

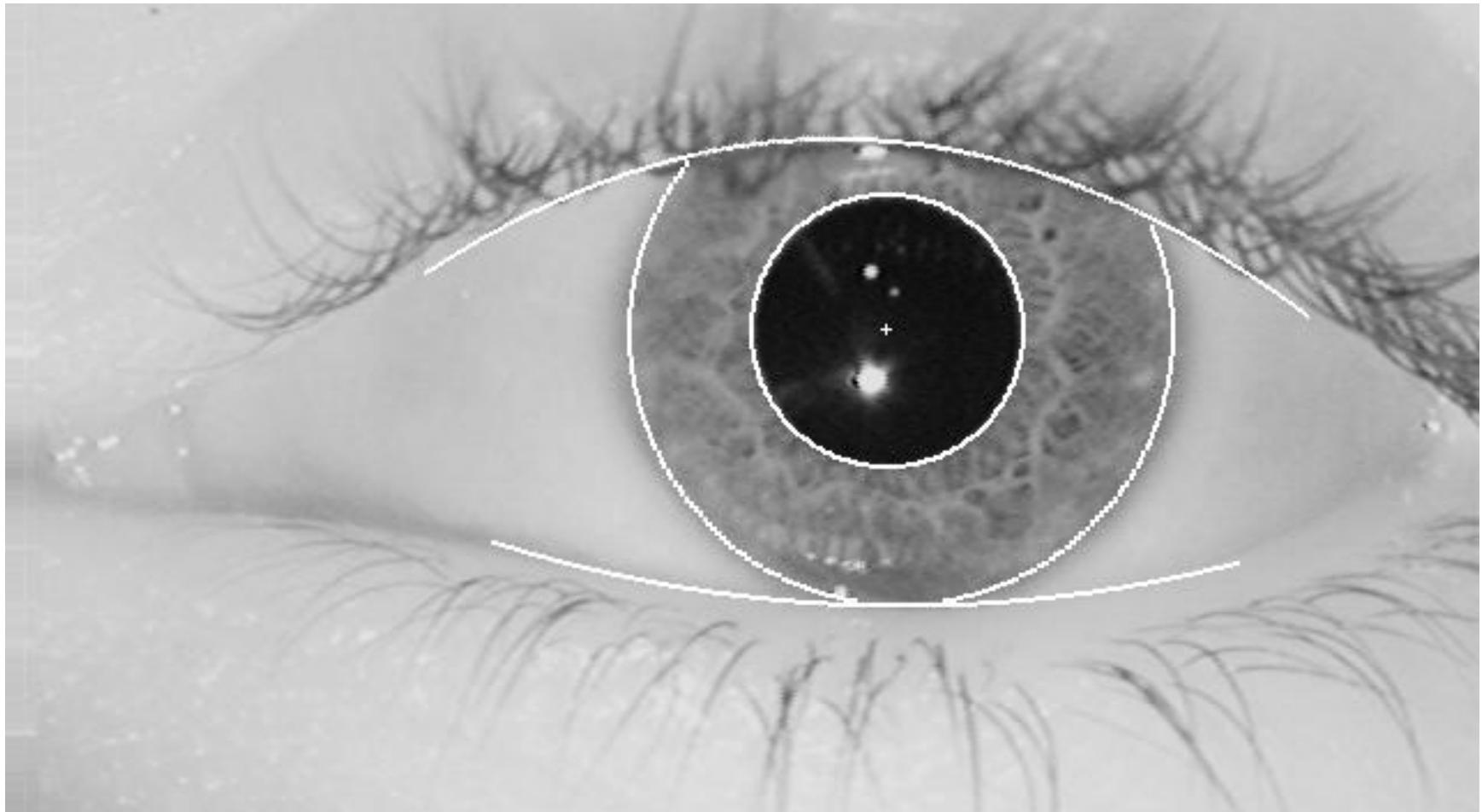
Patterns  
and  
Pattern Recognition

# Examples

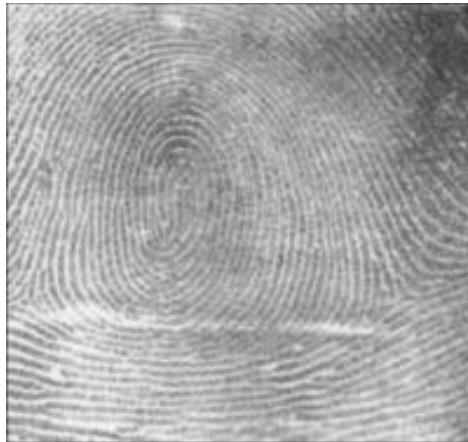
# Product recognition / identification



# Iris authentication



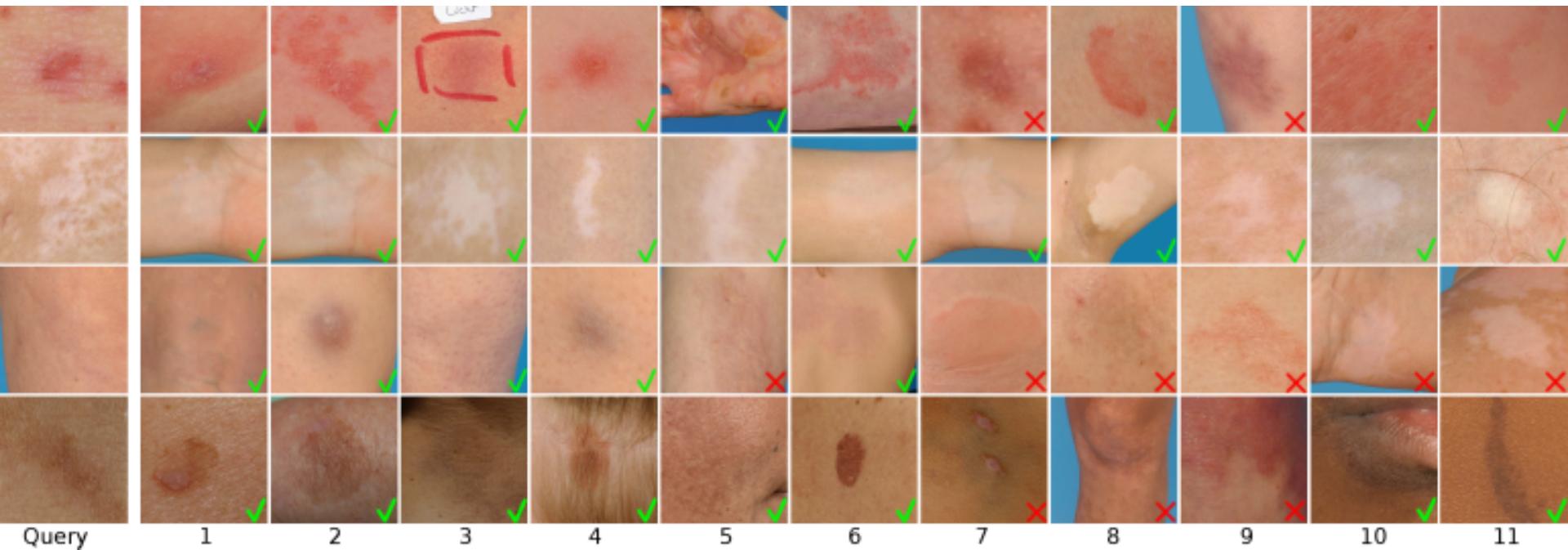
# Finger print identification



# Hand/palm authentication



# Medicine – computer aided diagnosis





## How it Works



Melanoma is the fastest growing cancer worldwide and the most deadly of all skin cancers, if not caught early. Performing regular self-exams could save your life or that of a loved one.

### Checking a mole or freckle is quick and easy:

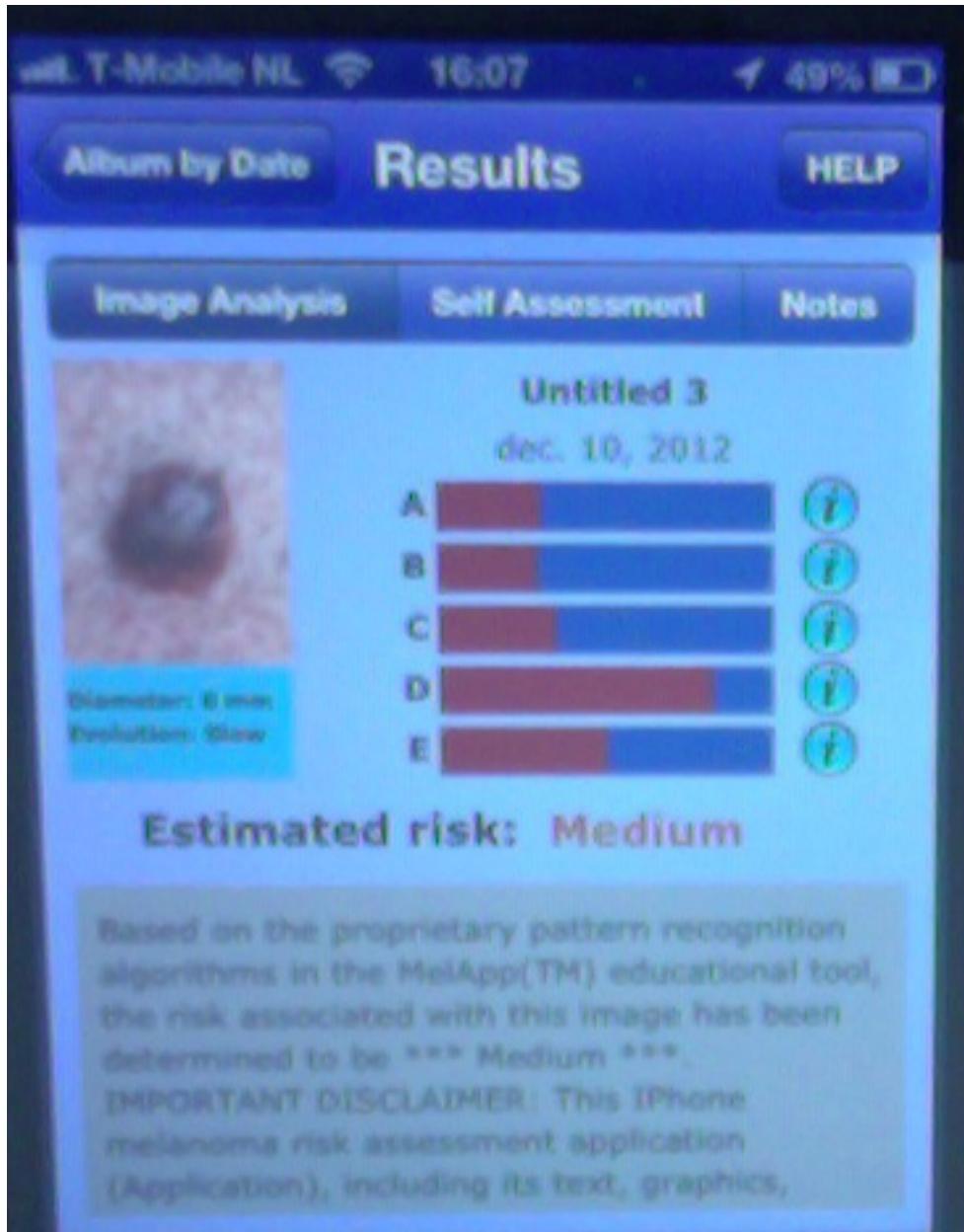
1. Use MelApp to take a picture of the skin lesions of concern with a smartphone's camera, enlarging it with the zoom feature to fit into the green box, then
2. Pin point the mole size and its evolution by sliding the corresponding indicator bar and tap on "Check Risk." Within seconds MelApp will provide a risk analysis of the uploaded picture being a melanoma.

