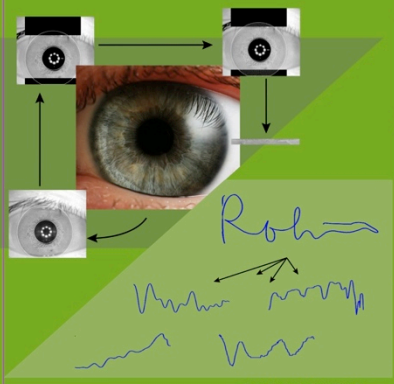
Nový předmět katedry kybernetiky, FEL ČVUT

# BIOMETRIE (A6M33BIO)



Předmět je zaměřen na výklad nejpoužívanějších metod v biometrii.
Sami si naimplementujete dynamické rozpoznávání podpisu, detekce vlastního otisku prstu či duhovky!

Disponujeme profesionálním vybavením, pracujeme v Matlabu s předpřipravenými skripty, neztrácíte zbytečně čas na na cvičeních.
Soustředíme se na bezpečnostní rizika biometrických systémů.
Pro každý biometrický systém je provedeno vyhodnocení z hlediska rychlosti, ceny a přesnosti.

Předmět doporučujeme zejména studentům oborůl Otevřená informatika, Kybernetika a robotika a Biomedicínská informatika & inženýrství.

Zdroje: duhovka - Petr Novák, Wikipedia
podpis - databáze SVC2004

? Jak funguje snímač otisku prstů?

? Proč je detekce duhovky nejpřesnější metodou?

? Proč se neujalo rozpoznávání hlasu?

? Lze jednoduše prolomit biometrický systém?

! www.predmet-biometrie.cz

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# Biometrics Introduction

**Daniel Novák**

**18.9, 2012, Prague**

**Acknowledgments:**
**Chang Jia,**
**Andrzej Drygajlo**

laboratory Gerstner

# Podmínky předmětu

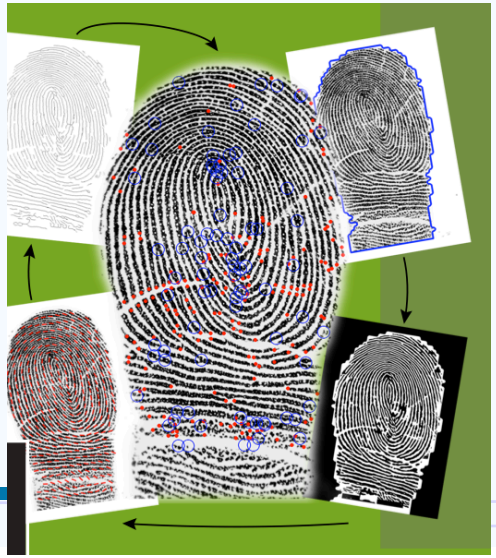
- Garant předmětu: Daniel Novák, místnost E225, xnovakd1@labe.felk.cvut.cz
- Stránky předmětu
  - https://cw.felk.cvut.cz/doku.php/courses/a6m33bio/start
  - 3. laboratorní úlohy – každá za 20 bodů, celkem 60 bodů
  - Klasifikovaný zápočet – 20 otázek, každá za 2 body
- Podmínky předmětu
  - https://cw.felk.cvut.cz/doku.php/courses/a6m33bio/podminky

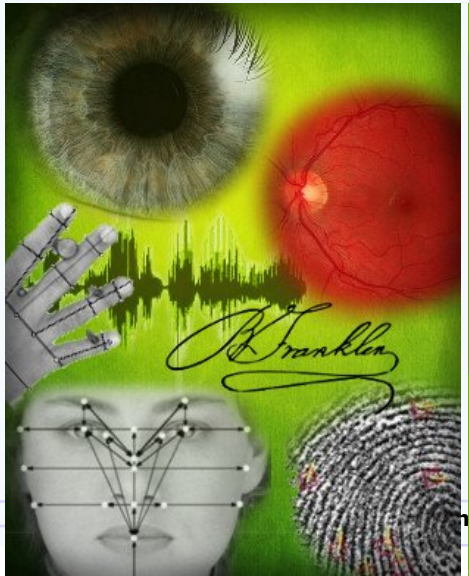
| Body z předmětu | Stupeň ECTS | Známka |
|---|---|---|
| 100–90 | A | výborně |
| 89–80 | B | velmi dobře |
| 79–70 | C | dobře |
| 69–60 | D | uspokojivě |
| 59–50 | E | dostatečně |
| 49 a méně | F | nedostatečně |

