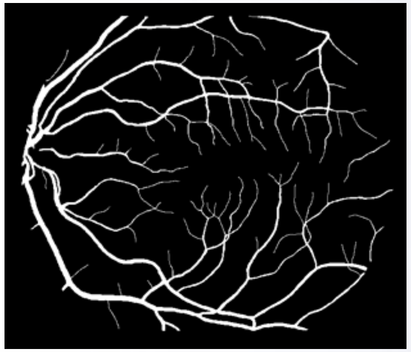
How to extract Vessels?

Matched Filter

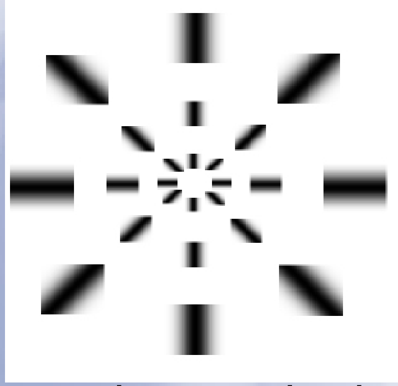
-- Because the cross-section of vessel is approximate to Gaussian, a filter with shape of Gaussian can be used to match the vessel,

$$g(x,y) = -\exp\left(-x^2/\sigma^2\right) - m, \quad \text{for } |x| \le 3\sigma, \quad |y| \le L/2$$

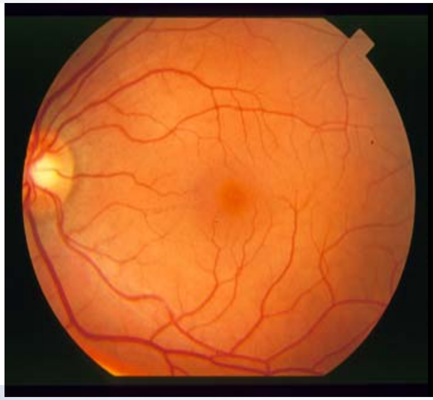
where σ represents the scale of the filter; $m = -\left(\int_{-3\sigma}^{3\sigma} \exp\left(-x^2/\sigma^2\right) dx\right)/6\sigma$ is used to normalize the mean value of the filter to 0 so that the smooth background can be removed



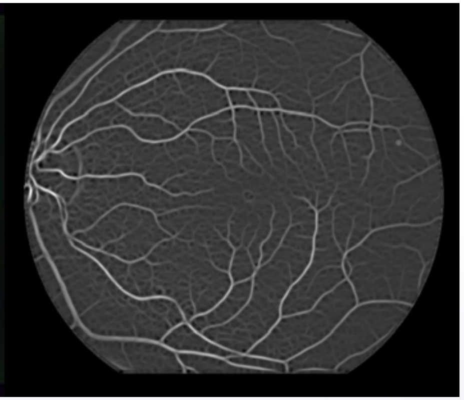
Hand-labeled ground truth



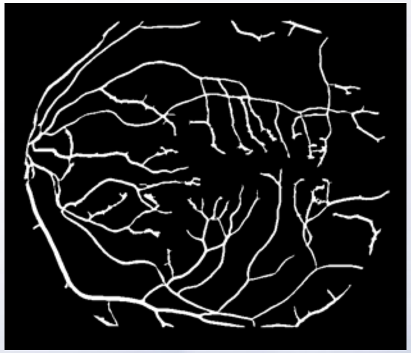
The matched filters in 3 scales and 8 directions



A Retinal Image



Matched filter response

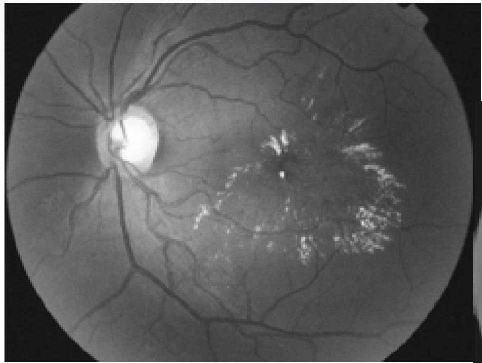


Extraction result by matched filter

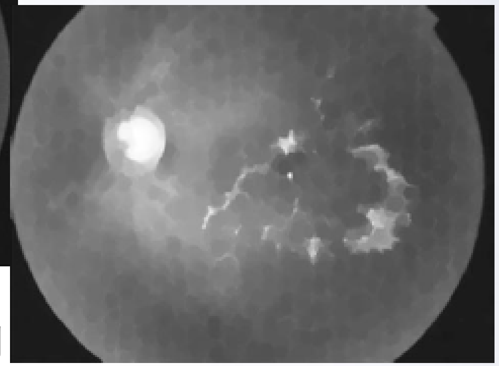
How to extract Bright Lesions?

❑ Morphological Method

1) A morphological closing is used to erase all vessels;



A retinal image



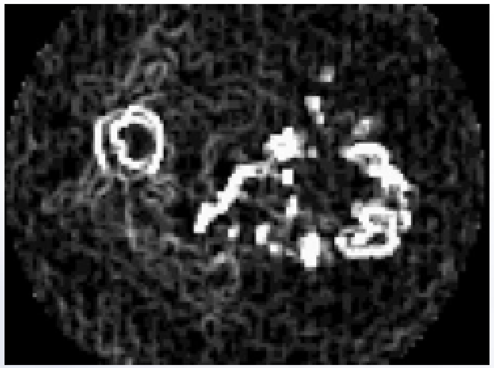
Closing

2) The local variation is calculated to find the bright lesion boundary, the local variation is defined as:

$$e_2(x) = \frac{1}{N-1} \cdot \sum_{\xi \in W(x)} (e_1(\xi) - \mu_{e_1}(x))^2.$$

where *W* is the local window, and μ is the mean.

3) The local variation is thresholded.



Local variation

Thresholding the local variation to obtain bright lesion candidates

How to extract Red Lesions?

❑ SVM based Method

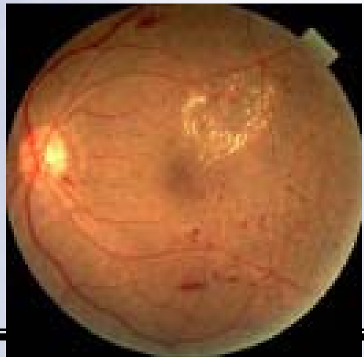
1) Some red lesions of the images are manually cut to obtain the red lesion feature.

2) The eigen vectors of the covariance matrix of the training data are calculated to reduce the feature dimension.

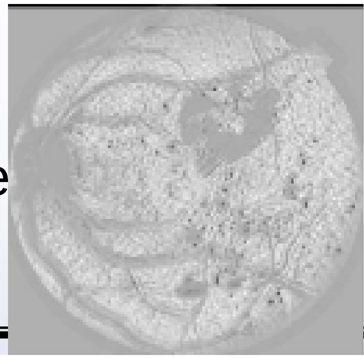
The first 10 Eigen vectors (Eigen redLeions)

3) SVM evidence is calculated and the optimal separating hyper-plane is defined as $f(x) = \operatorname{sgn}\left(\sum_{i=1}^{l} y_i \alpha_i K(x_i, x) + b \right)$

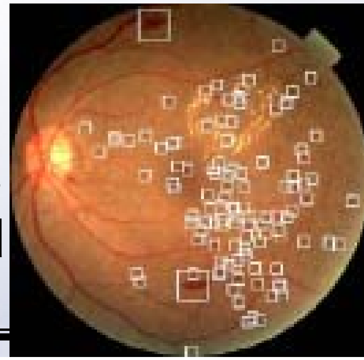
A retinal image



SVM evidence map



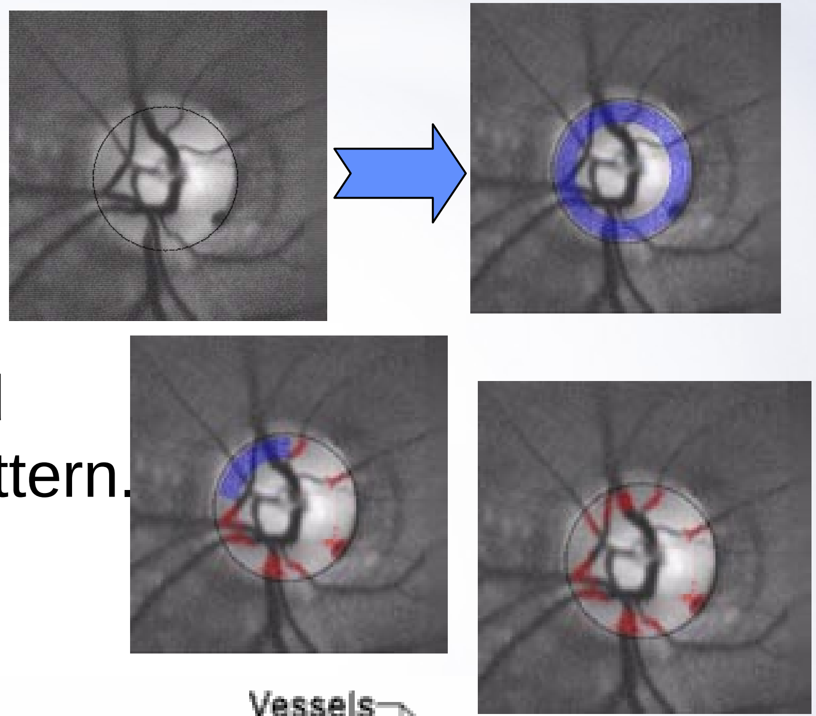
Red lesions located

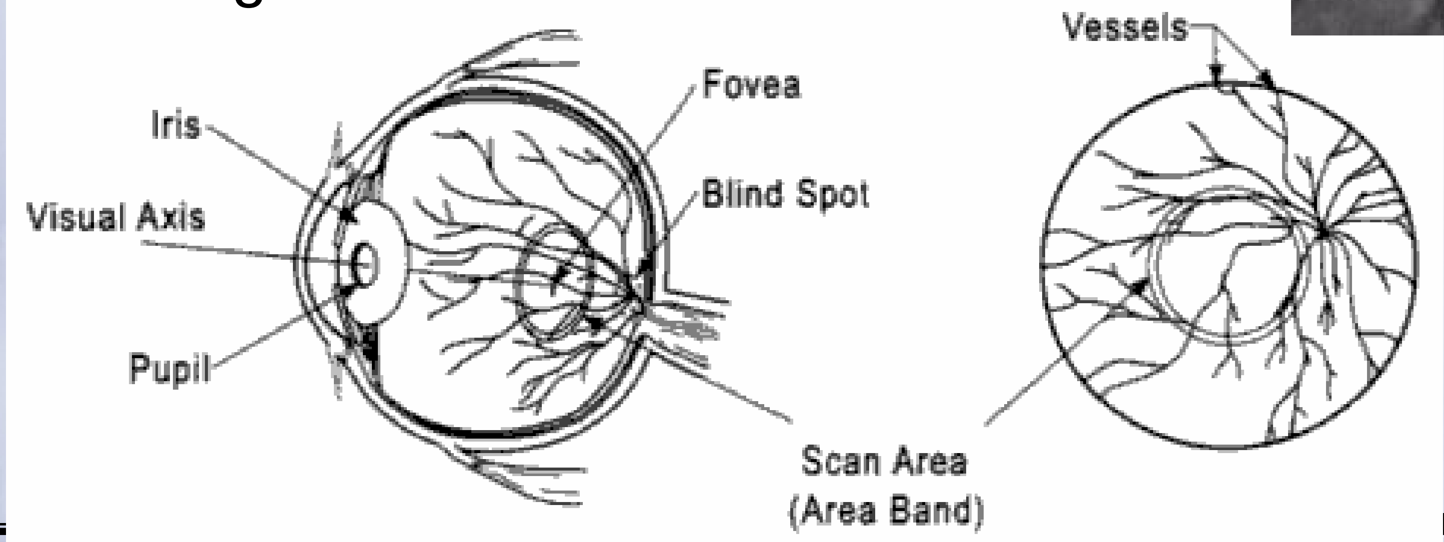


System Overview

Three basic steps:

1. Image acquisition: optic disk is located and photographed.
2. Circular bar code: software translates *vessel thickness* and *angulations* into a summary pattern.
3. Pattern matching: pattern is matched against stored record.





Performance Evaluation

- Retina scan devices are probably the **most accurate** biometric available today.
- The **continuity** of the retinal pattern throughout life and the **difficulty in fooling** such a device also make it a great long-term, high-security option.
- Unfortunately, the **cost** of the proprietary hardware as well as the inability to evolve easily with new technology make retinal scan devices a bad fit for most situations.
- It also has the stigma of consumer's thinking it is potentially **harmful to the eye**, and in general **not easy to use**.
- High performance. Source of error:
  - Lack of Fixation
  - Insufficient pupil size
  - Incorrect eye distance to camera
  - Distortion of the optical path
  - Ambient light interference

Retina Summary

Retina

Strengths

- Accuracy
- Stability of biometric Sample
- Resistant to fraud
- Small temple

Weaknesses

- Difficulty to use
- Consumer perceptions
- Static Design
- Cost

- This is not convenient if you wear glasses or are concerned about having close contact with the reading device.
- For these reasons, retinal scanning is not warmly accepted by all users, even though the technology itself can work very well.

Iris Verification

❑ *Current State*

- Analyze features found in the colored ring of tissue that surrounds the pupil, use a fairly conventional camera element and require no close contact between the [redacted] and the reader.

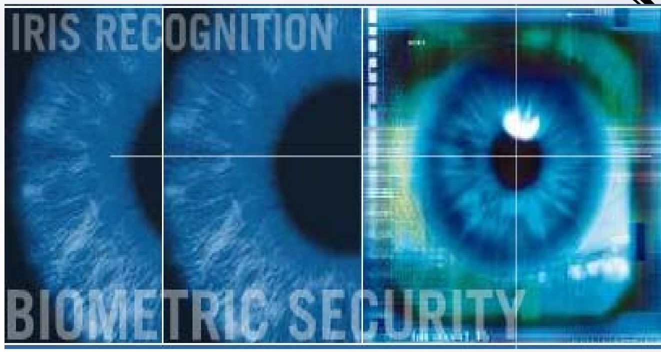
door_open_iris2.swf

- As a high accuracy biometrics, iris has more details than a fingerprint. Highly detailed and unique texture will remain stable over decades of life.

❑ *Feature Set*

Textures with striations, contraction furrows, pits, collagenous fibers, filament, crypts (darkened areas resembling excavations), serpentine vasculature, rings, and freckles

Iris: History



- The idea of using iris patterns for personal identification was originally proposed in 1936 by ophthalmologist Dr. Frank Burch.
- By the 1980's the idea had appeared in James Bond films, but it still remained science fiction and conjecture.
- In 1987 two other ophthalmologists, Aran Safir and Leonard Flom, patented this idea, and in 1989 they asked John Daugman (then teaching at Harvard University) to try to create actual algorithms for iris recognition.
- These algorithms, which Daugman patented in 1994 and are owned by Iridian Technologies, are the basis for all current iris recognition systems and products.