MelApp uses highly sophisticated patent protected state-of-the-art mathematical algorithms and image based pattern recognition technology to analyze the uploaded image. The app was validated using DermAtlas, an open access, physician-edited database of over 10,000 high quality histological and clinical images of skin conditions.

These pictures also can be stored on MelApp and saved according to date, label or risk. Archiving your pictures lets you review them for changes in the skin lesions occurring over time.



# The concept of feature vector



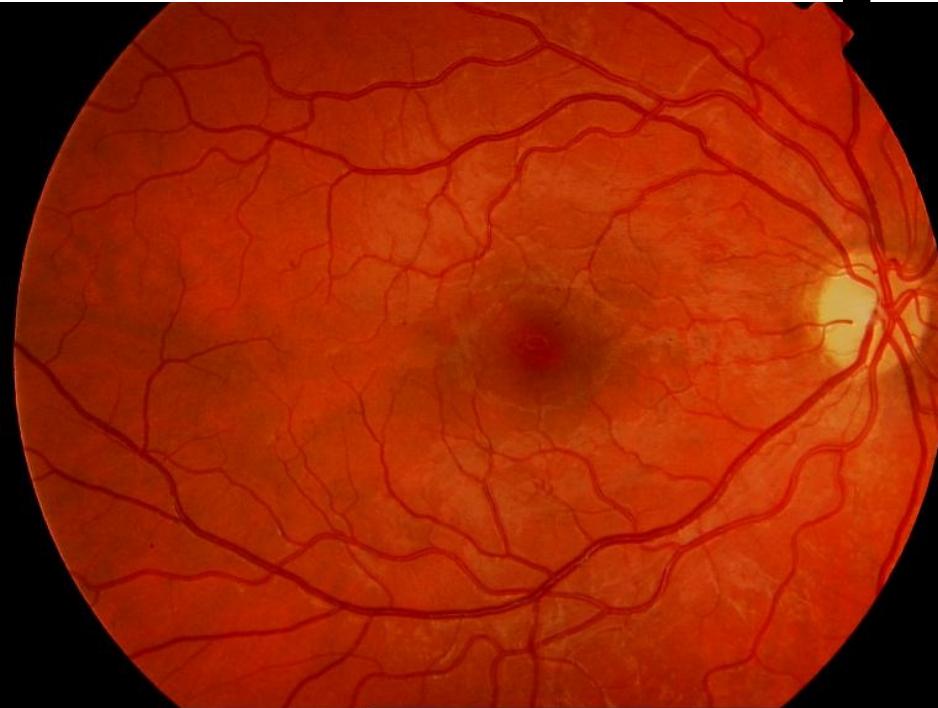
Five numbers are extracted or provided that characterize the mole:

- A – asymmetry
- B – fractalness of the boundary
- C – color (black is worse)
- D – diameter
- E – evolution (speed of change)

We call these characteristics ‘features’ and put their values in a ‘feature vector’ (A,B,C,D,E)

The pattern to be classified is thus represented by a feature vector.

# Medicine – computer aided diagnosis



Normal retina (2002)



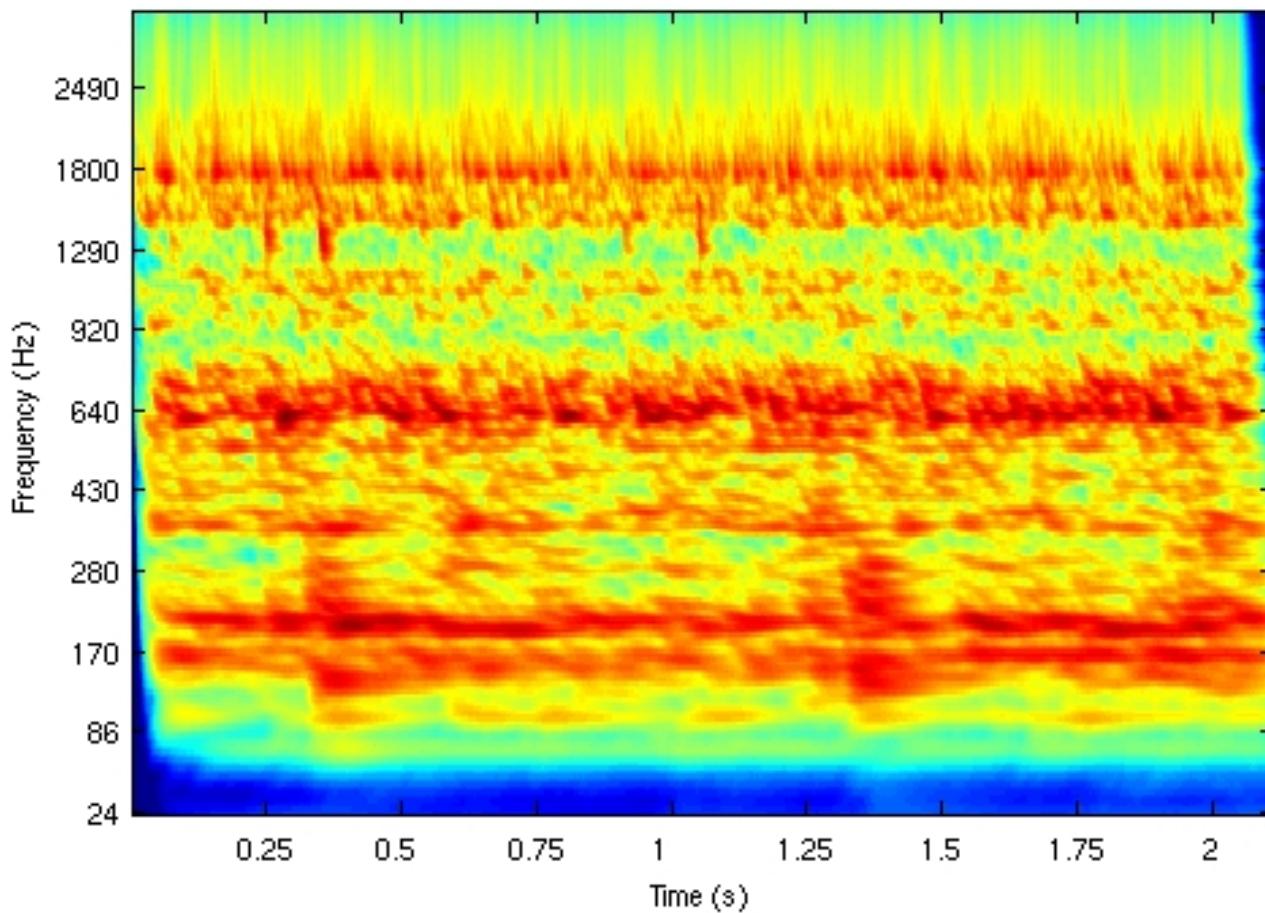
Diabetic retinopathy (2009)