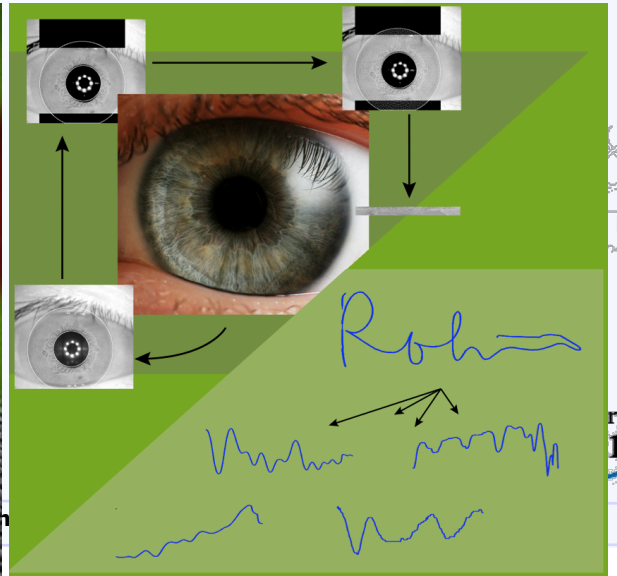
laboratory Gerstner

# Facebook, Twitter, Web

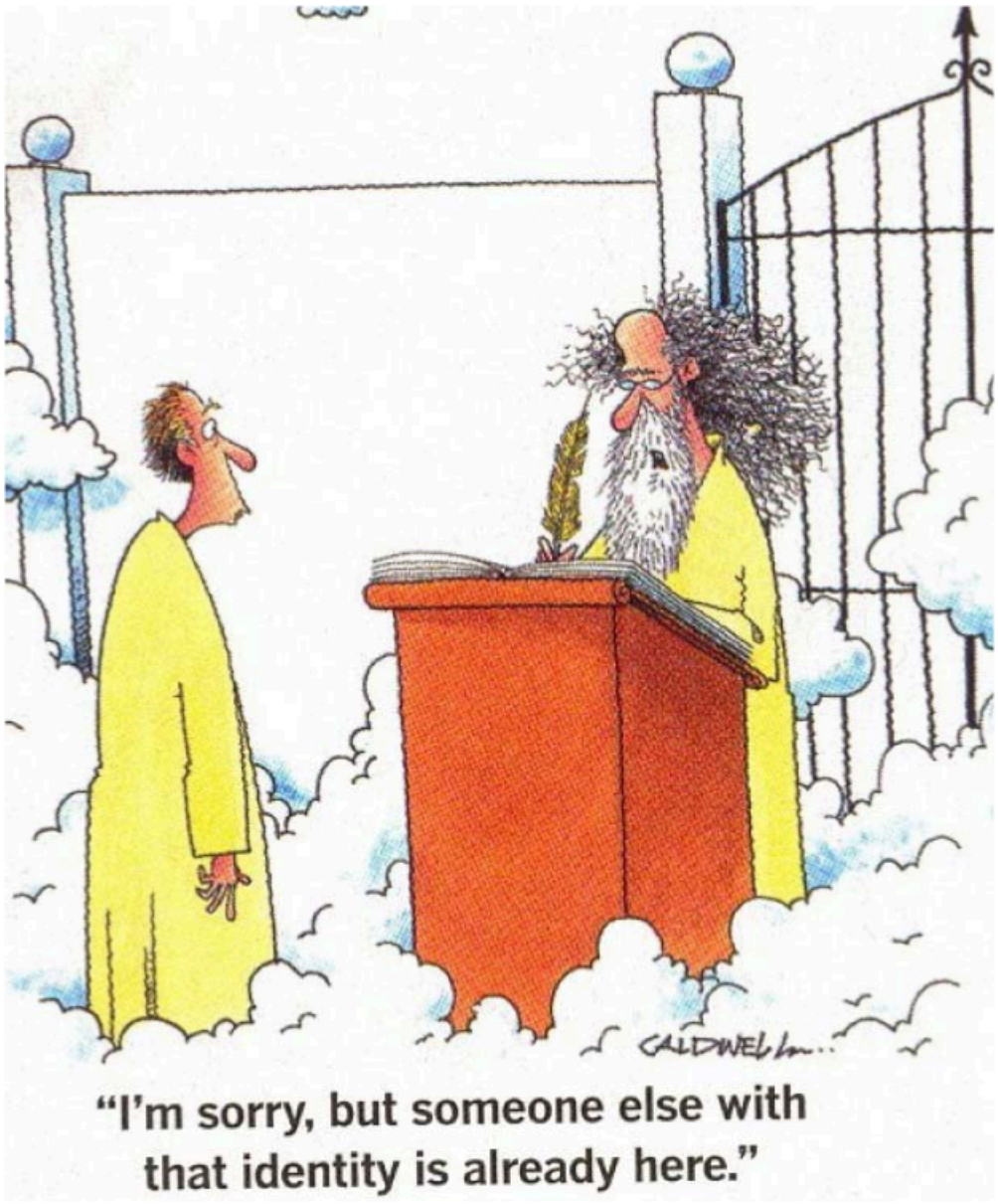
- **Prispivejte zejmena vy!!!!**
- Facebook (zalikujte, pokud se vam predmet bude libit:)
  - http://www.facebook.com/biometrieCVUT
- Twitter
  - http://www.facebook.com/biometrieCVUT
- Webove stranky
  - http://www.predmet-biometrie.cz/