Why Iris?

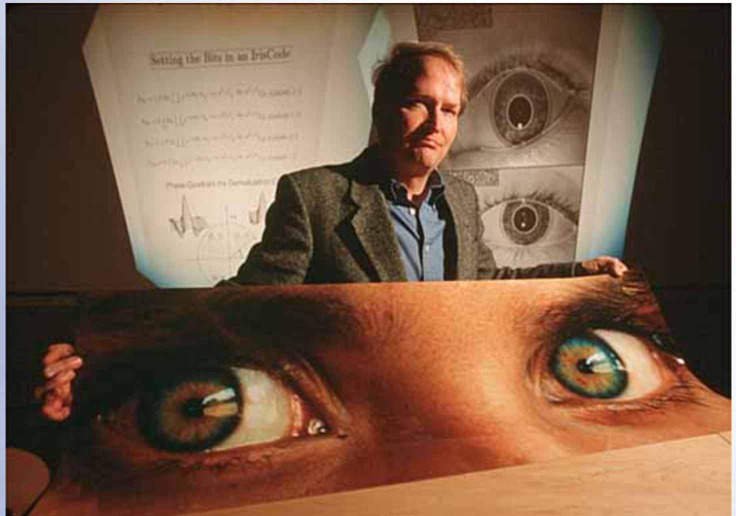
- Highly complex unique texture, which is unchanged over decades of life
- The probability of two identical irises by random chances is approximately 10^{-35}
- An internal organ protected by cornea cannot be surgically modified without damage to vision

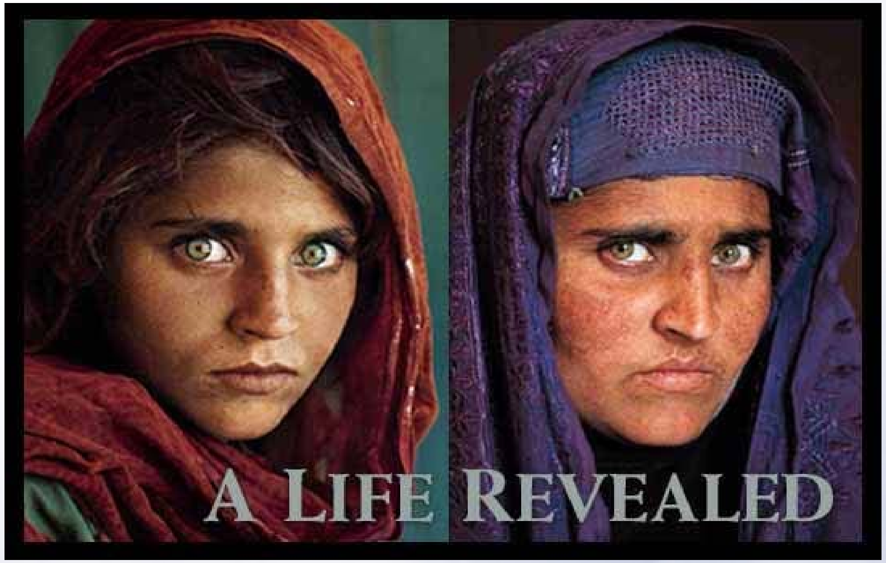
Iris properties

- Iris pattern possesses a high degree of randomness: extremely accurate biometric.
- Genetically independent: even twins have different iris pattern.
- Stable throughout life.
- Highly protected, internal organ of the eye.
- Patterns can be acquired from a distance (1m).

Afghan Woman Identification

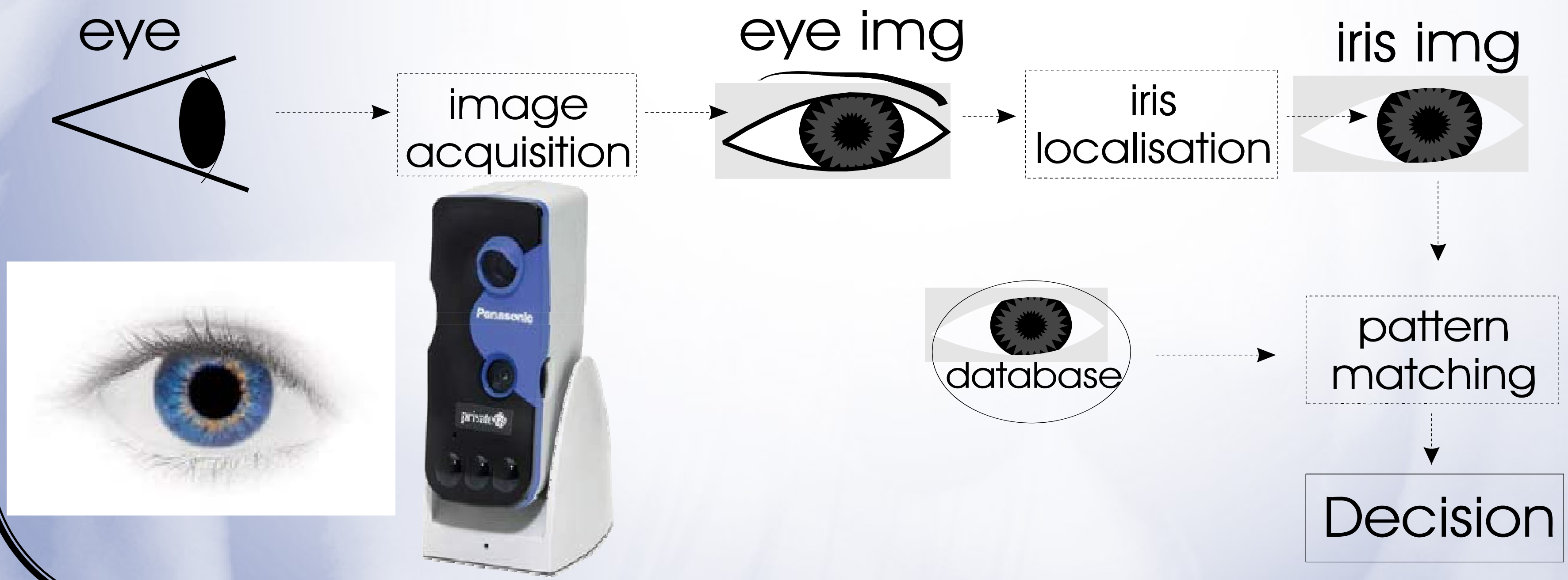
- The best know example involved using iris recognition to confirm the identification of a mysterious young Afghan woman originally photographed by Nation Geographic photographer Steve McCurry in 1984.
- Some 18 years later, McCurry photographed Sharbat Gula in Afghanistan.
- Dr. John Daugman, compares the iris in the photographs using his algorithms, and concluded that the eyes were a match.





How Iris Recognition Works?

- Uses a video image of the iris
- Analyzes the iris patterns
- Creates a 512 byte IrisCode® template to describe the patterns
- Matches the code to all IrisCodes® in a database
- Authenticates or rejects individual



Iris Process Overview

Eye Sensor → Segmentation → Feature Extraction

mera takes a

outer boundaries

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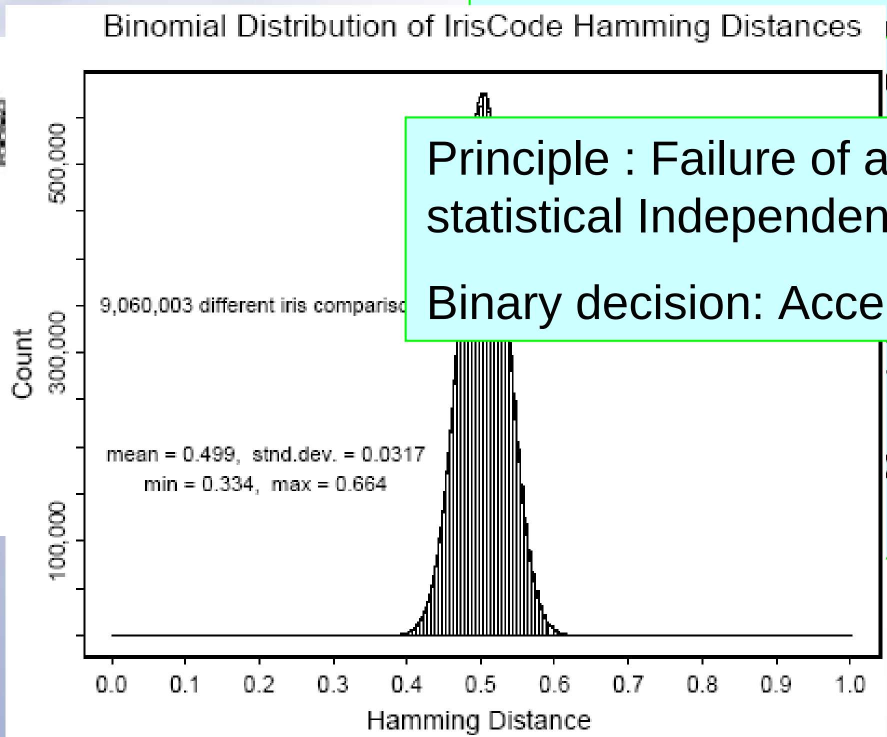
organ
orm,
y, color and general
ce, the iris texture
ochastic or possibly



Principle : Failure of a test of statistical Independence

Binary decision: Accept/ reject

Hits or false alarm (FA); very low standard deviation high probability of FA; high degree of freedom results in low FA

Iris Image Acquisition

Iris

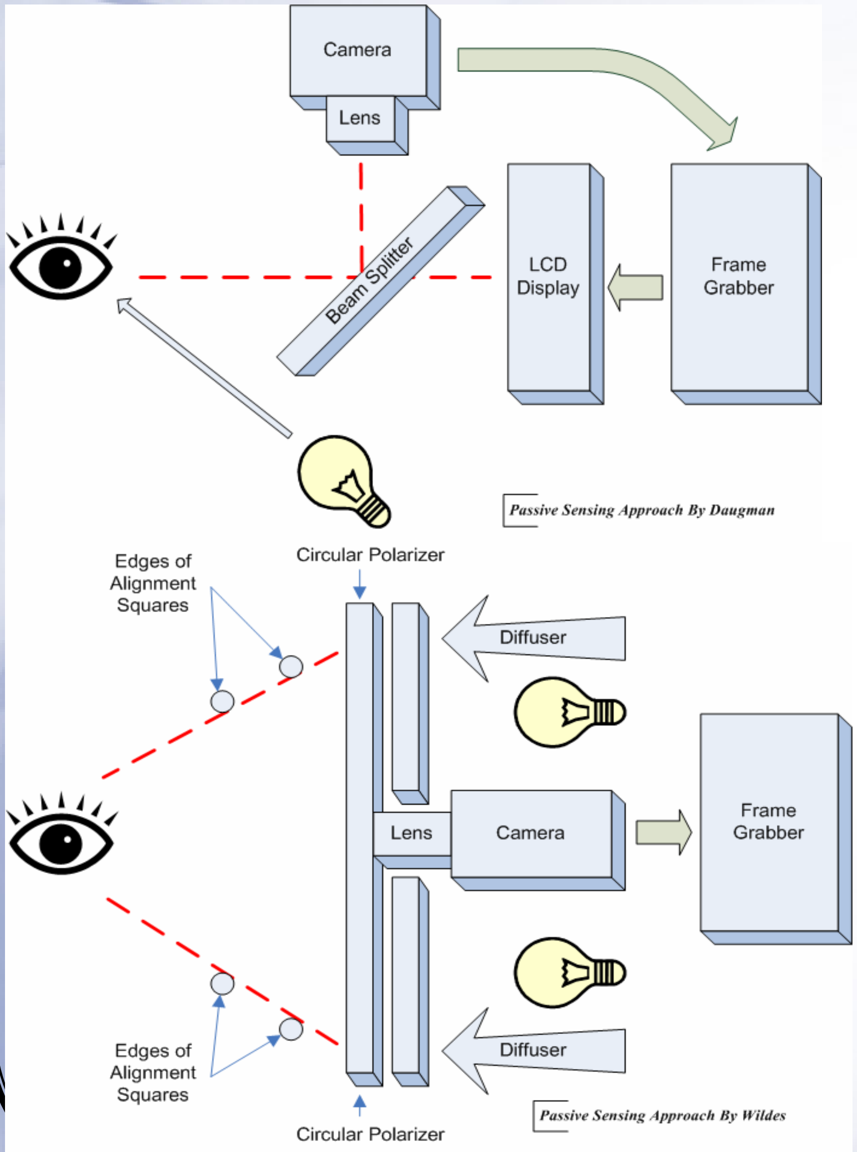
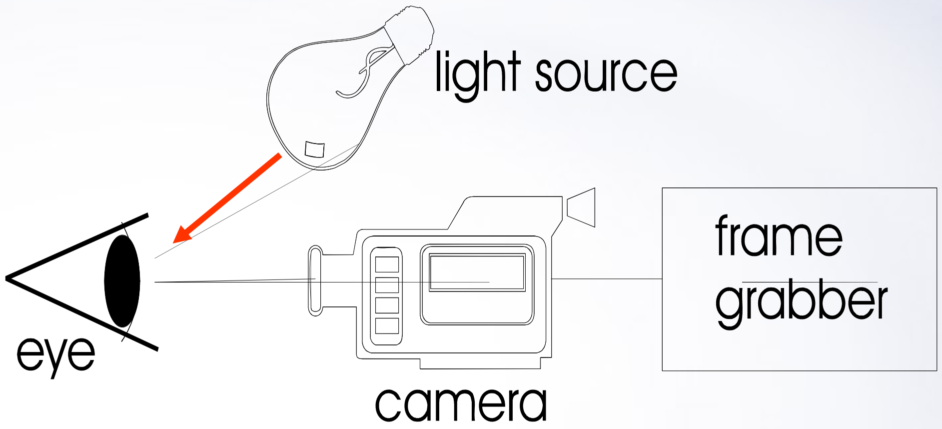
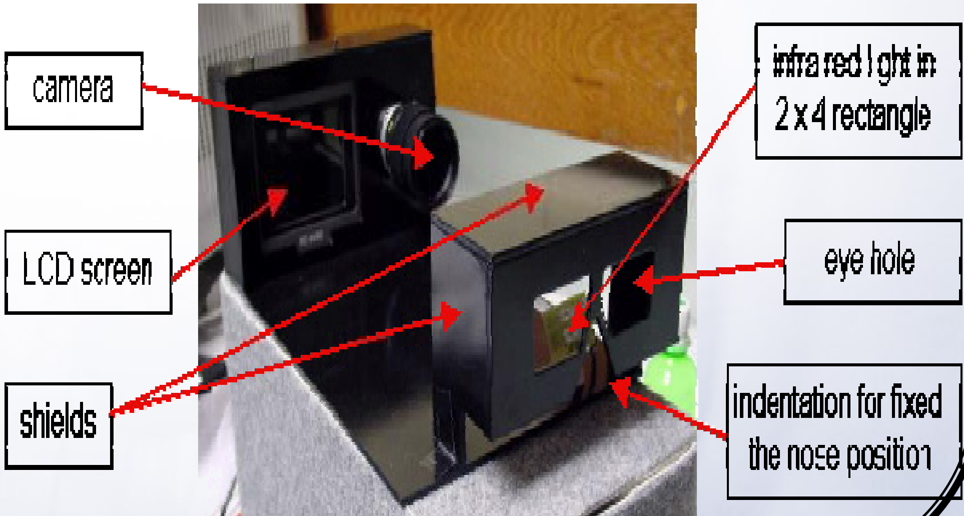