# License plate recognition

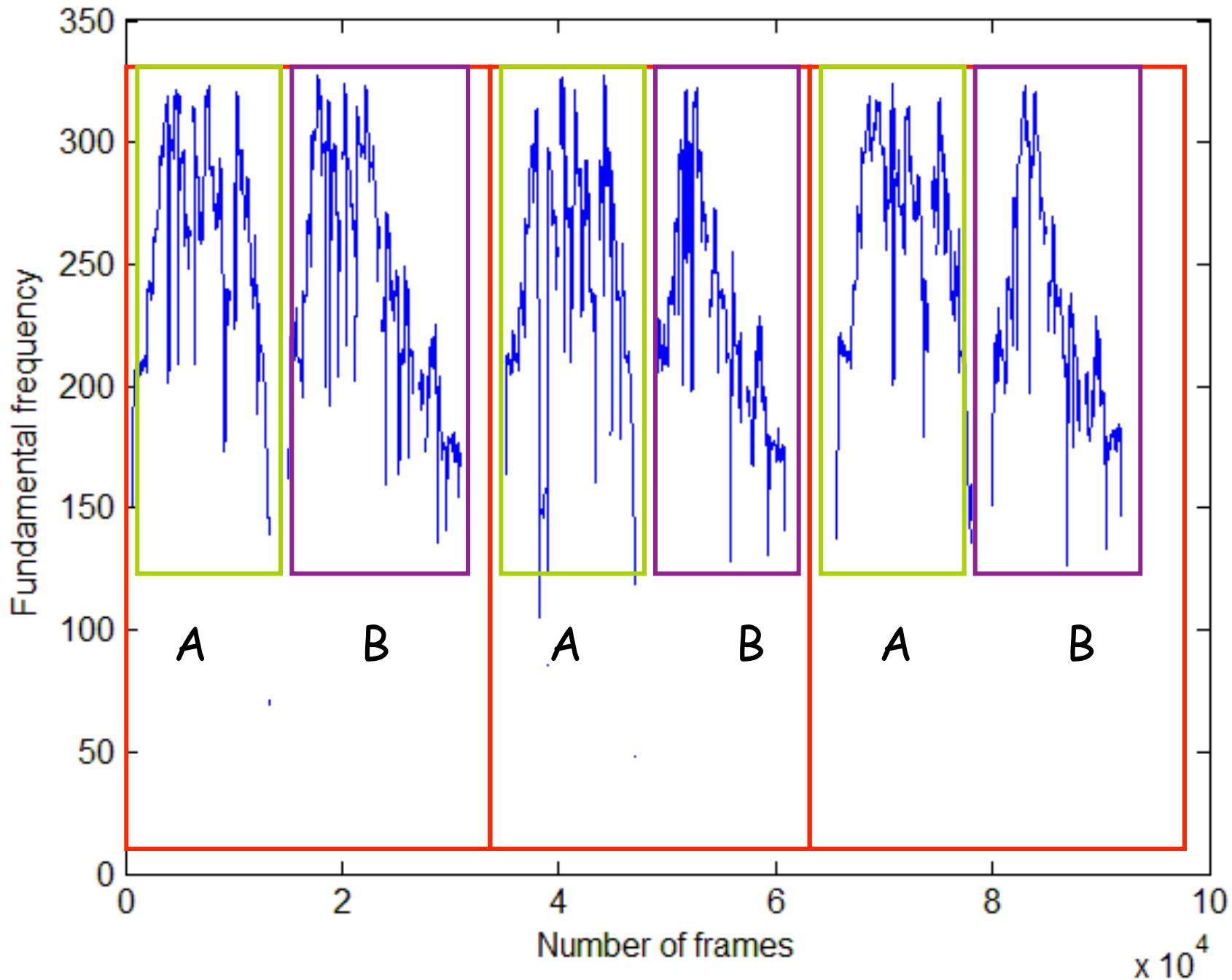


<http://www.dacolian.com/>  
<http://www.q-free.com/>

# Sound/speech recognition



### Pitch contour

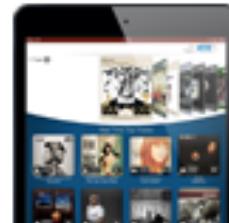


# Music recognition

## Get Shazam on your device

Shazam is the best way to discover, explore and share more music and television you love.

If you don't yet have the Shazam App on your smartphone, it's available for every major platform.



# Face identification/detection



<http://www.face-rec.org>

# Spam detection

Dear Sir or Madam:

Please reply to

Receiver: China Enterprise Management Co., Ltd. (CMC)

E-mail: unido@chinatop.net

As one technical organization supported by China Investment and Technical Promotion Office of United Nation Industry Development Organization (UNIDO), we cooperate closely with the relevant Chinese Quality Supervision and Standardization Information Organization. We provide the most valuable consulting services to help you to open Chinese market within the shortest time:

1. Consulting Service on Mandatory National Standards of The People's Republic of China.
2. Consulting Service on Inspection and Quarantine Standards of The People's Republic of China.
3. Consulting Service for Permission to Enter Chinese Market

We are very sorry to disturb you!

More information, please check our World Wide Web: <http://www.chinatop.net>

Sincerely yours

# Phishing detection

Your mailbox has exceeded the storage limit set by your administrator.

You may not be able to send or receive new mail until your mailbox size is increased by your system administrator. You are required to contact your system administrator through e-mail with your Username: { } and Password: { } to increase your storage limit.

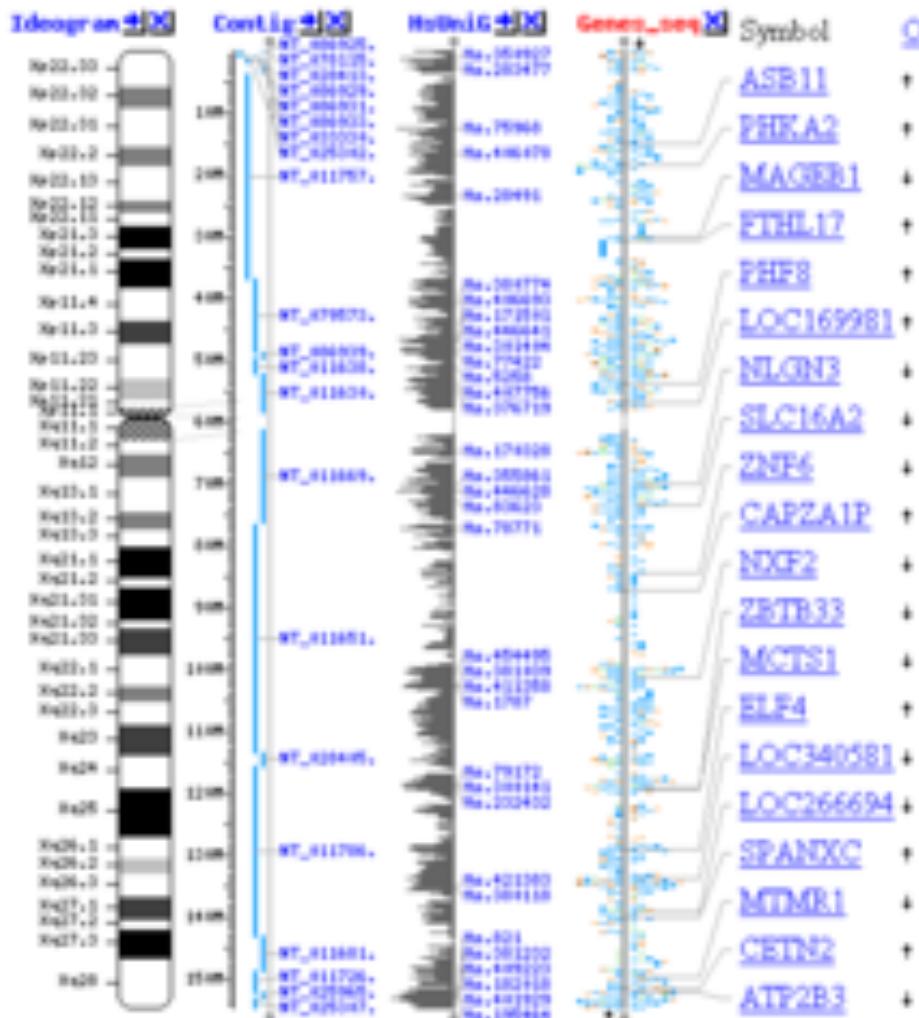
System Administrator

E-mail: ...

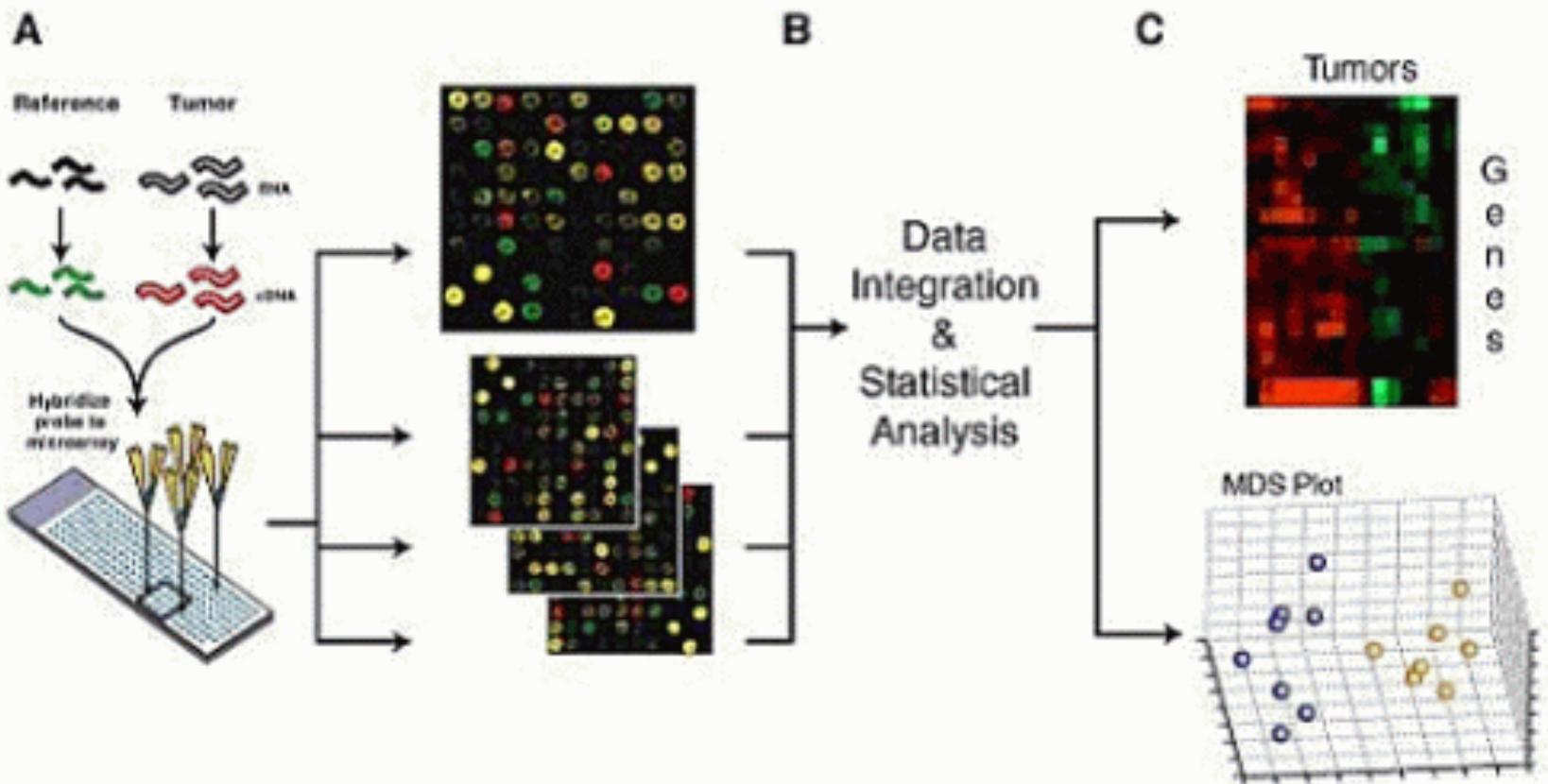
You will continue to receive this warning message periodically if your inbox size continues to exceed its size limit.