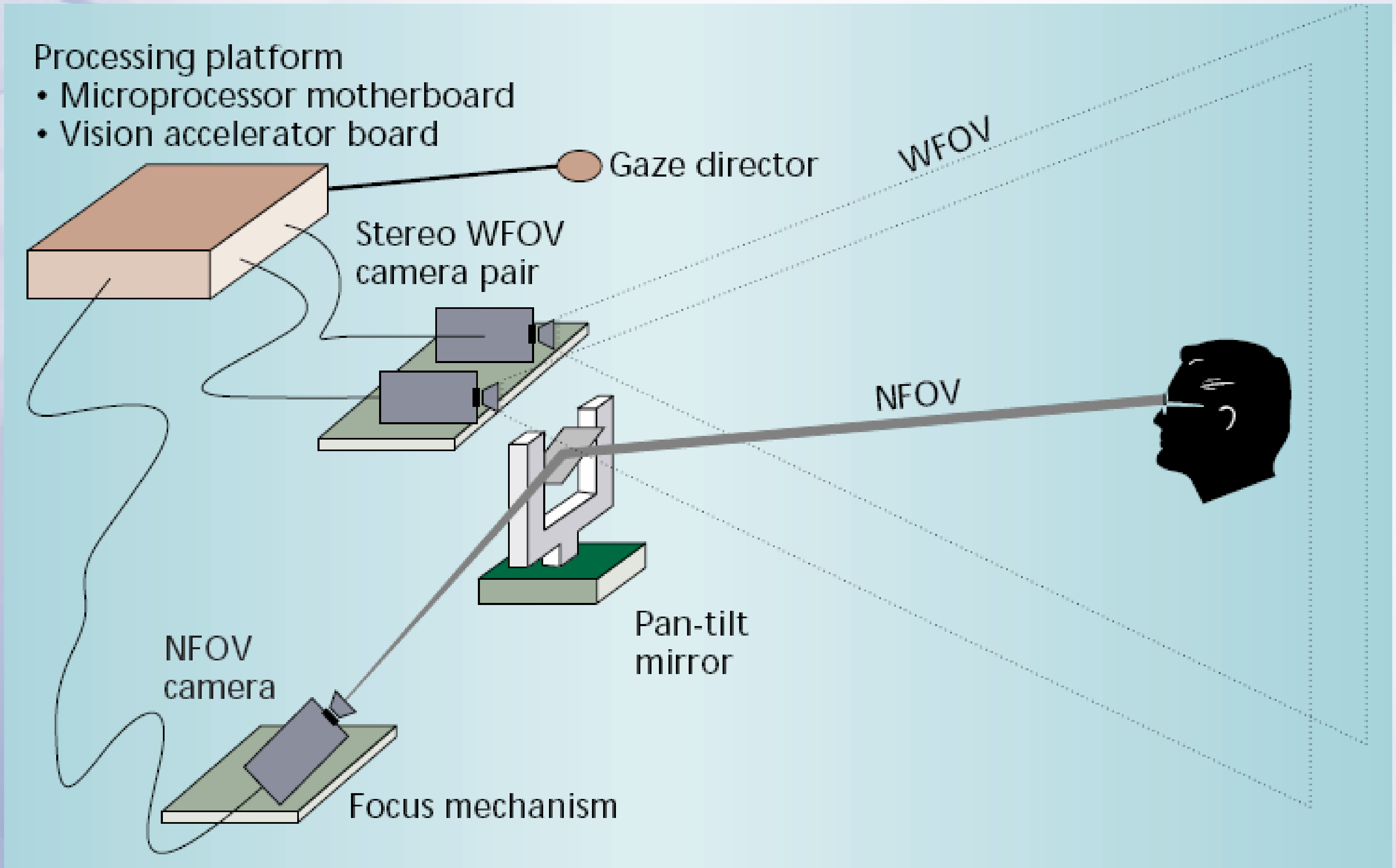
Figure derived from R.Wildes, Iris recognition: an emerging biometric technology. Proceedings of the IEEE, 85(9), 1348-1363, 1997



Sensor: Optical with infrared lights



Multiple-Camera System

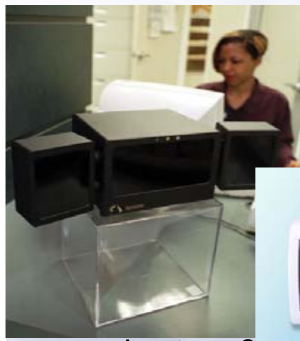
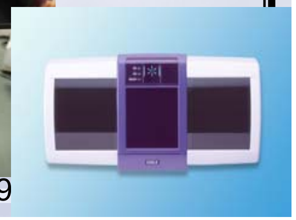


The public use multiple-camera system for correctly positioning and imaging a subject's iris.

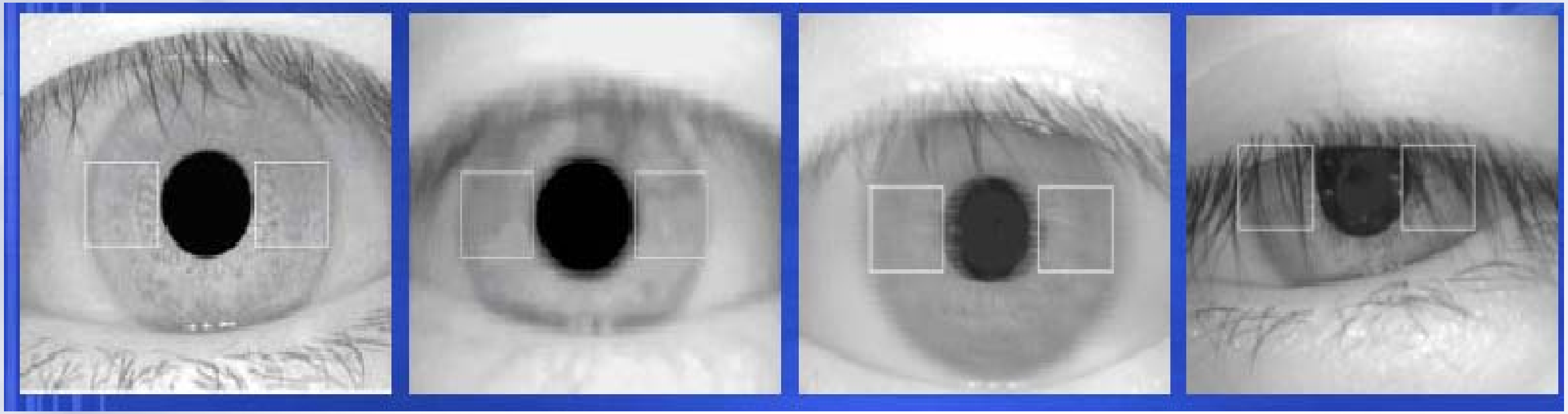
Acquisition Devices Comparison

Acquisition Device	Presentation Method	Acquisition Process	Audio/Visual Feedback
LG IrisAccess 3000 EOU, 3000 ROU	L/R iris presented **separately**	L/R iris acquired in **separate** sequences	**Audio** feedback
OKI IrisPass-WG	L/R iris presented **simultaneously**	L/R iris acquired in **separate** sequences	**Visual** feedback
Panasonic BM-ET300	L/R iris presented **simultaneously**	L/R iris acquired in **same** sequence	**Audio and visual** feedback



Evaluation & Selection of Iris Image

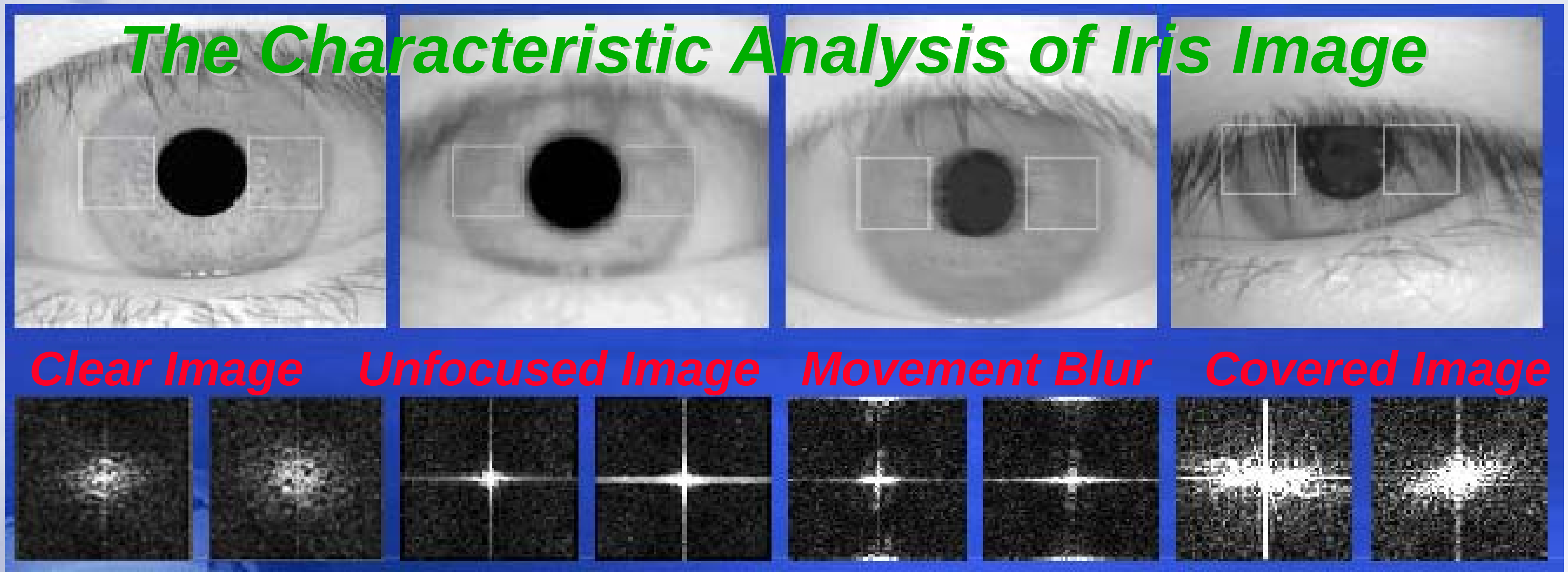


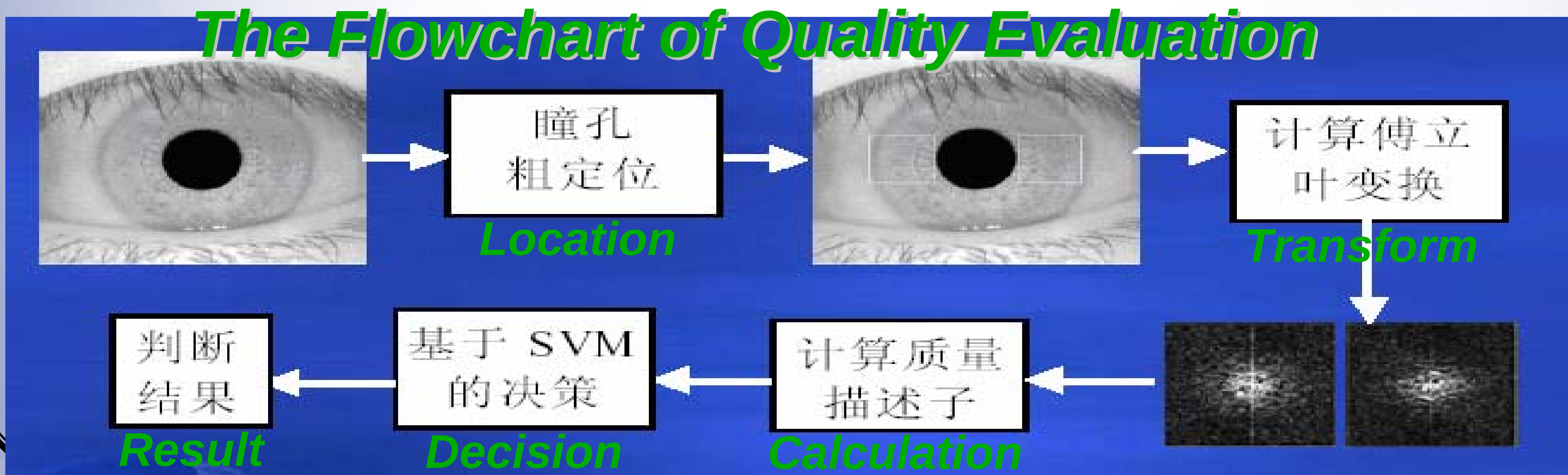
Clear Image *Unfocused Image* *Movement Blur* *Covered Image*

It is necessary to evaluate the quality of iris image.

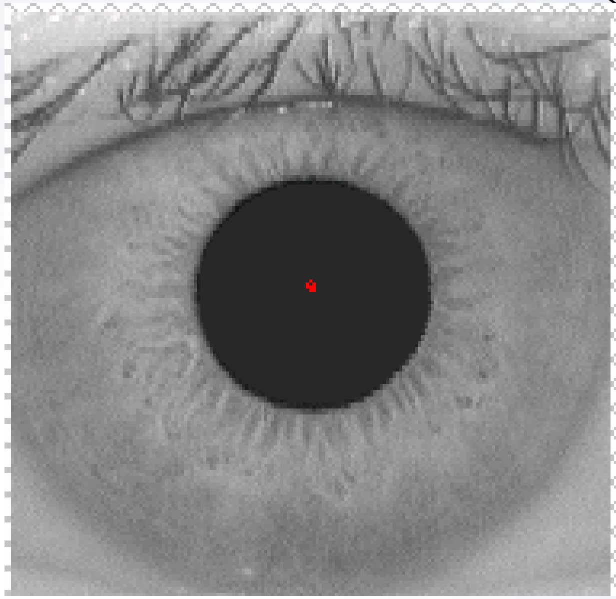
- Daugman: Estimate High Frequency Energy of Fourier Transform of Iris Image
- Zhang: Detect the Degree of Changing between Pupil and Edge of Iris

Evaluation & Selection of Iris Image

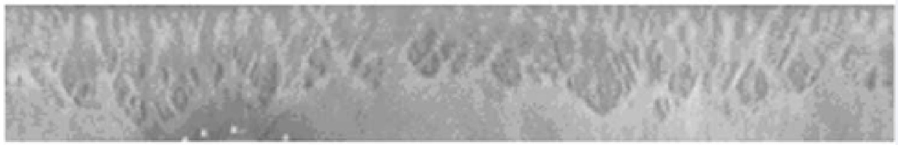




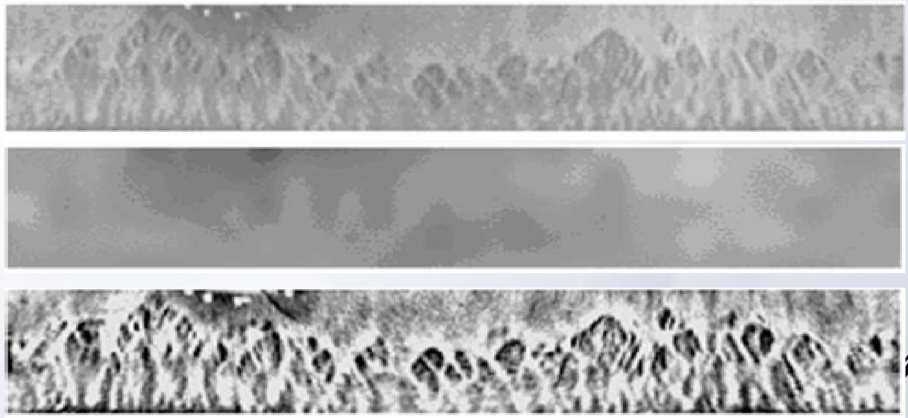
Iris Image Processing



- Localization
  - Find centroid by x and y transforms
  - Binarize the image and estimate the radius of pupil
  - Approximate the radius of iris by some image processing techniques

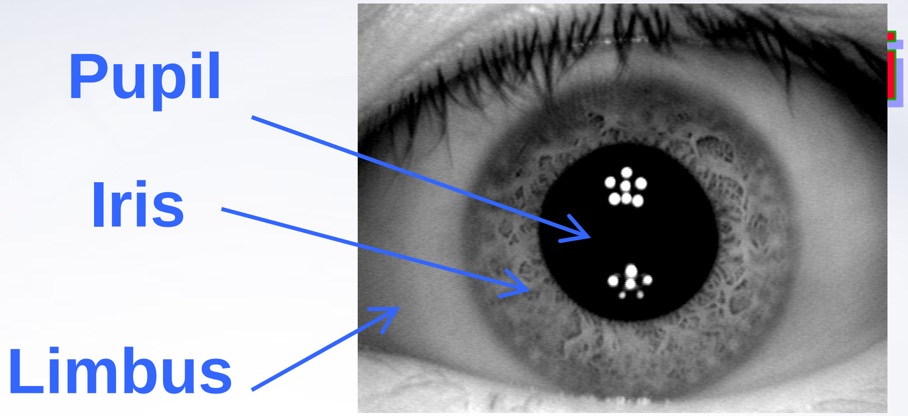


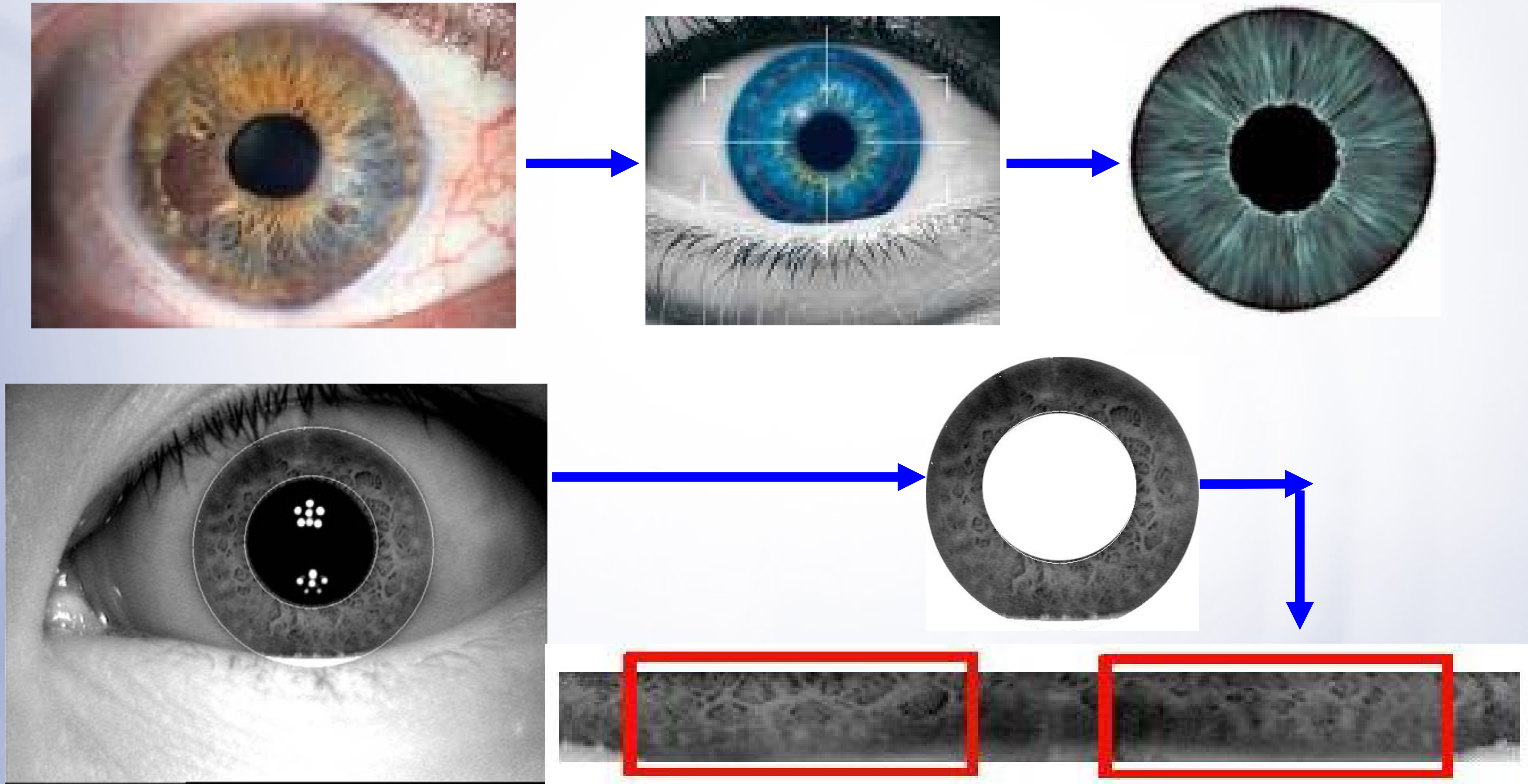
- Normalization
  - Counter -clockwise unwrap the annular iris to a rectangular block with fixed size



- Enhancement
  - Mean of 16 x 16 Block
  - Bicubic Interpolation
  - Subtract from original image

Result of Image Processing



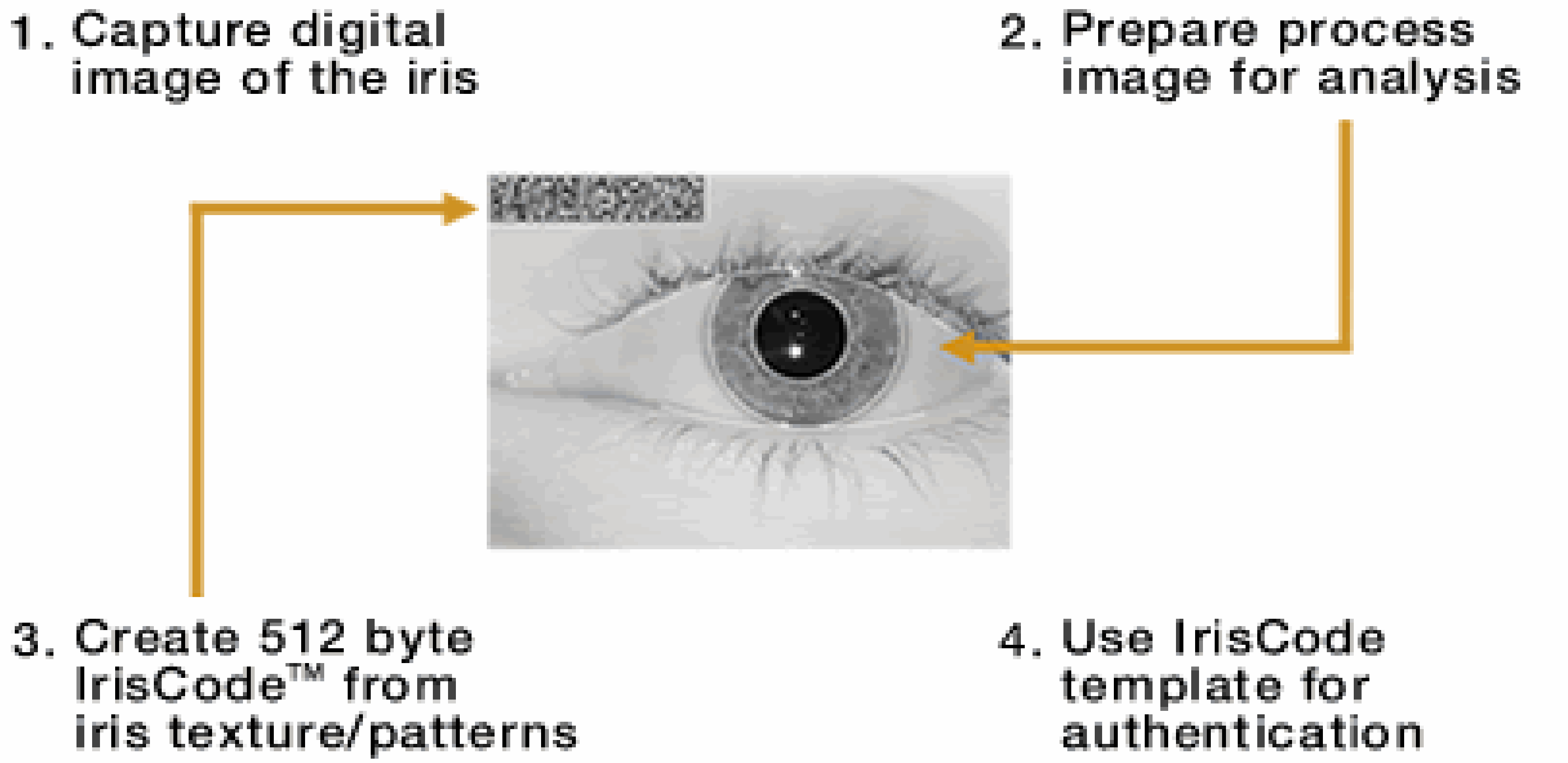


Finding the Iris in the Image

- Find the circular boundaries of the iris

Masking

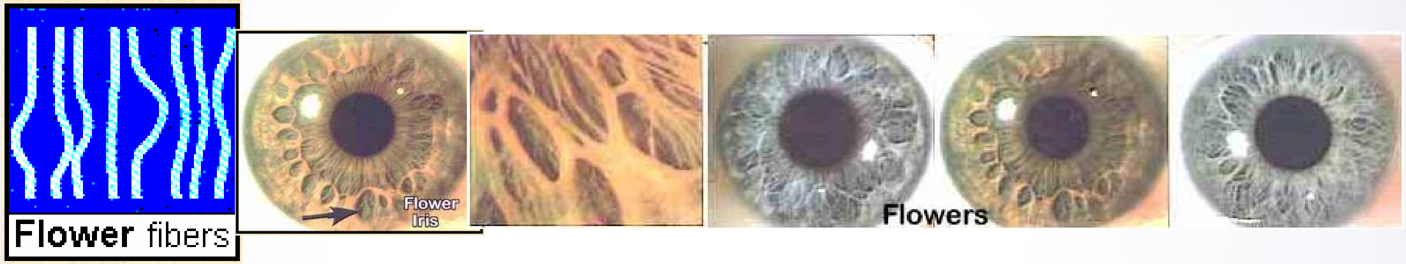
- Find the boundaries of the eyelids;
- Detect eyelashes and reflections;
- Mask these areas out.