This email is intended only for the use of the individual or entity to which it is addressed and contains information that is privileged and confidential.

# Gene finding/recognition

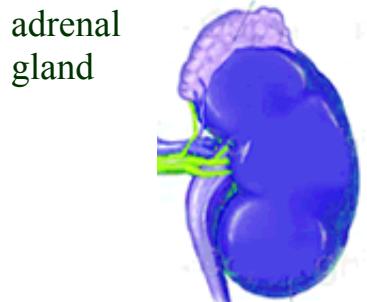


# Bioinformatics

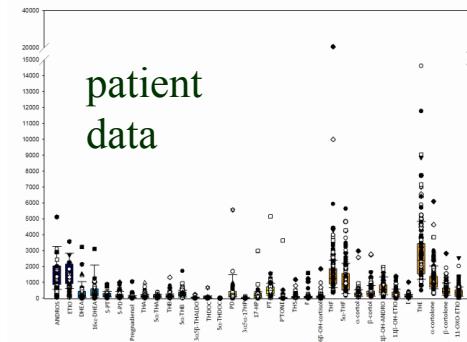


# Tumor Classification

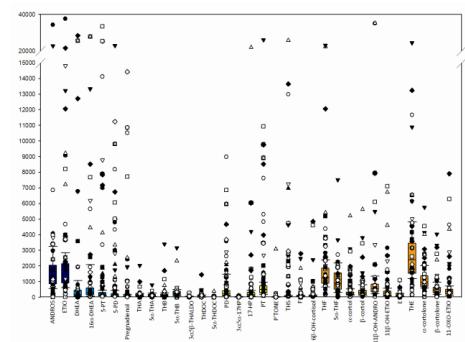
adrenocortical



adenomas (ACA)



carcinomas(ACC)



32 medical tests are done with each patient. Each test delivers a number that represents the concentration of a certain steroid in the urine. Thus each patient is represented by a feature vector of 32 numbers.

The above plots are superpositions of the data from many patients.

# Definitions

**Pattern:** (relevant part of) acquired or sensed data

(e.g. a face or an iris in an image, the sound of a gun shot in an audio signal, a specific combination of words in a text)

**Pattern recognition:**

- data acquisition
- segmentation of relevant data
- extraction of features (descriptors)
- classification / detection / identification / authentication

Bar code – a pattern easily  
recognized by a computer

# Bar codes

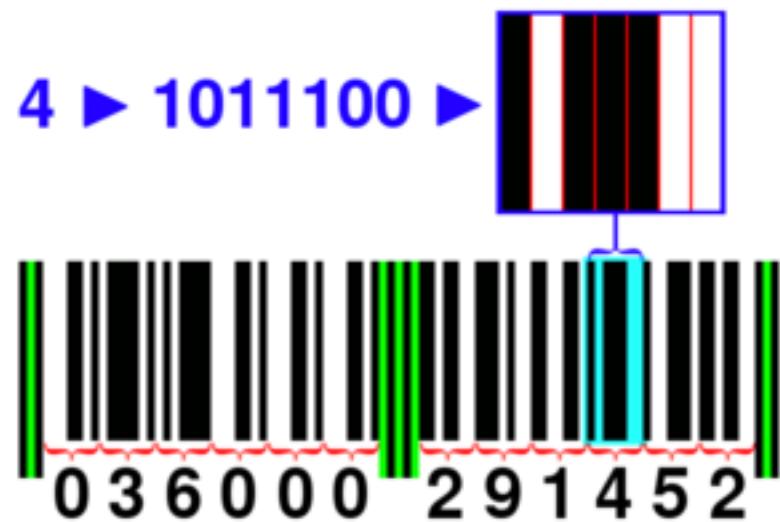


# Universal product code (UPC)



# Universal product code (UPC)

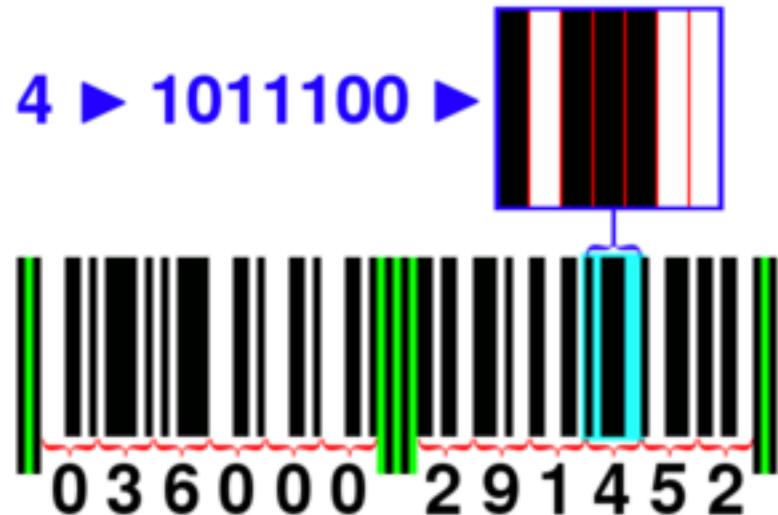
- 30 bars that code for 95 bits
- Starts and ends with 101
- 01010 in the middle
- A group of 7 bits codes a decimal digit, e.g. 1011100 = 4



# Automatic UPC recognition

## Feature extraction

- segment UPC in an image
- divide UPC in 95 segments of equal width
- assign 1 or 0 to dark or light segments
- result: 95 bits (binary features);
- for a given product **ALWAYS THE SAME, NO SPREAD IN VALUES**