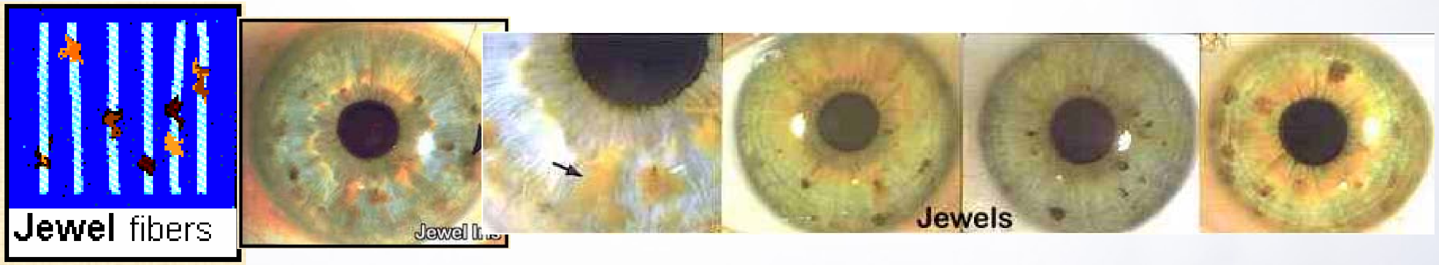
Iris Structures

Stream Iris Structure

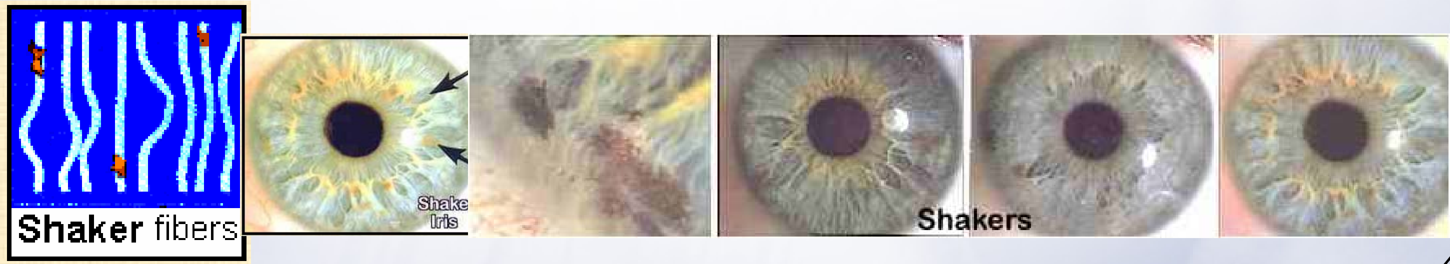
Flower Iris Structure



Jewe Iris Structure

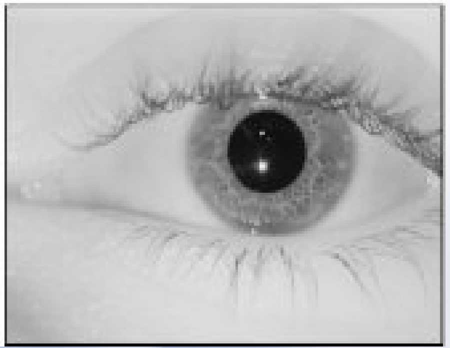


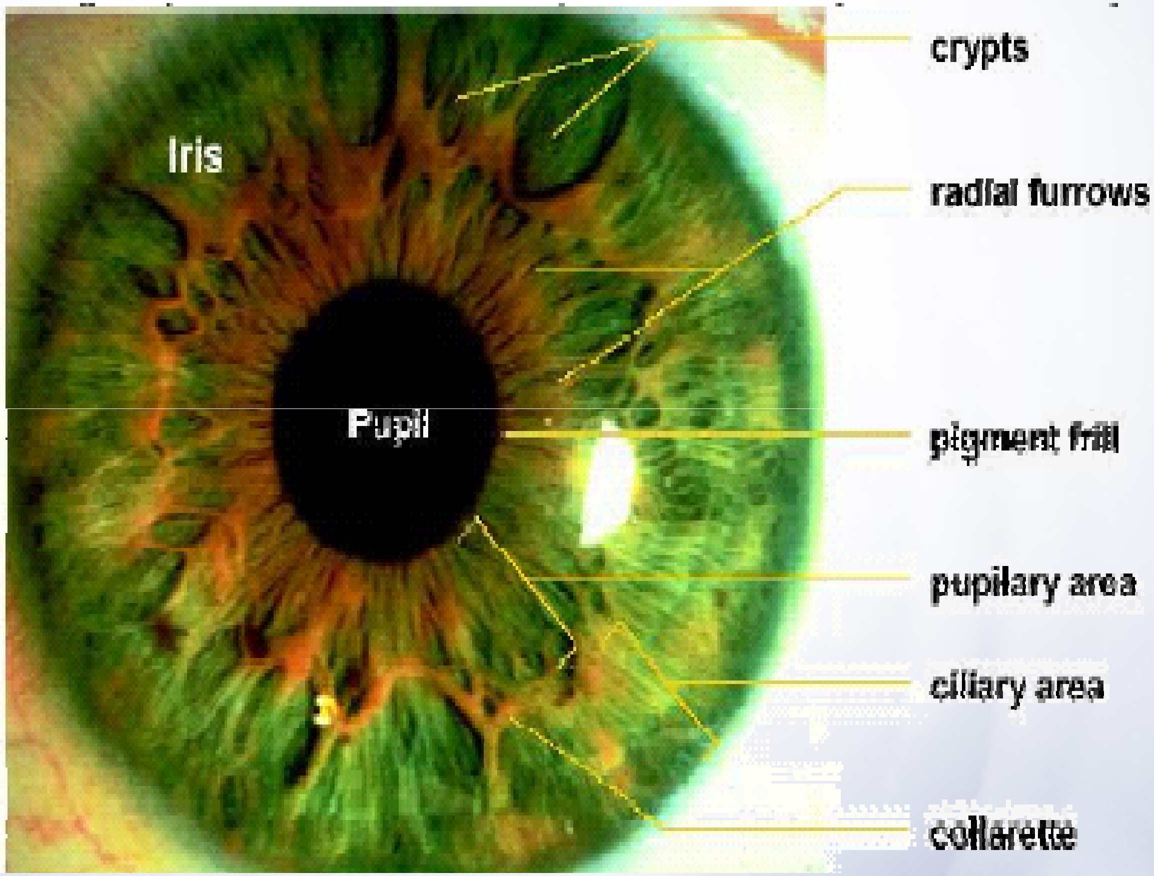
Shaker Iris Structure



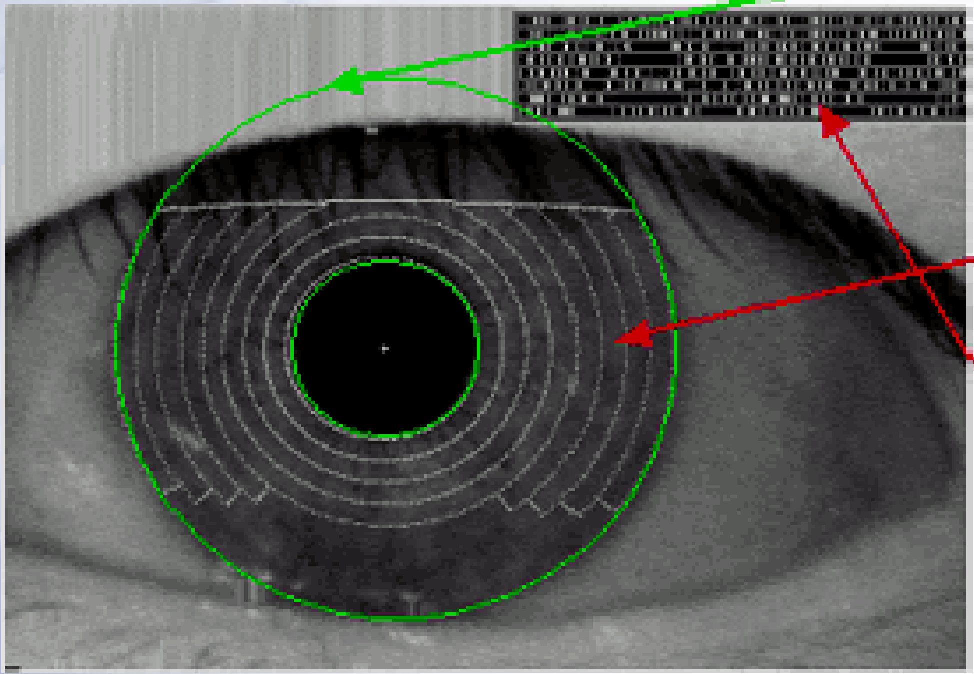
Iris Feature

- A primary characteristic is the trabecula meshwork, a tissue that gives the appearance of dividing the iris in a radial fashion.
- Other visible characteristics include rings, furrows, freckles, and the corona.





Overview: Daugman's Approach



1. search for the boundary of iris
2. divide into 8 sectors without regards of iris and pupil size
3. create 512 Byte Iriscode
4. compare to IrisCode in DB

- J. Daugman, "High confidence visual recognition of persons by a test of statistical independence", *IEEE Transactions on Pattern Analysis and Machine Intelligence,* vol. 15, no. 11, pp. 1148-1161, 1993.
- J. Daugman, "Biometric personal identification system based on iris analysis," U.S. Patent No 5,291,560, 1994.

Gabor Wavelets

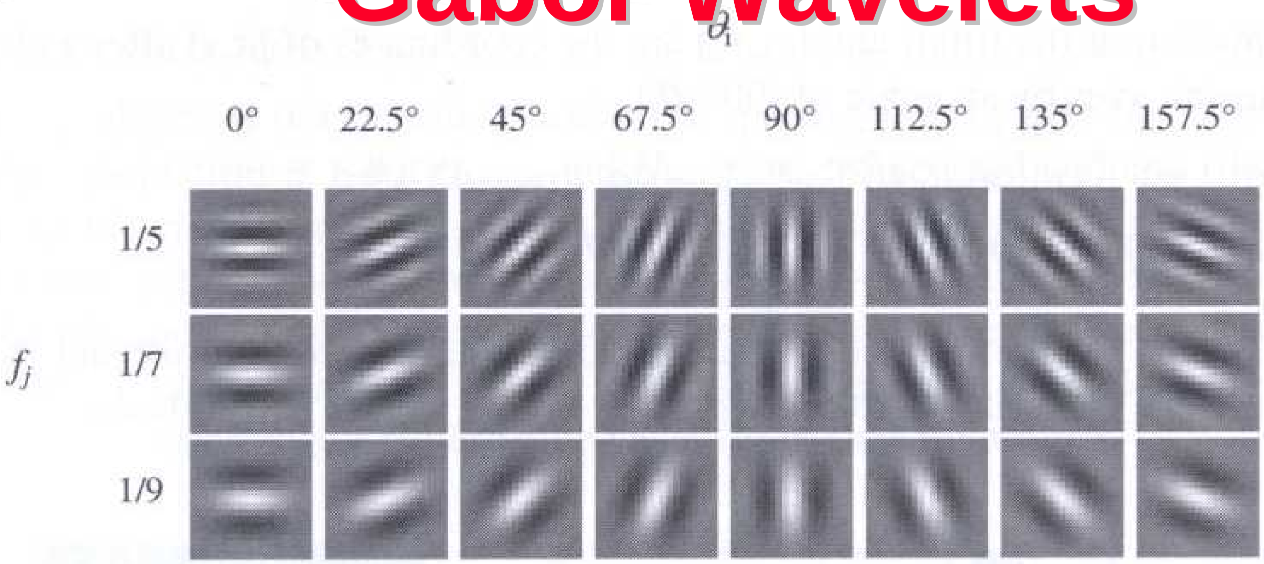


Figure 3.29. A graphical representation of a bank of 24 ($n_o = 8$ and $n_f = 3$) Gabor filters where $\sigma_x = \sigma_y = 4$.

- Gabor Wavelets filter out structures at different scales and orientations
- For each scale and orientation there is a pair of odd and even wavelets
- A scalar product is carried out between the wavelet and the image (just as in the Discrete Fourier Transform)
- The result is a complex number

Phase Demodulation

- The complex number is converted to 2 bits
- The modulus is thrown away because it is sensitive to illumination intensity
- The phase is converted to 2 bits depending on which quadrant it is in

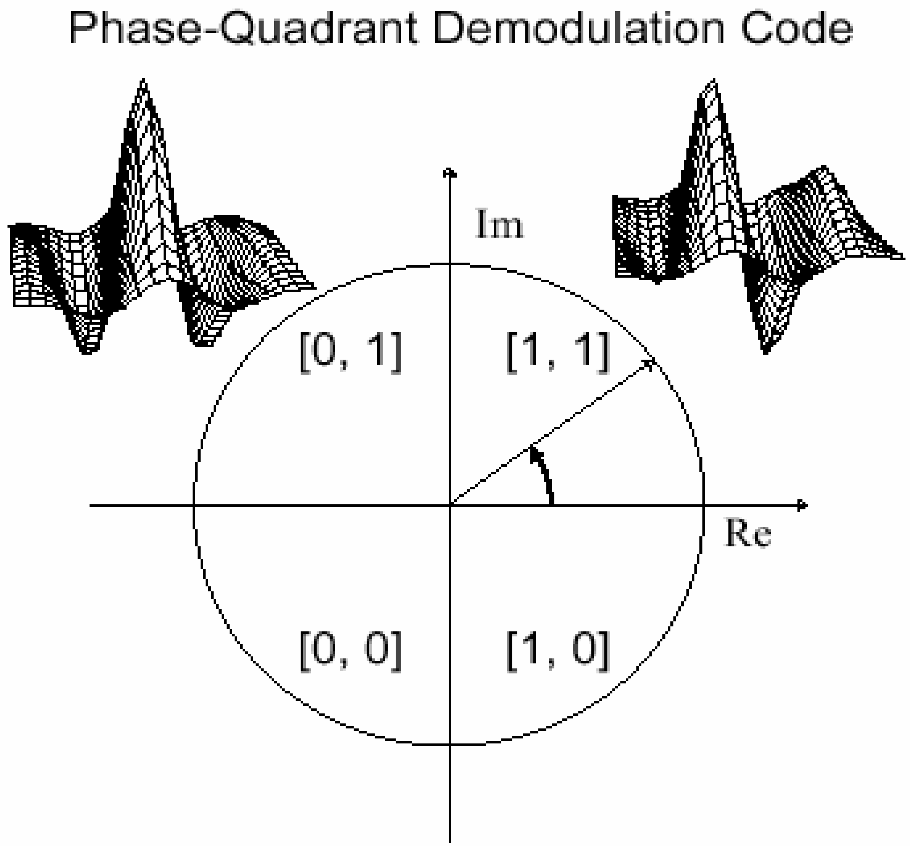
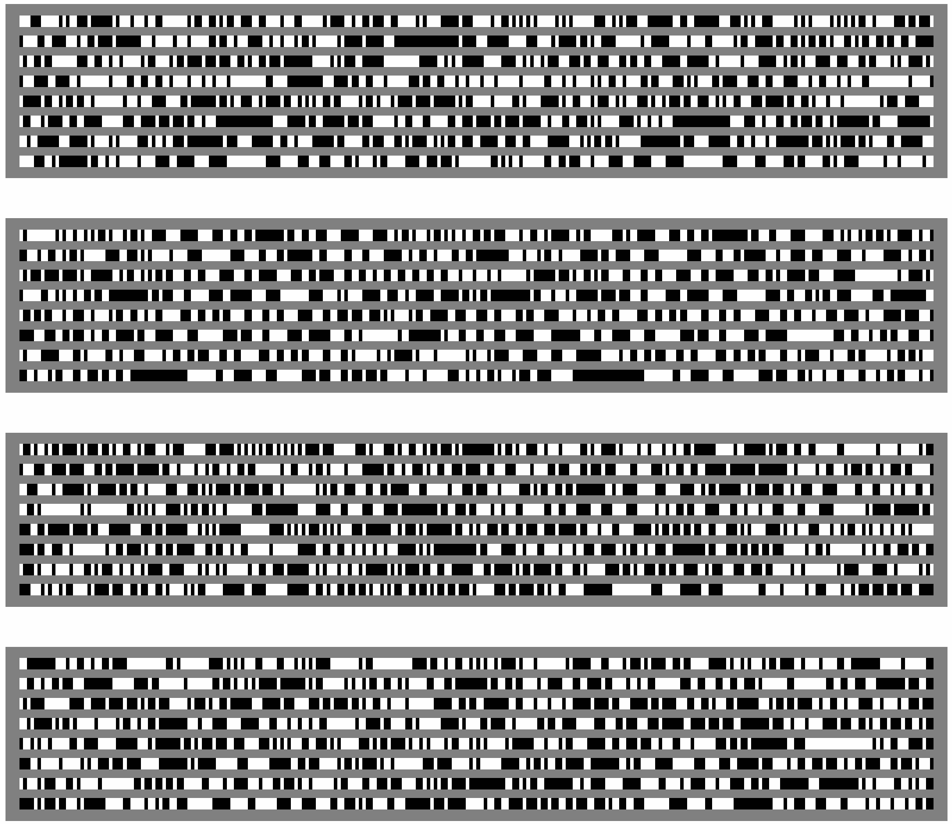


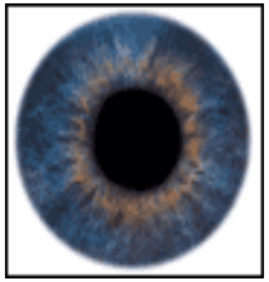
Figure 2: The phase demodulation process used to encode iris patterns. Local regions of an iris are projected (Eqt 2) onto quadrature 2D Gabor wavelets, generating complex-valued coefficients whose real and imaginary parts specify the coordinates of a phasor in the complex plane. The angle of each phasor is quantized to one of the four quadrants, setting two bits of phase information. This process is repeated all across the iris with many wavelet sizes, frequencies, and orientations, to extract 2,048 bits.

IrisCodes

- This process is carried out at a number of points throughout the image.
- The result is 2,048 bits which describe each iris uniquely
- Two codes from different irises can be compared by finding the number of bits different between them – this is called the Hamming distance
- This is equivalent to computing an XOR between the two codes. This can be done very quickly
- To allow for rotation of the iris images the codes can be shifted with respect to each other and the minimum Hamming distance found

Pictorial Examples of four IrisCodes

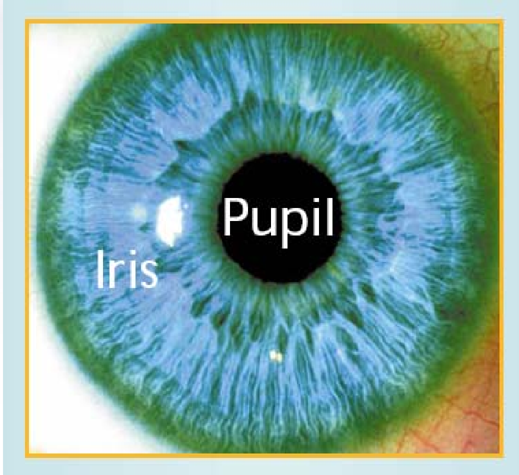




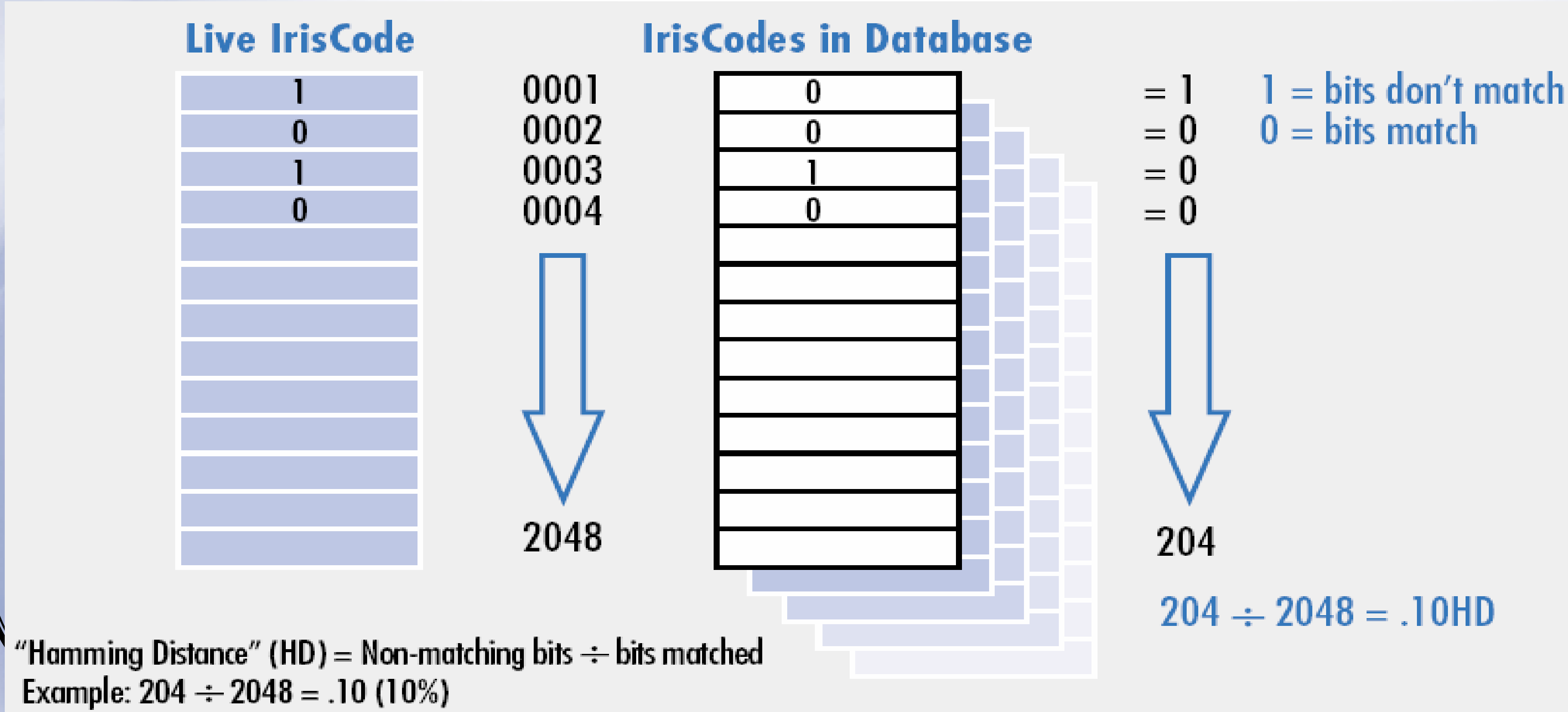
010010101110101011101010101101001000010
100101011010101011010101001010111101010
001010101000100100000010101011101011110
101010110100110101010101110111010100101
110101010111101010101110101010101010101
011010110101101111011110101001000010110

Hamming Distance

$$\mathrm{HD} = \frac{\|(codeA \otimes codeB) \cap maskA \cap maskB\|}{\|maskA \cap maskB\|}.$$



$$\mathrm{HD} = \frac{\text{No. of bits different}}{\text{Total no. of bits}}$$



Binomial Distribution

- If two codes come from different irises the different bits will be random
- The number of different bits will obey a binomial distribution with mean 0.5

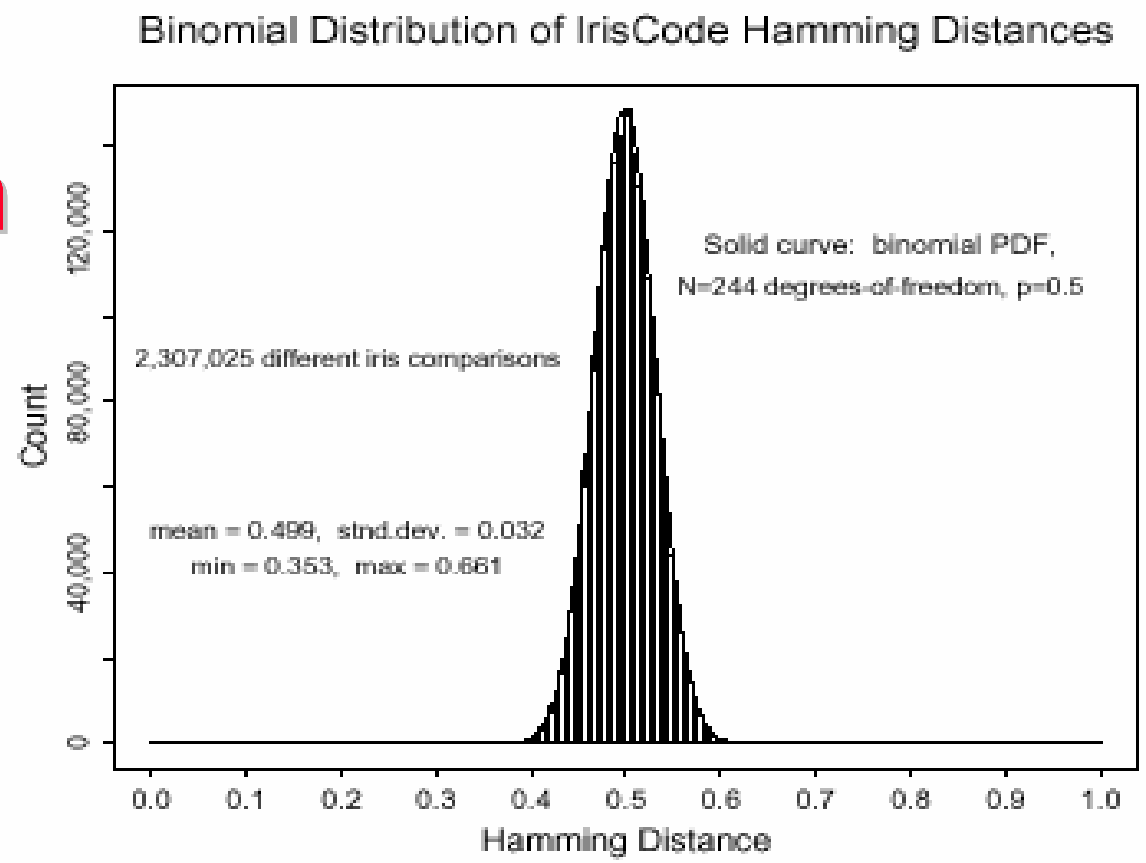
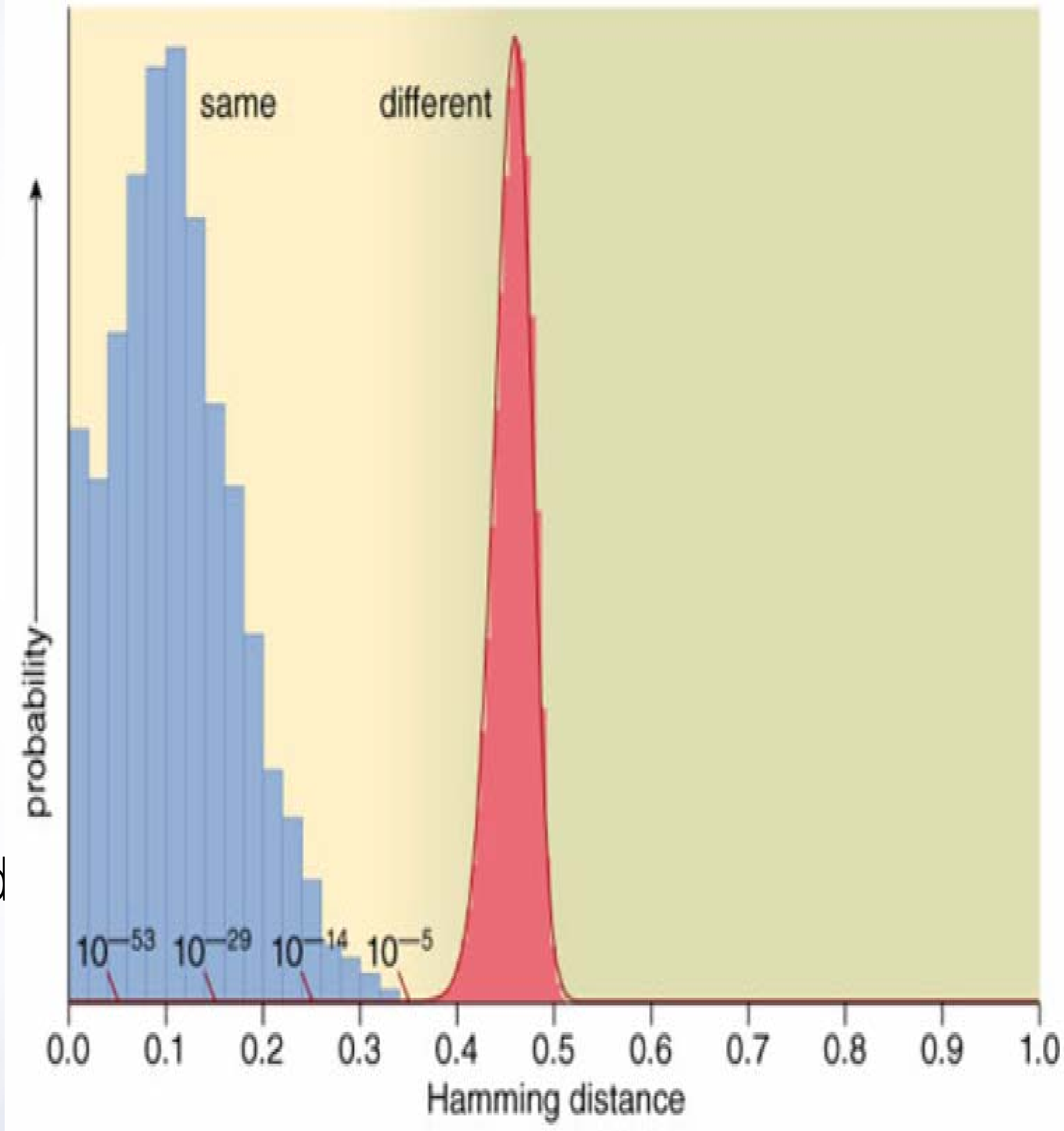