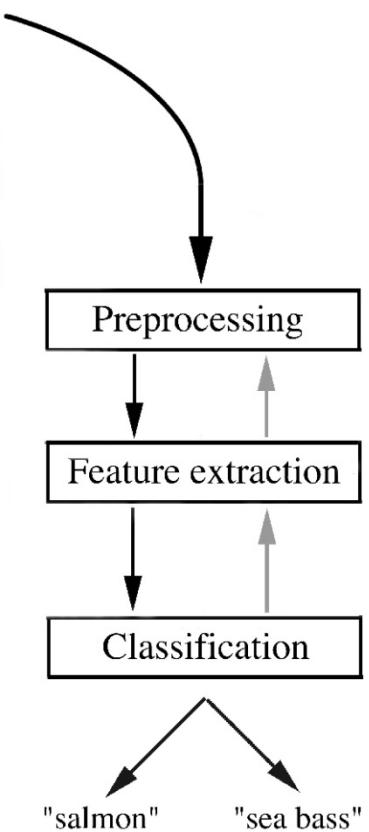


# Recognizing natural patterns

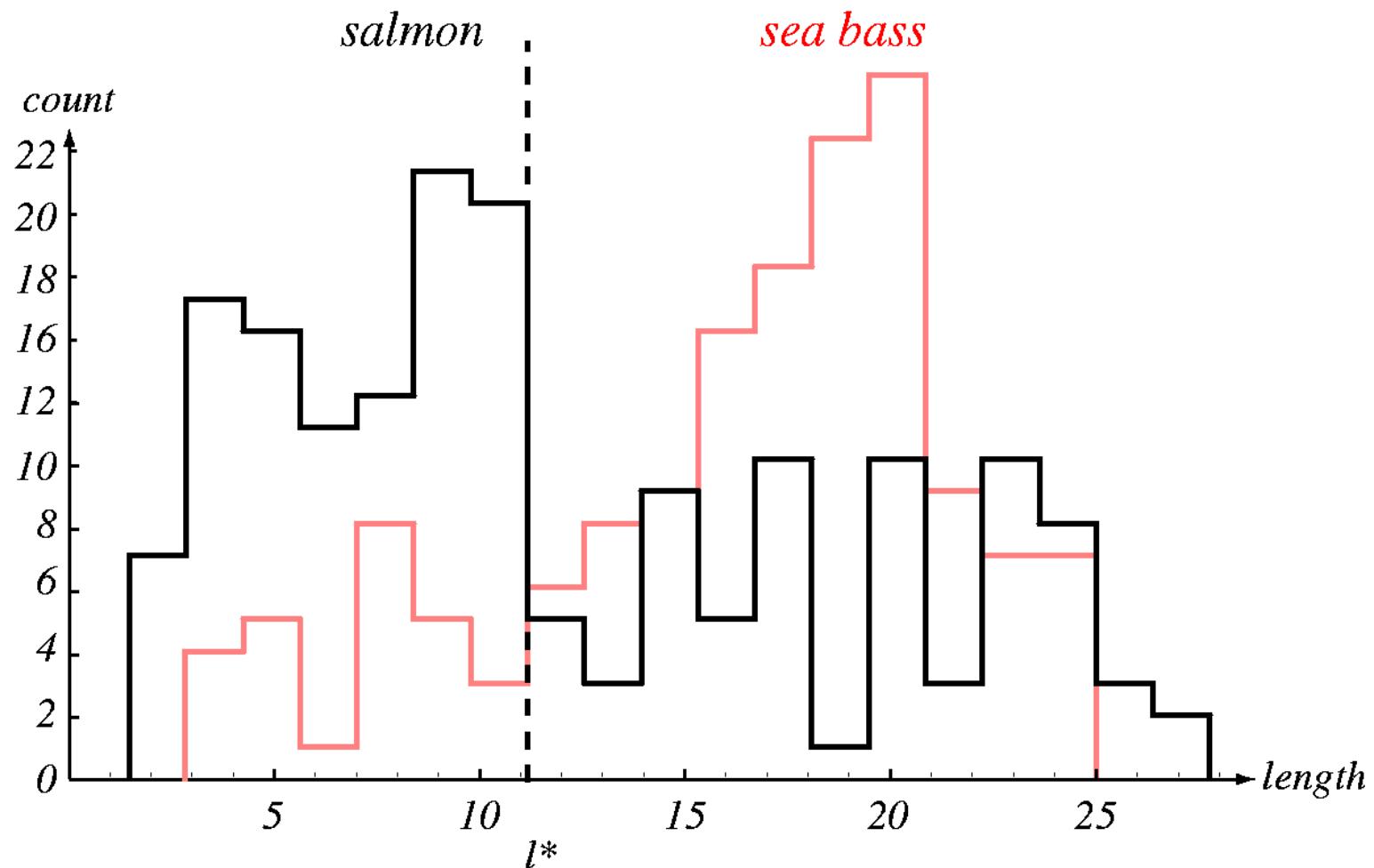
# Recognizing natural objects

## Example:

Automatic sorting  
of fish on a  
conveyor belt

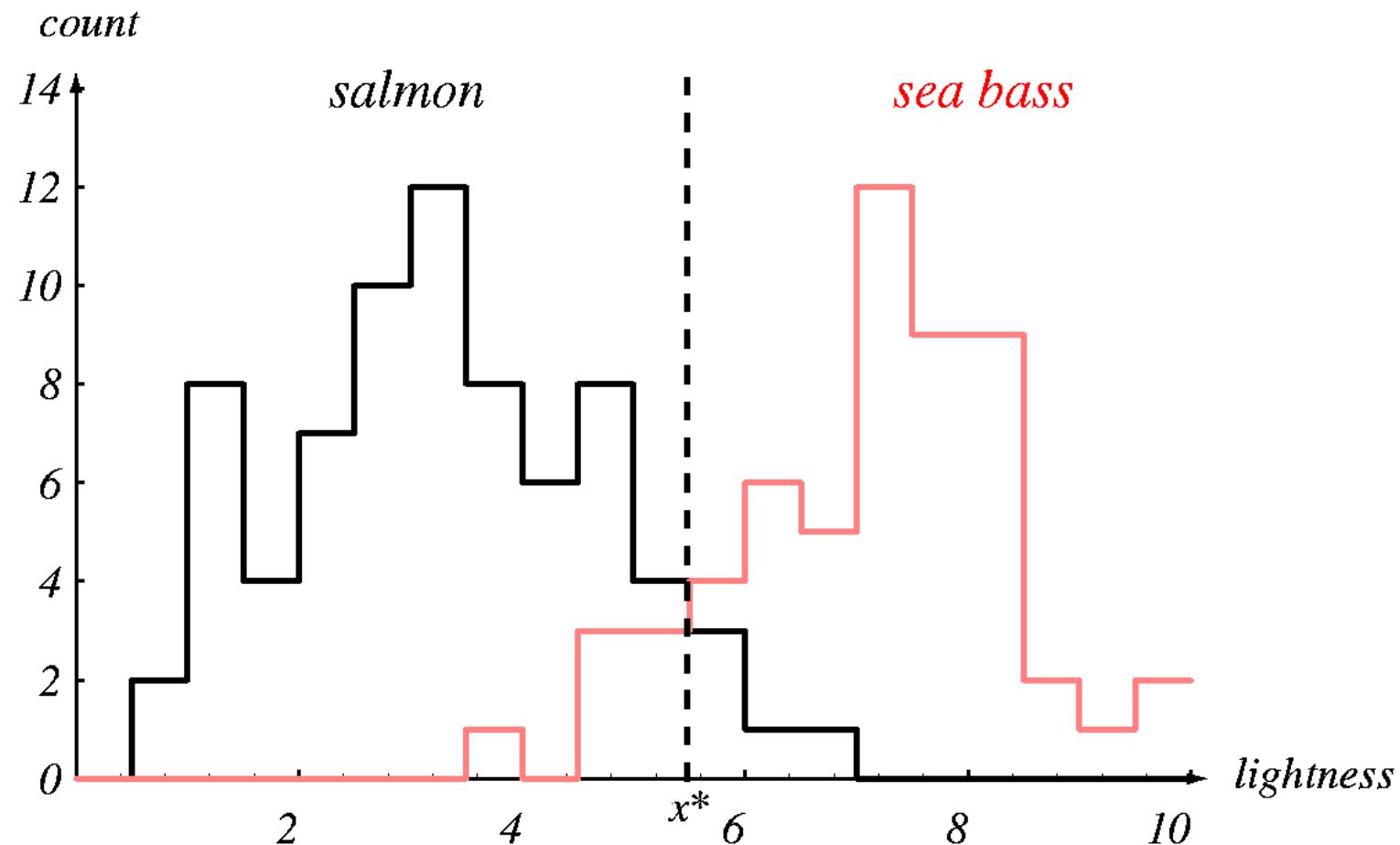


# Features values extracted from natural objects



Histograms of the “length” feature for the two categories  
(from Duda, Hart, Stork (2001) Pattern classification)

# Features values extracted from natural objects



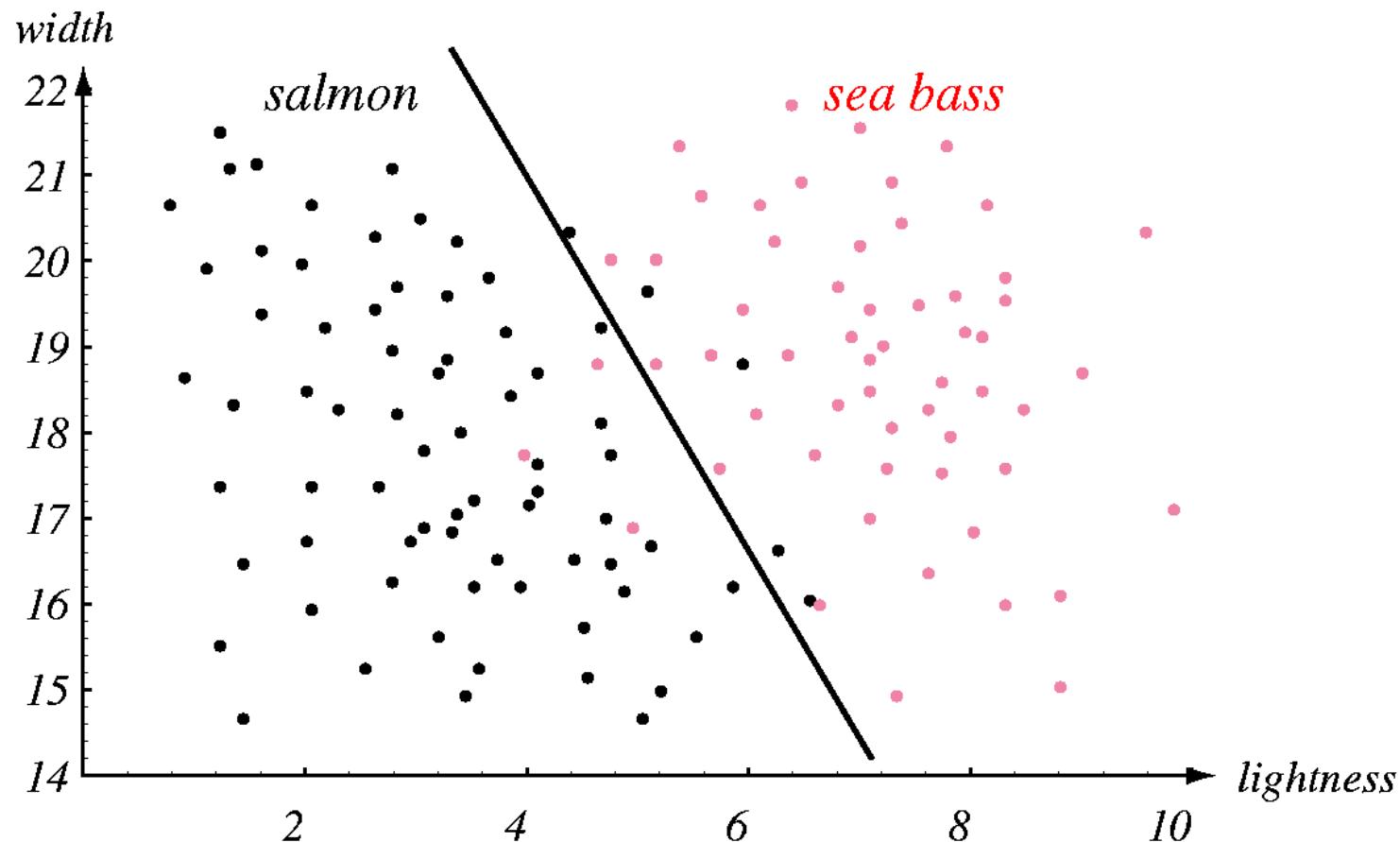
Histograms of the “lightness” feature for the two categories  
(from Duda, Hart, Stork (2001) Pattern classification)

# Classification using a decision boundary

In the above examples, classification is done by taking a certain value, called *decision criterion*, and classifying objects to class A or B, depending on whether their feature values are larger or smaller than the decision criterion.