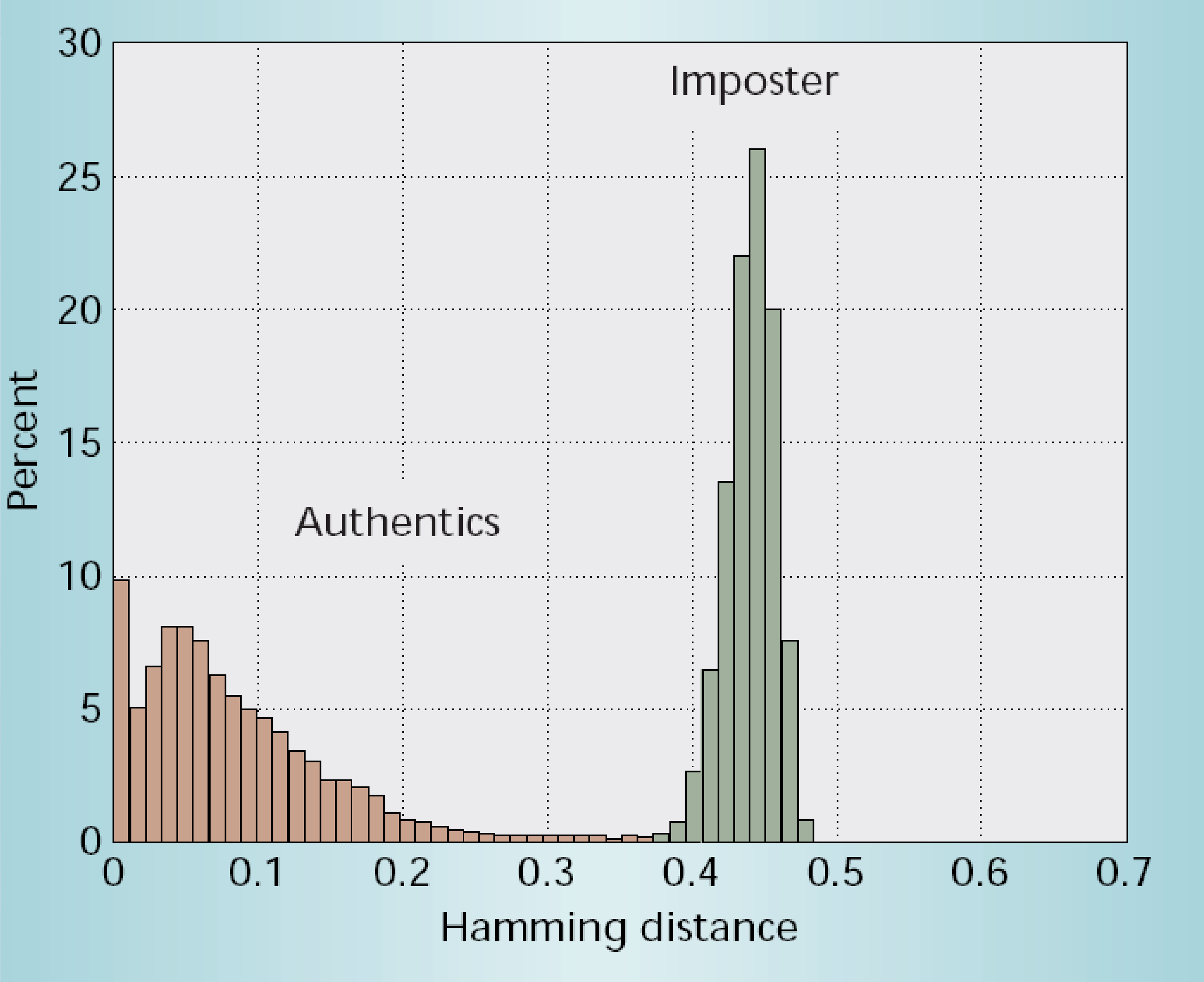
Figure 4: Distribution of Hamming Distances from all 2.3 million possible comparisons between different pairs of irises in the database. The histogram forms a perfect binomial distribution with $p = 0.5$ and $N = 244$ degrees-of-freedom, as shown by the solid curve (Eqt 4). The data implies that it is extremely improbable for two different irises to disagree in less than about a third of their phase information.

Identification

- If two codes come from the same iris the differences will no longer be random
- The Hamming distance will be less than expected than if the differences were random
- If the Hamming distance is < 0.33 the chances of the two codes coming from different irises is 1 in 2.9 million
- So far it has been tried out on 2.3 million people without a single error



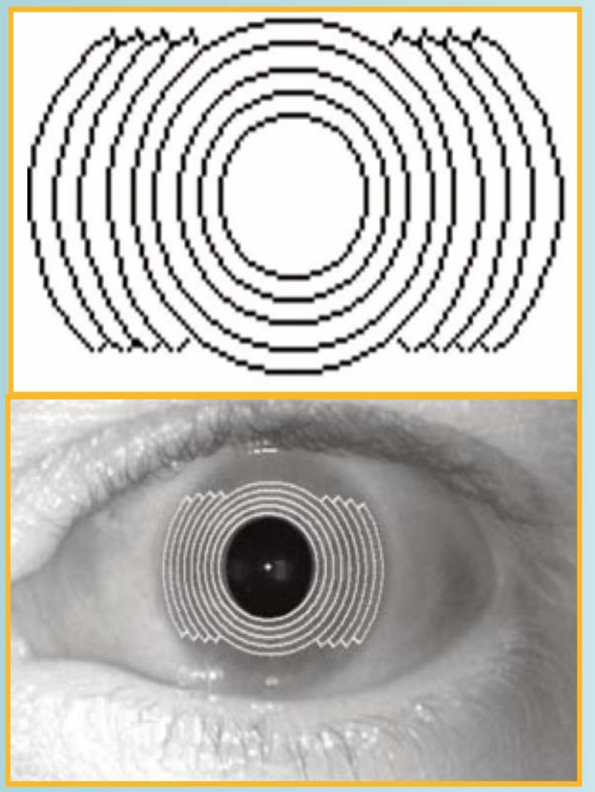
Verification Distributions



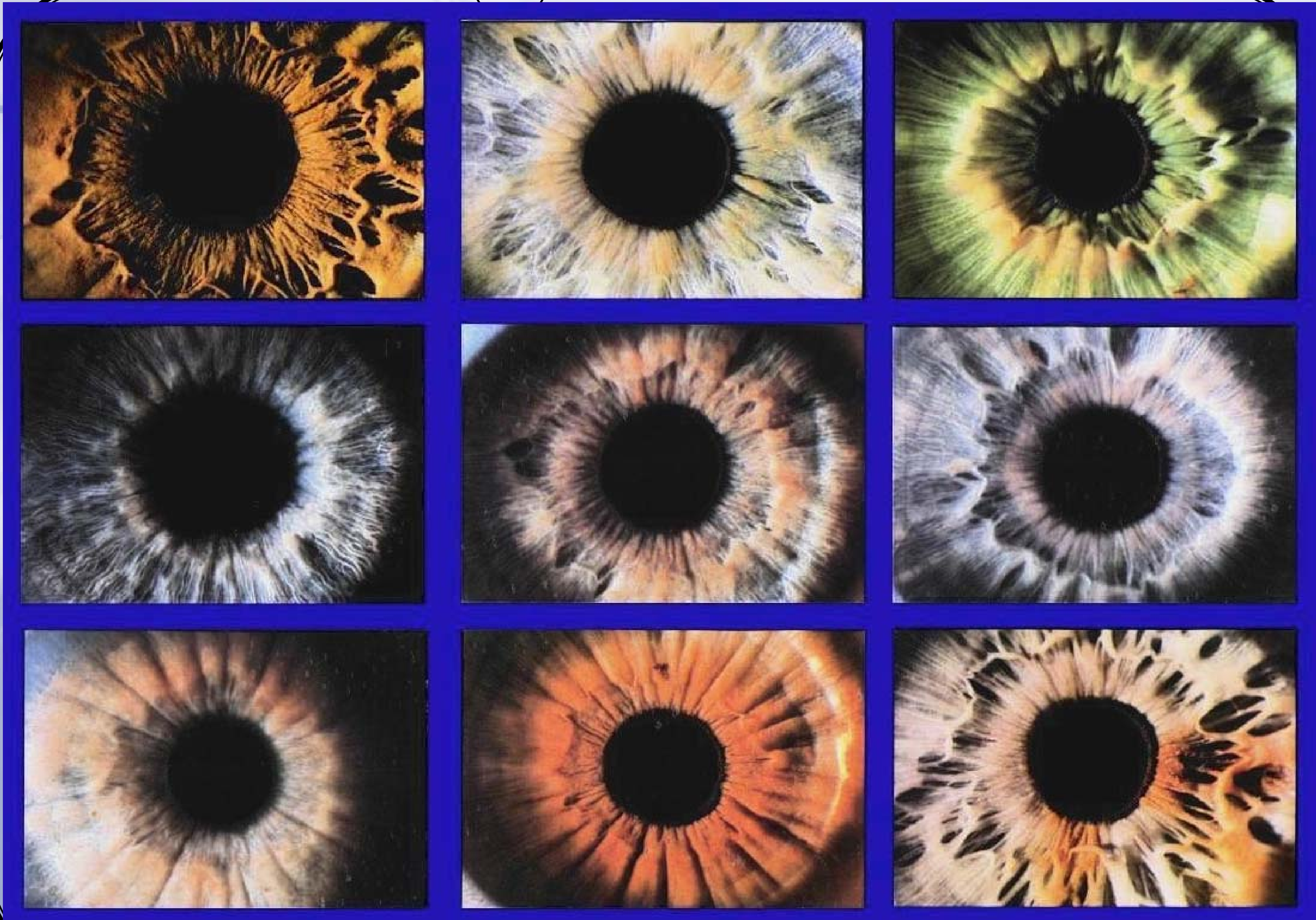
Iris Recognition Procedures

1. A user stands one to three feet from the system, which contains three standard video cameras.
2. Two wide-angle cameras image the user's torso. Using technology developed specifically for this application, the system determines the position of the eyes.
3. A third camera focuses on an eye and captures a single black-and white digital image. Successful identification can be made through eyeglasses and contact lenses, and at night. If needed, the picture is rotated to compensate for a tilted head.

Iris Recognition Procedures



4. The system uses a circular grid as a guide to encode the pattern in the iris.
5. The grid is overlaid on the eye’s image. The system looks at the patterns of light and dark iris areas and their distribution inside the grid, then generates a 512-byte human bar code for that person. The system will perform properly even if eyelashes or the eyelid obscure part of the grid.
6. The system checks the bar code against the version stored in a computer data-base. The entire process, from first picture to verification, takes about 2s.



Irises with highly complex and unique texture

Evaluation

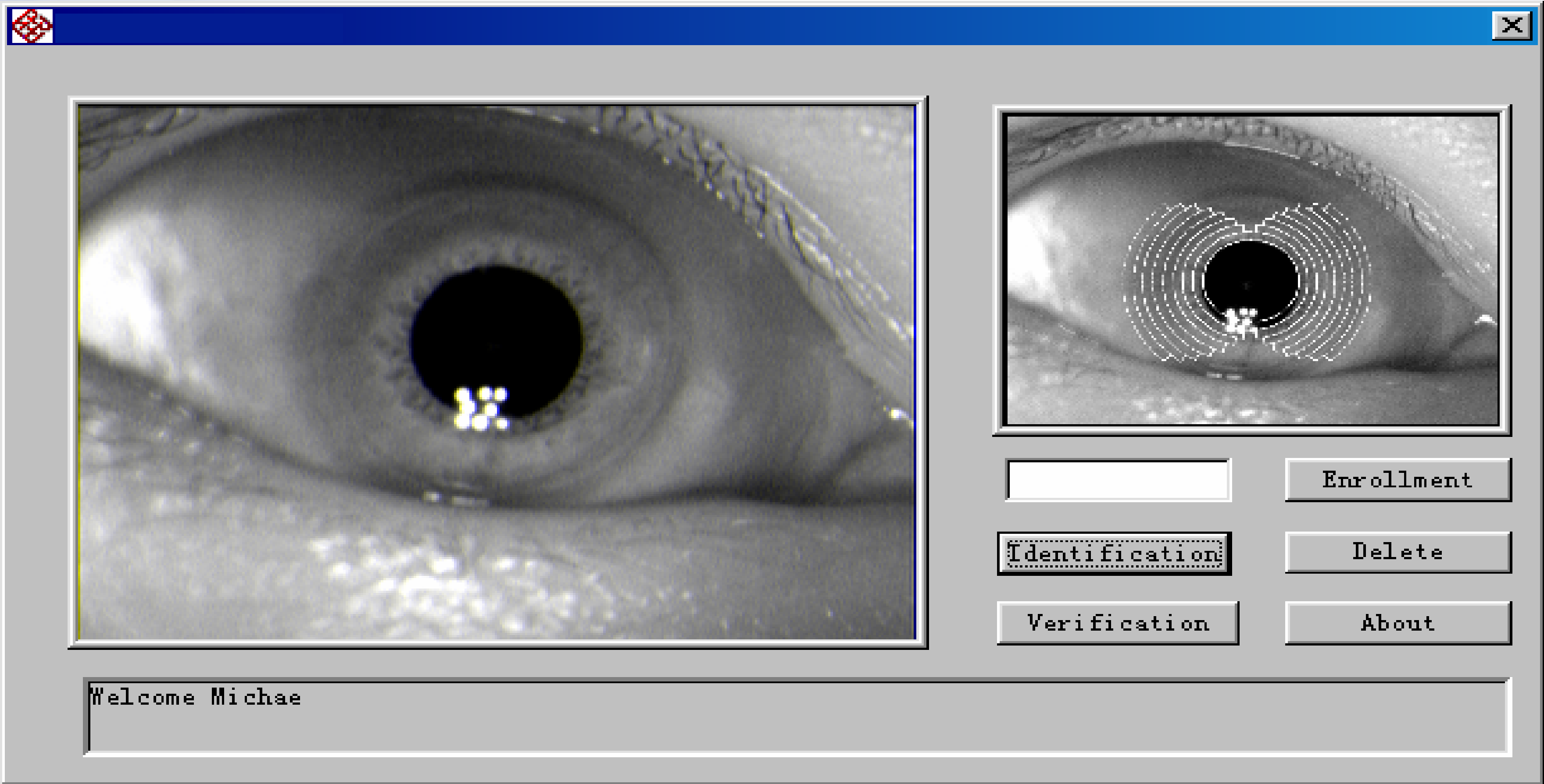
- The uniqueness of eyes, even between the left and right eye of the same person, makes iris scanning very powerful for identification purposes.
- The likelihood of a false positive is extremely low and its relative speed and ease of use make it a great potential biometric.
- The only drawbacks are the potential difficulty in getting someone to hold their head in the right spot for the scan if they are not doing the scan willingly.
- It also takes up a bit more memory for the data to be stored, but with the advances in technology, this is unlikely to cause any major difficulty.

Performance

- Statistical analysis of iris code comparisons shows the iris to be **a discriminating biometric**, with a lower limit error rate for false rejects and false accepts, equally, of approximately one in 1.2 million.
- This extremely low error rate makes the iris ideal for large database identification applications.
- When the threshold set to 0.32, there is no false accept.
- In practice, the false-reject rate for a single try is approximately 0.5 % for all users, with and without eyeglasses.