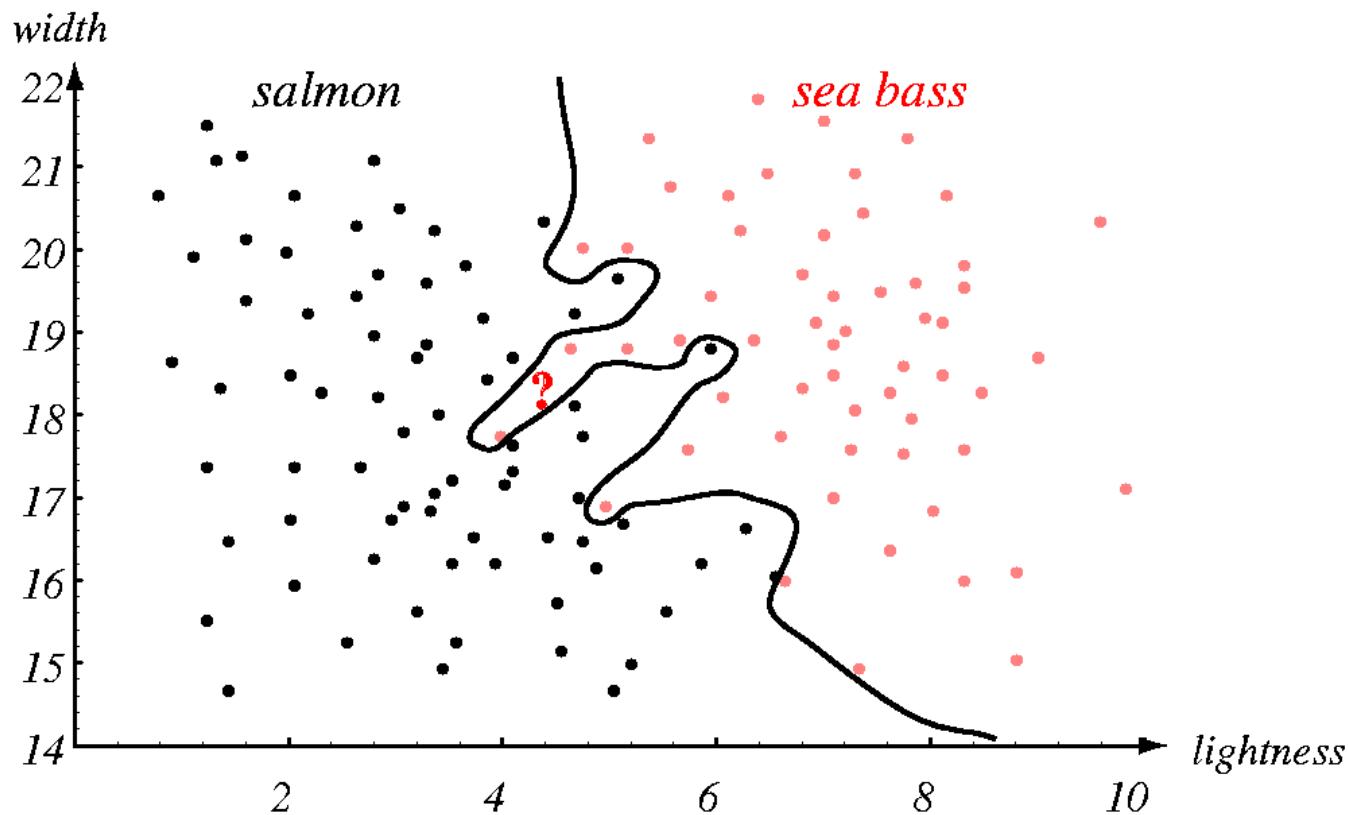
One single feature (length or lightness) might not be enough to achieve good classification. We can pack them in a feature vector  $x = (\text{length}, \text{lightness})$ . In that case, we use a *decision boundary*.

# One possible decision boundary



(from Duda, Hart, Stork (2001) Pattern classification)

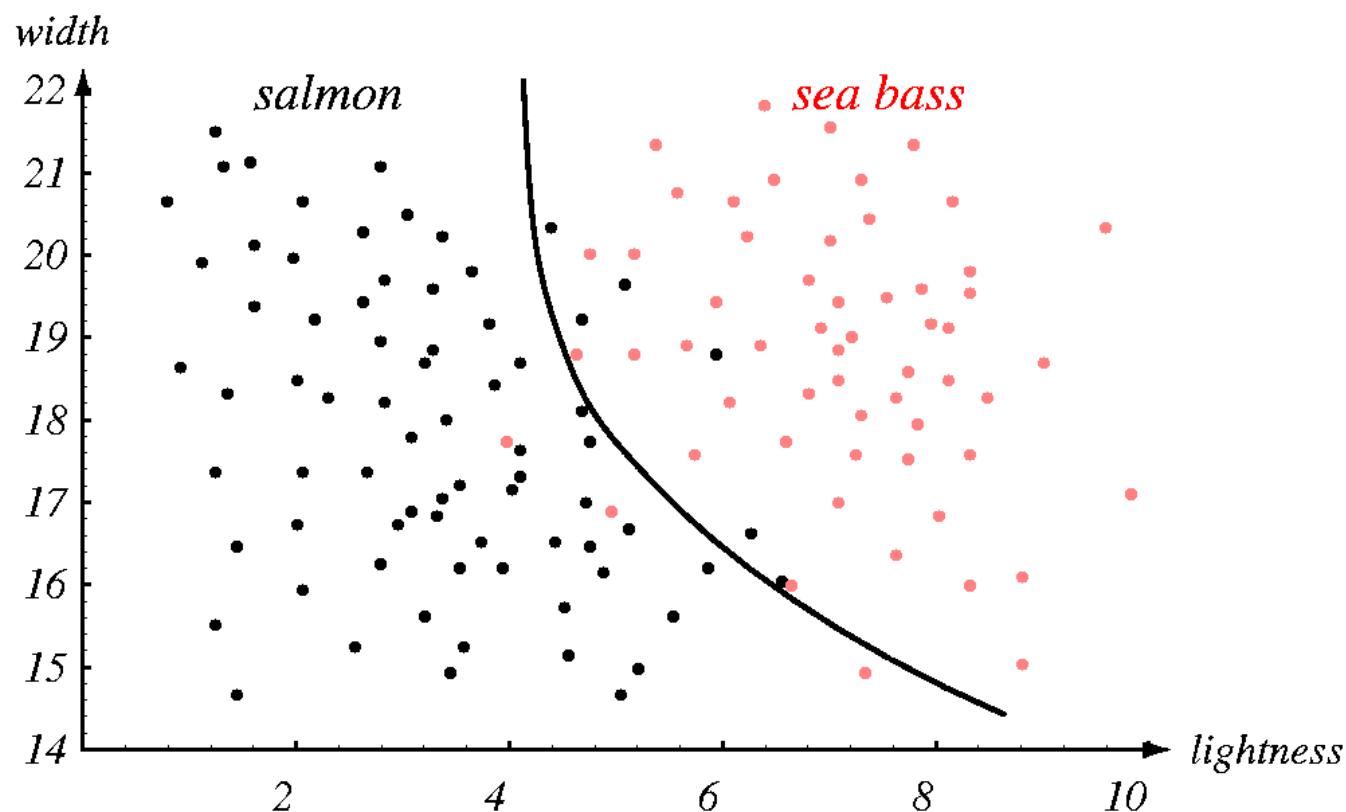
# Another possible decision boundary



**A complex decision boundary**

(from Duda, Hart, Stork (2001) Pattern classification)

# Yet another possible decision boundary



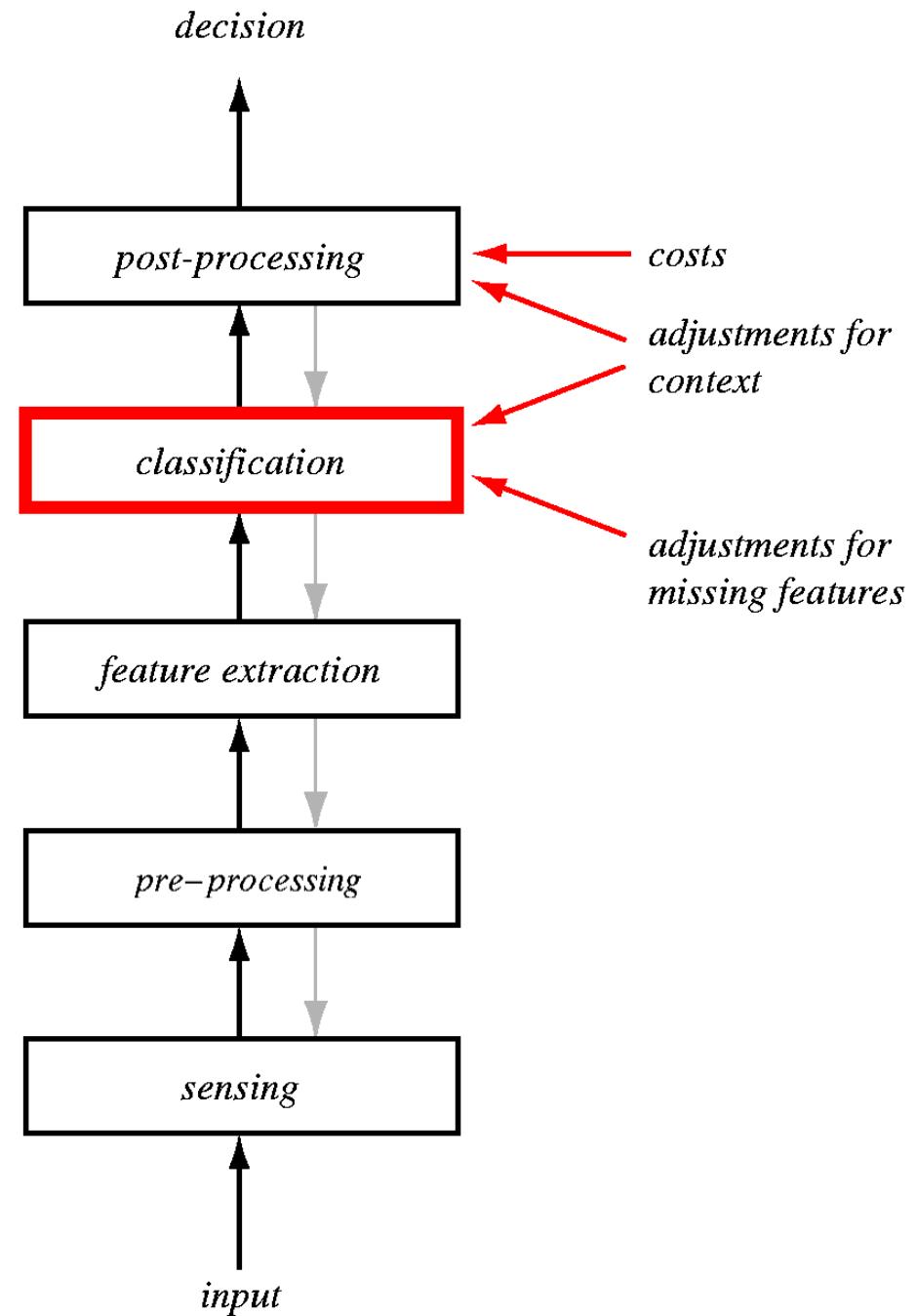
**Optimal (?) decision boundary**

(from Duda, Hart, Stork (2001) Pattern classification)

# Statistical Pattern Recognition

- The values of the features extracted from natural objects exhibit a certain spread
- This spread is dealt with by statistical methods
- The inferences made are stated in terms of probabilities
- The quality of classification is measured in terms of error rates

# Components of a pattern recognition System



# Stages of PR

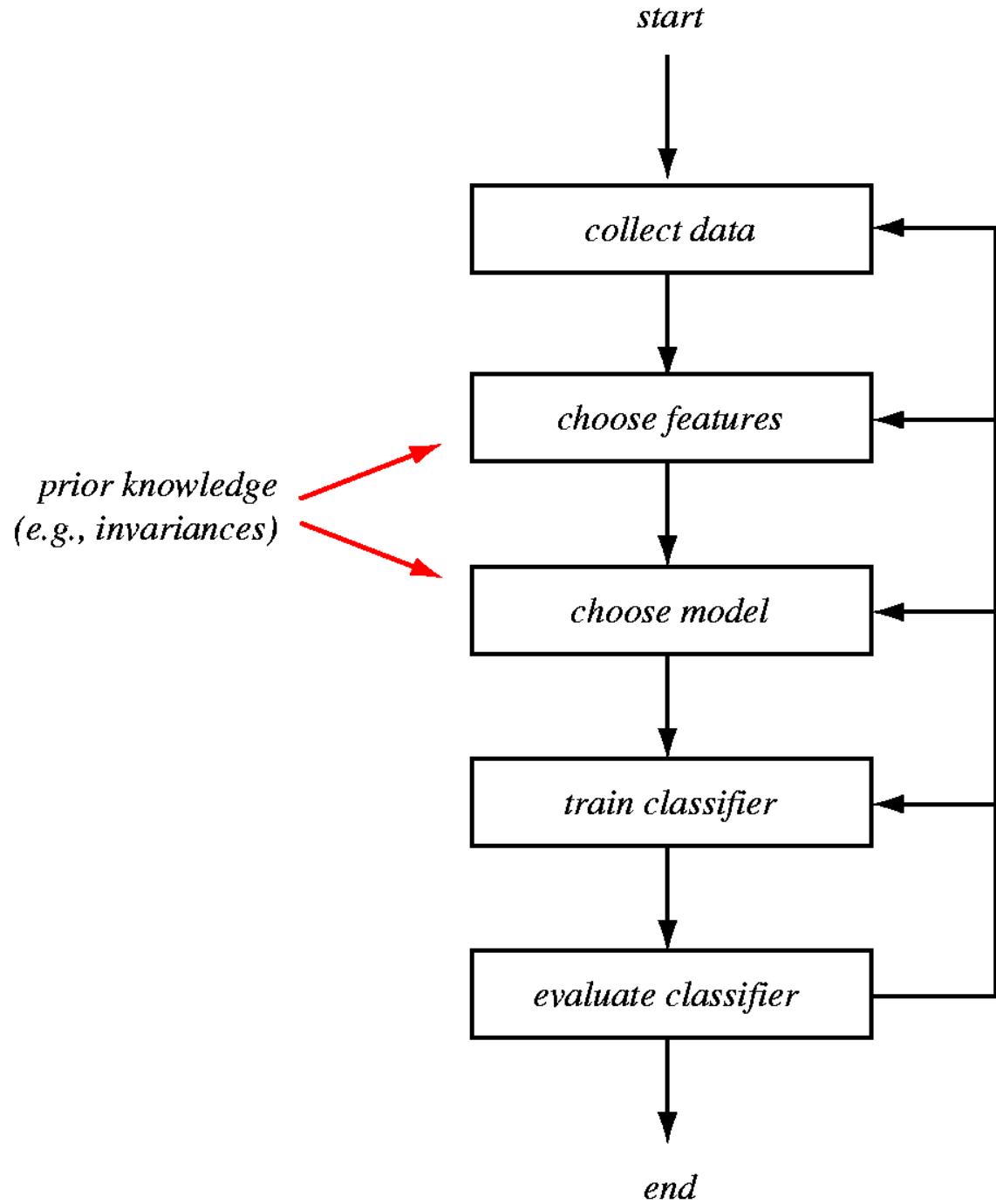
**Pre-processing/segmentation** – select relevant information from input data

**Feature extraction** - extract numerical or symbolic values

**Classification** – assign a category to an object

**Post-processing** – e.g. take some action taking into account error/risk/cost

# Design of a pattern recognition system



# Learning

A pattern (object) that is represented by a feature vector needs to be classified. This can be achieved by comparing this feature vector with previously stored feature vectors for which it is known what types of object they represent.

The process of providing an automatic pattern recognition system with such feature vectors can be considered as ‘learning’. More generally, ‘*learning*’ means using training data to automatically adjust some inner parameters of a classifier system. The commonly used term is ‘*machine learning*’.

The type of learning in which a feature vector is provided with a label that specifies the class of the object is called ‘*supervised learning*’.

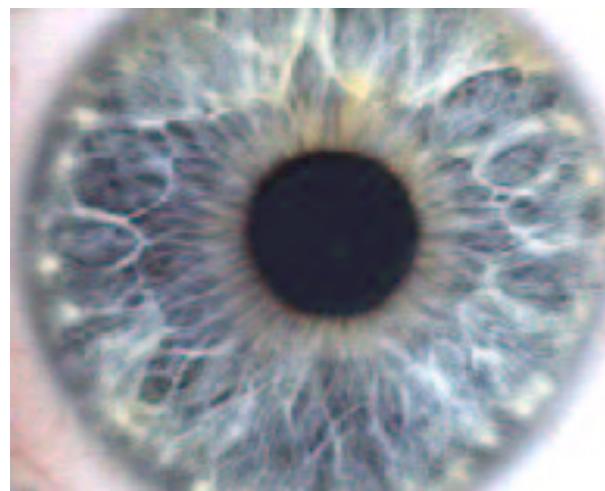
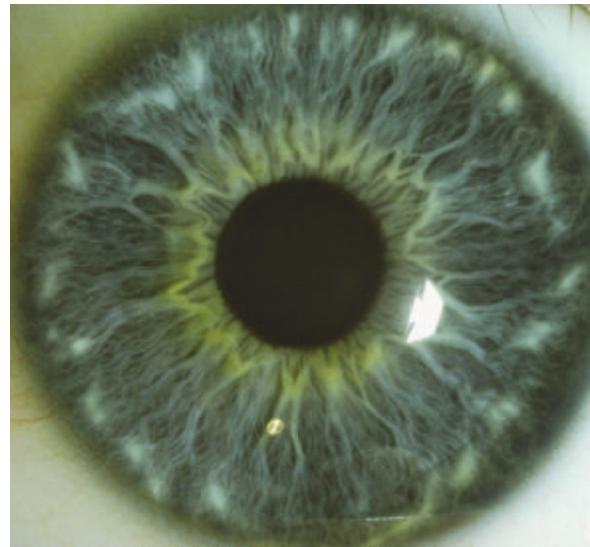
# Summary of concepts and facts

- Pattern, pattern recognition, examples
- Bar code, UPC
- Features, mapping of objects into a multi-dimensional feature space
- Decision criterion/boundary
- Difference between bar code and feature vectors of natural objects
- Aspects of statistical pattern recognition
- Components of a pattern recognition system
- Learning

Recognition based on (dis)similarity  
to a prototype  
and  
Statistical decision theory  
(Hypothesis testing)