Our Demo Program

Testing database size	238 images from 48 persons
Identification accuracy	1.5% equal error rate
Speed	2 seconds
Features used	Texture feature only

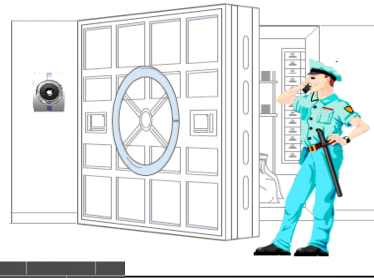


(BRC)

Applications

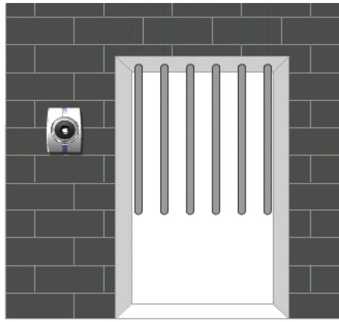
Intelligence bureau

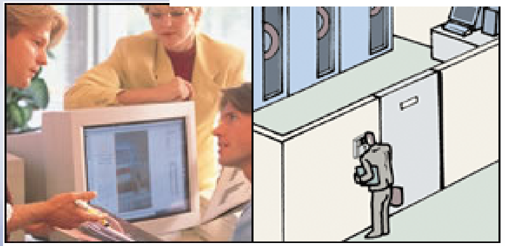
Bank



Military base

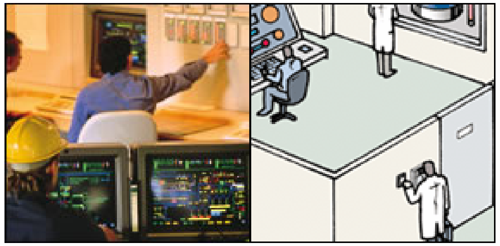
Penitentiary





Offices

Data Center, Material storage, safes, executive offices, secure meeting rooms

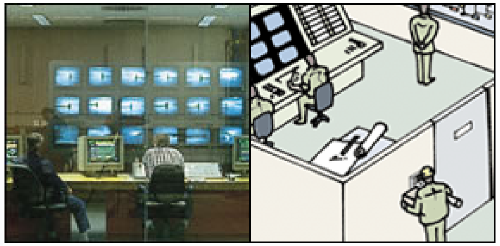


Lifeline facilities

Power generator rooms, dam management offices, gas company control rooms

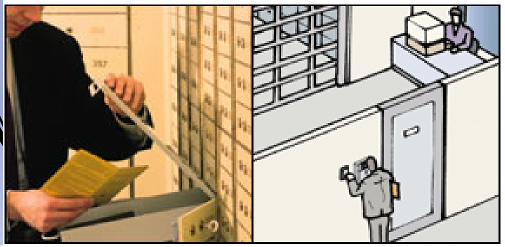
Laboratories and factories

Drug or dangerous materials storage rooms, night or holiday entry control



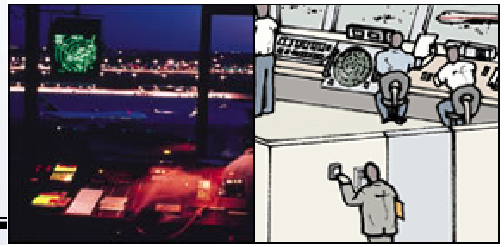
Traffic control centers

Expressway administration centers, railroad dispatcher rooms



Financial institutions

Safes, safety deposit box rooms

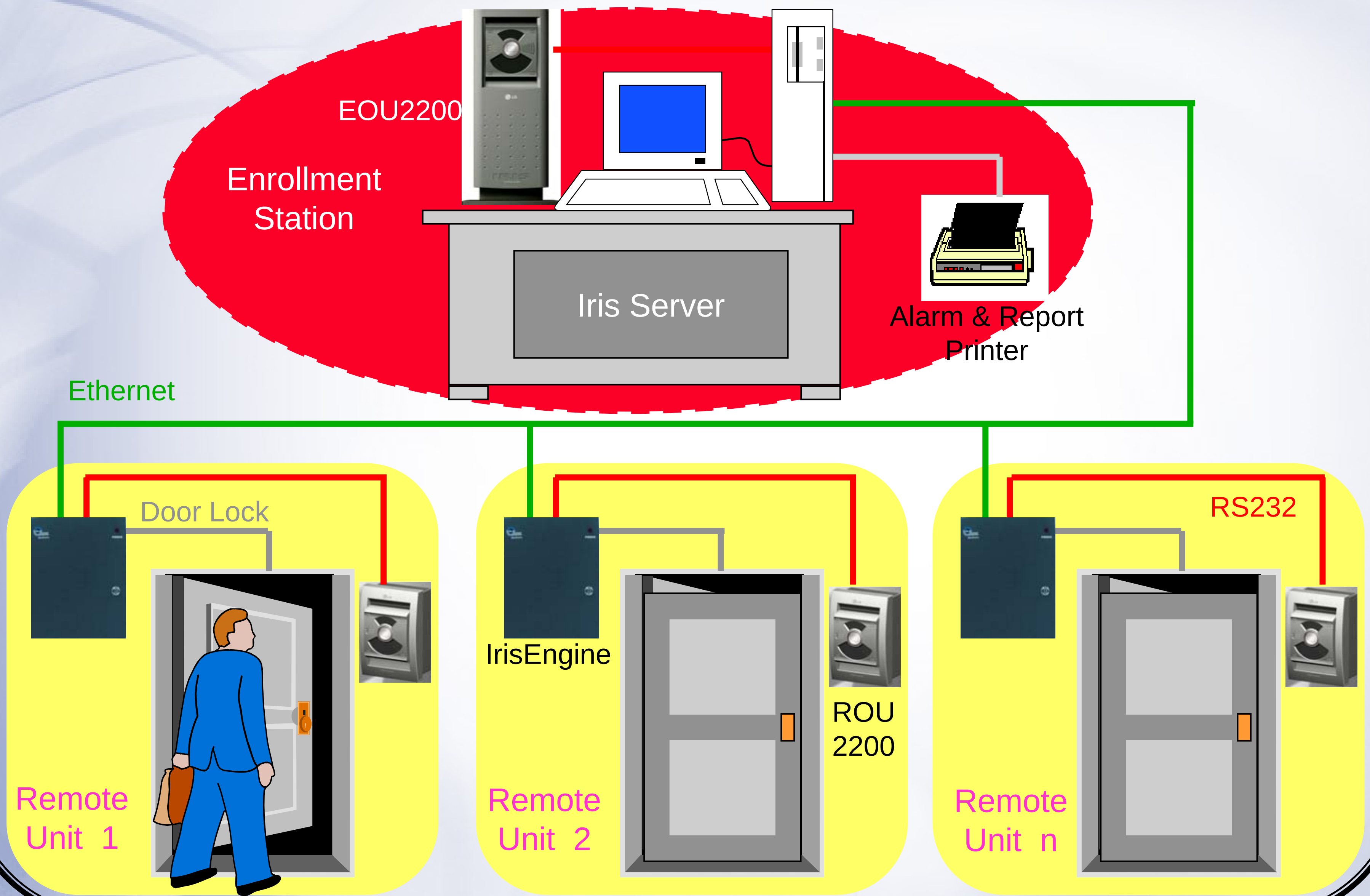


Airport and harbor facilities

Staff gates, Immigration, workshops

Various Iris-Scan Applications

Sample: LG IrisAccess™2200



Iris Scan in Real Life

Passenger Authentication at Airports - Traveler using iris scan security system

Iris

- **Airport security; border crossings**
  - New York -JFK, Washington-Dulles (EyeTicket JetStream™)
- **Physical Access point; building security**
  - Iris recognition cameras by Panasonic
  - Nuclear power stations (Union electric / Calloway Nuclear)
  - 60,000 Prisoners in US state Penitentiaries (FL, NY, PA, NH)
  - Vice President Cheney's office
- **Data Security; computer and network access**
  - Iridian (PrivateID™, KnoWho™)
  - Panasonic (Authenticam™ , Eye-Passport™)
  - Computer Associates (e-Trust™ , e-True™)

A Demo

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Iris Summary

Strengths

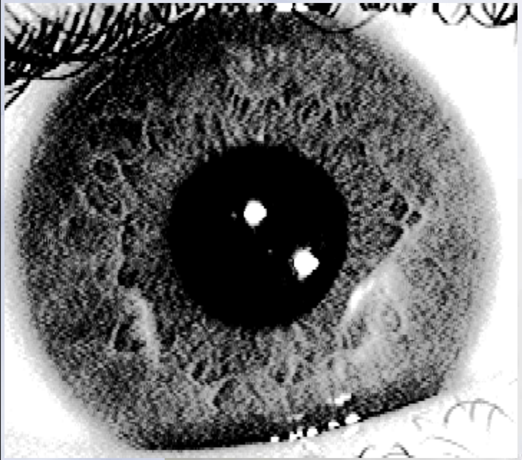
- Very high levels of accuracy
- Each iris is a unique structure
- Capable of reliable identification as well as verification

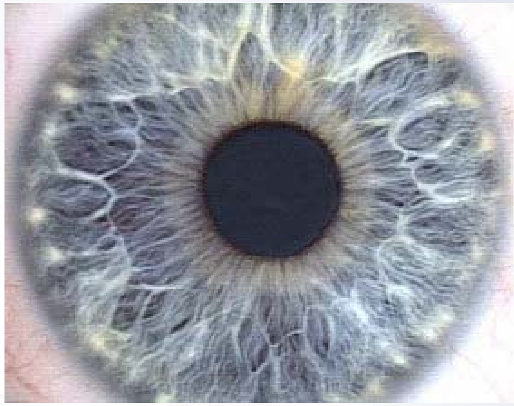
Weaknesses

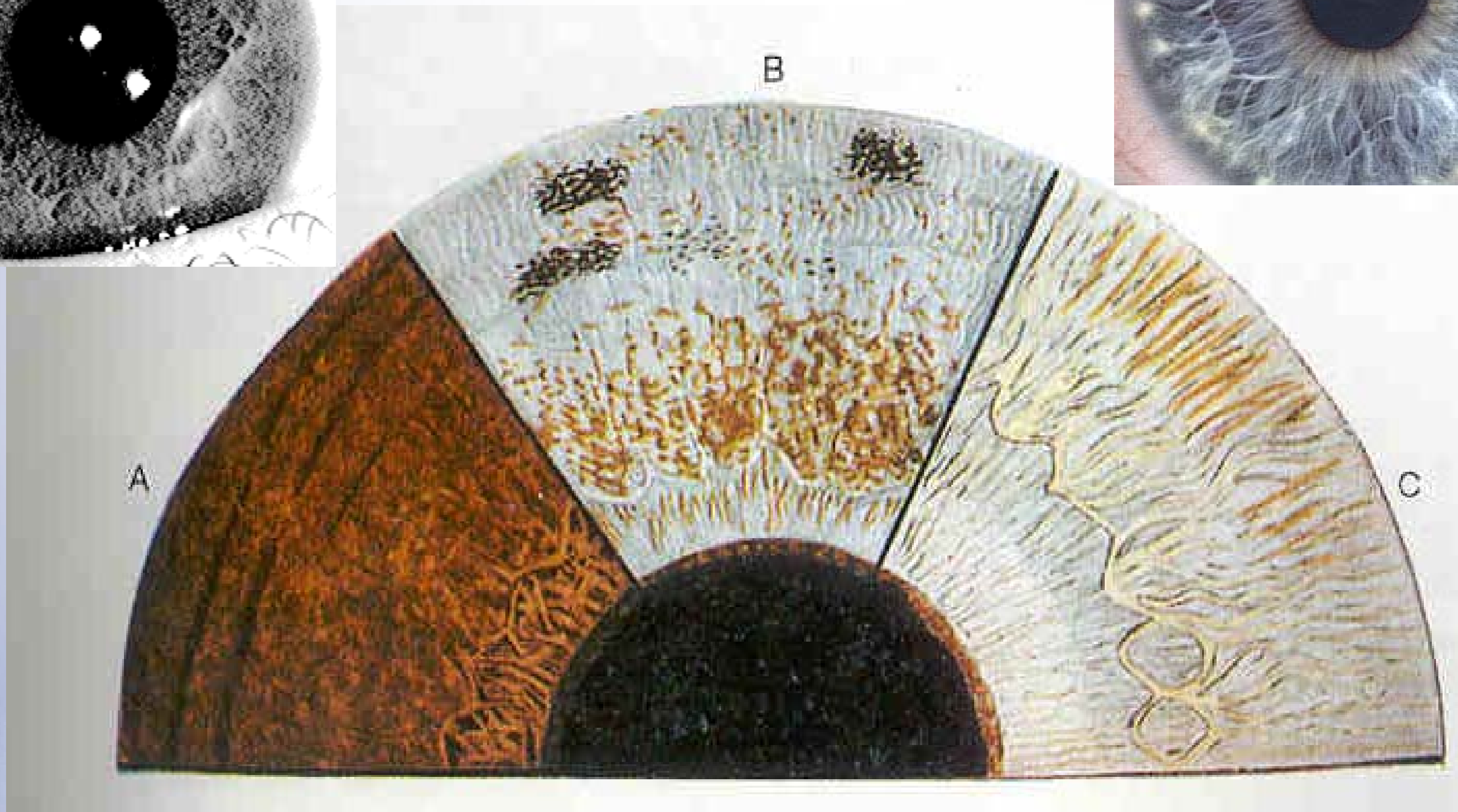
- Potentially low contrast pattern in dark irises. Also, some users don't accept eye-based technology
- High cost capture devices or inconvenient devices
- Not easy to use since light sensitivity of humans
- Accuracy decreases when users wear eyeglass, Obscured by eyelashes, lenses/reflections
- Any unusual lighting situations may affect the ability of the camera to acquire its subject.

-- Recently, IBG (International Biometric Group) tests iris on one-many mode. Only 130 users, iris recognition has false matching. It means that their claims of prefect matching may not be reliable. See "*False match blow for iris scan vendor", Biometric Technology, pp. 1-2, Nov/Dec, 2002*

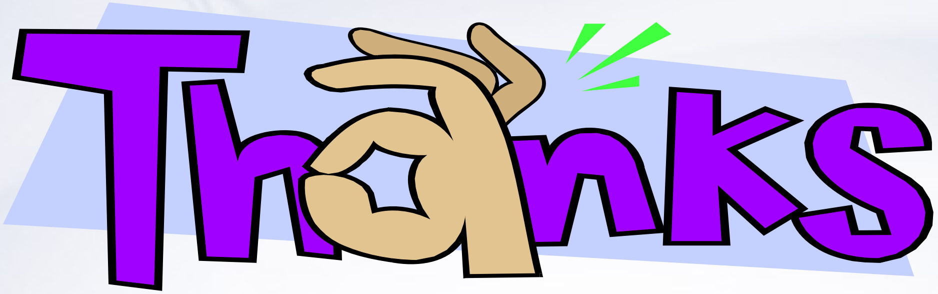
Iris: Different Regions







A: Eastern (B) and (C): Western



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