# Person authentication by iris pattern

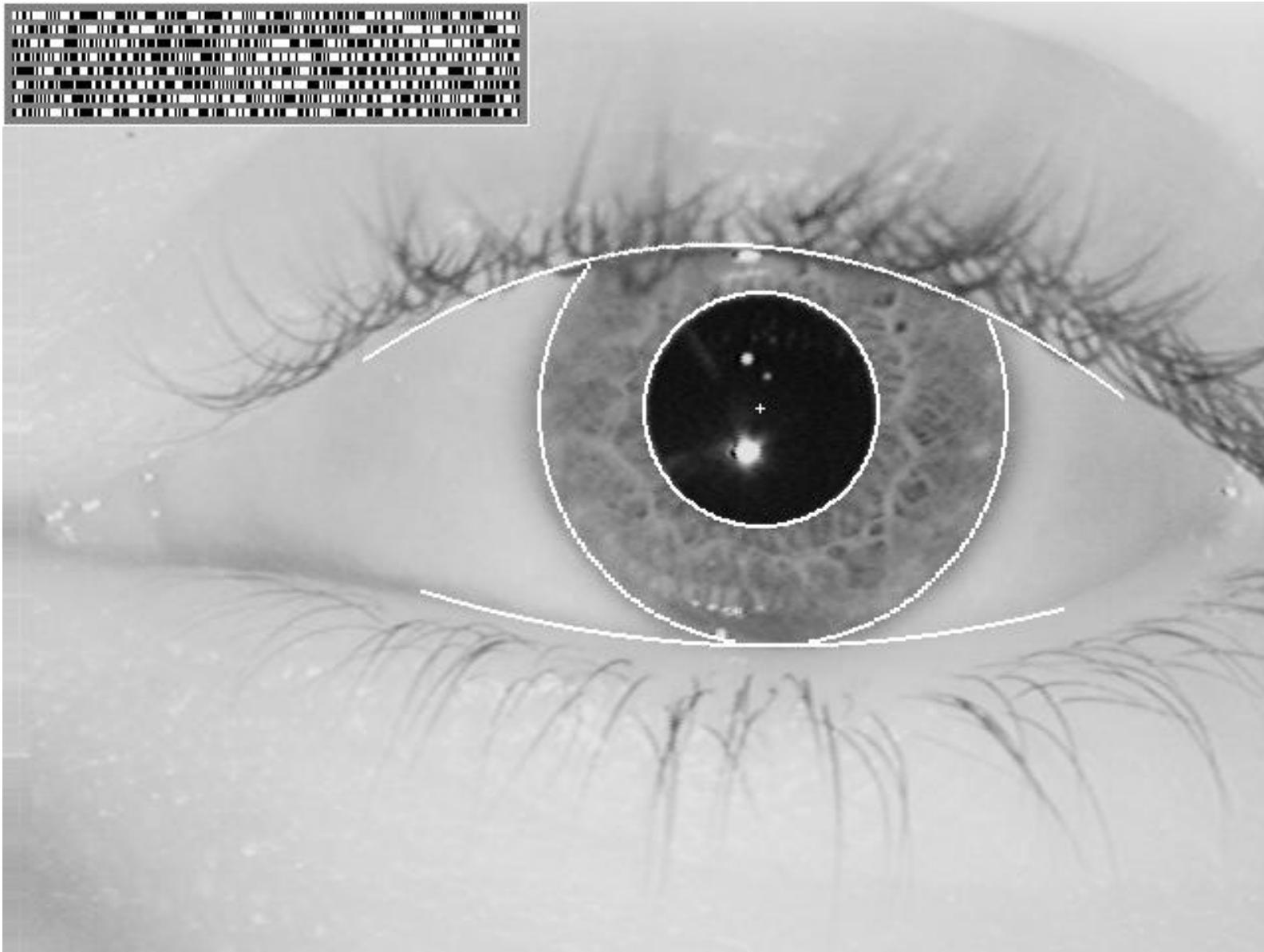
# Iris images



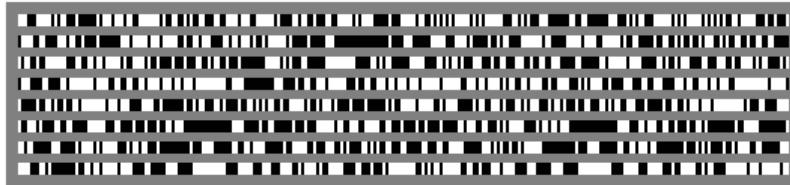
# Iris Scan



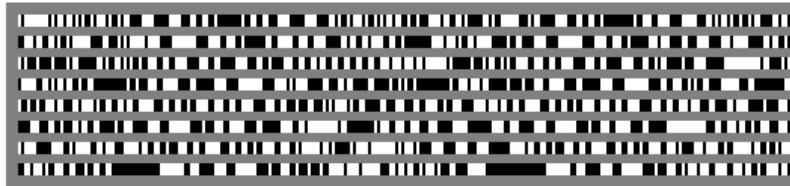
# Extracting binary code from iris



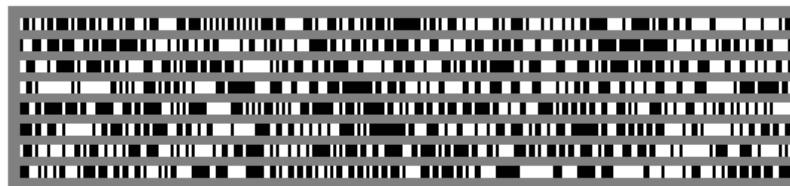
# Binary iris codes



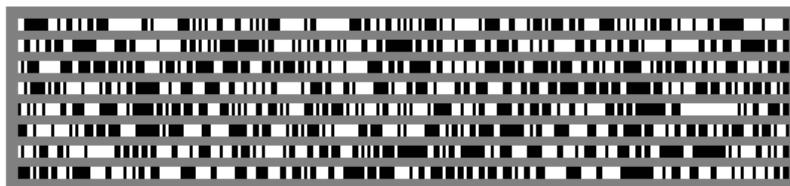
Person 1



Person 2



Person 3



Person 4

# Hamming distance between two iris codes

$I_t$  – test iris code,       $I_p$  – prototype iris code

$H(I_t, I_p) = |I_t \text{ XOR } I_p|$  - Hamming distance

$h(I_t, I_p) = H(I_t, I_p)/\dim(I)$  - normalized H. distance

Example:

$$I_t = (1, 0, 0, 1, 1, 0, 1, 0, 0, 1, 0, 1, 1, 1, 0)$$

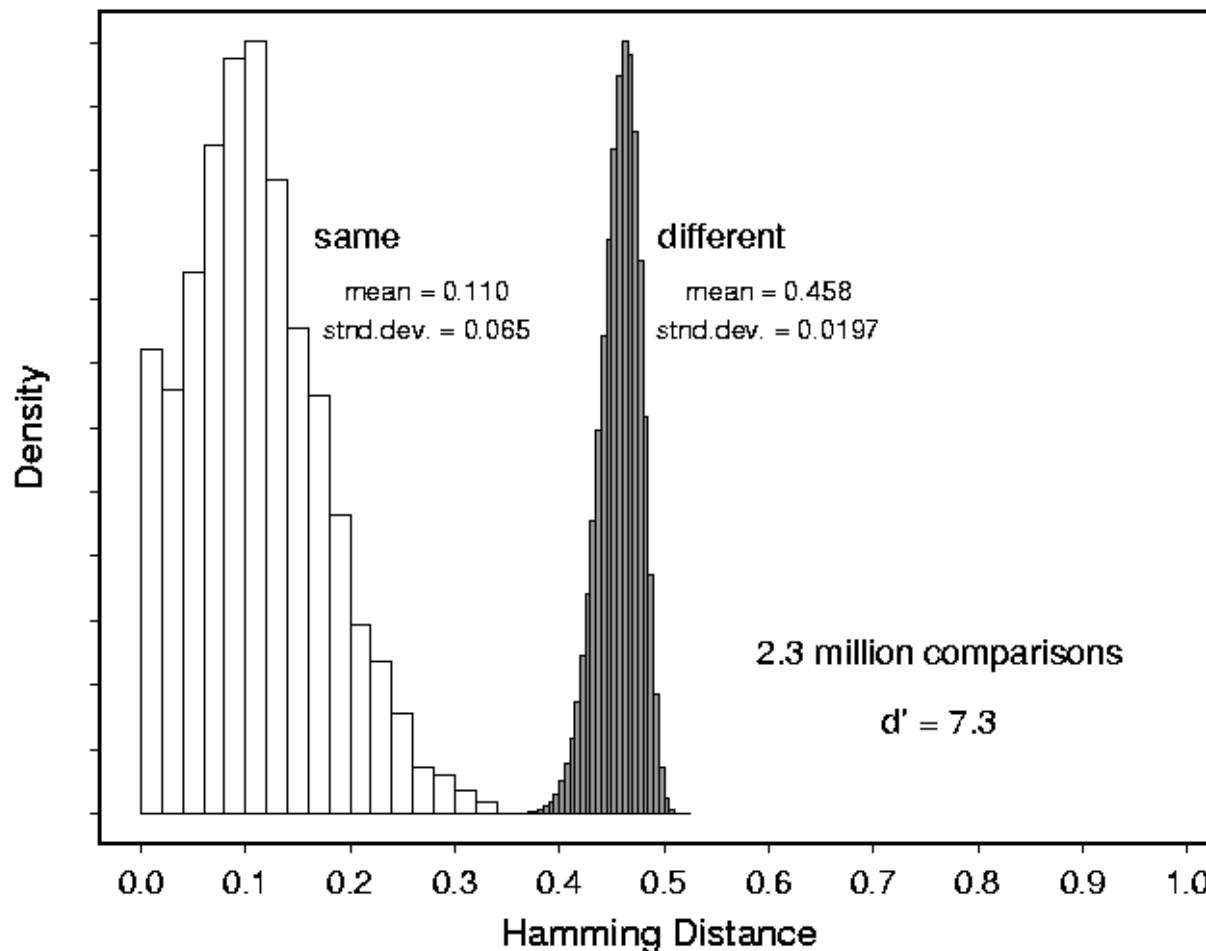
$$I_p = (0, 1, 0, 1, 0, 1, 0, 1, 1, 0, 0, 1, 1, 0)$$

$$I_t \text{ XOR } I_p = (1, 1, 0, 0, 1, 1, 1, 1, 1, 0, 0, 0, 0, 0)$$

$$|I_t \text{ XOR } I_p| = 7, \quad h(I_t, I_p) = 8/14 = 0.56$$

# Hamming distance of iris codes

Decision Environment for Iris Recognition



Histograms of the Hamming distances of pairs of iris codes (left – for the comparison of two iris patterns of the same person; right – for different persons)

# Model

The distribution of values of the Hamming distance of the iris codes of different persons can be modeled very well by a normal distribution, i.e. the envelope of that histogram can be fitted by a Gaussian function

$$N(\mu, \sigma^2) = \frac{1}{\sqrt{2\pi} \sigma} \exp\left(-\frac{1}{2} \frac{(x - \mu)^2}{\sigma^2}\right)$$

# Why do we need a mathematical model?

Because we can use it to compute the probability of measuring a certain value of the Hamming distance also in domains in which the histogram contains no data. (The fact that a histogram does not contain any data in a given domain does not mean that no such values will ever be measured.)

# Statistical decision theory (Hypothesis testing)

- Given the pdf(HD) that two irises are different
- Formulate hypotheses
  - $H_0$ , null hypothesis: the two irises are different
  - $H_a$ , alternative: the two irises are identical
- Select a **decision criterion** (HD value) C and a rejection region according to the desired significance level (odds of false decision or false rejection of  $H_0$ )
- Compare two iris codes and obtain their HD
- Test  $H_0$  hypothesis
  - do not reject  $H_0$  if  $HD > C$  (type II error, fn)
  - reject  $H_0$  and accept  $H_a$  if  $HD \leq C$  (type I error, fp)

# Decision error of type I (False acceptance of an imposter)

HD Criterion Odds of false decision

0.26      1 in  $10^{13}$

0.27      1 in  $10^{12}$

0.28      1 in  $10^{11}$

0.29      1 in 13 billion

0.30      1 in 1.5 billion

0.31      1 in 185 million

0.40      1 in 170

# Applications of Iris Recognition

- National border control
- Computer login
- Data security (control of privileged access)
- Anti-terrorism (e.g. passenger screening)
- Secure e-banking
- Bank ATM cash dispensers
- Anonymous authentication
- Drivers licenses, other personal certificates
- Birth certificates; missing or wanted persons
- Car ignition and unlocking, anti-theft devices
- Any existing use of keys, cards, PINs, passwords

# An Afghanistan story



An Afghan girl on the cover page of  
National Geographic (1984)

# Who is the authentic person?



Sharbat Gula (1984) identified (2002) by iris comparison

# More on Iris Scan

See: John Daugman

<http://www.cl.cam.ac.uk/~jgd1000/>

More on hypothesis testing

<http://wikipedia.org>

# Summary of concepts and facts

- Authentication by iris pattern
- Iris code extraction
- Hamming distance of iris codes
- Histogram and probability density function
- Hypothesis testing
- Errors of type I and II