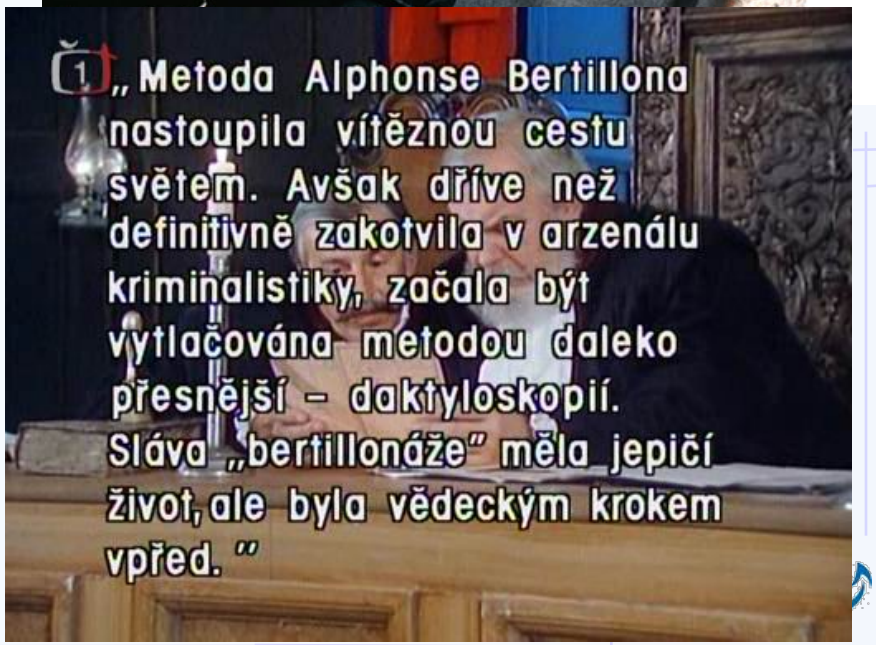


# Proč Biometrie ?

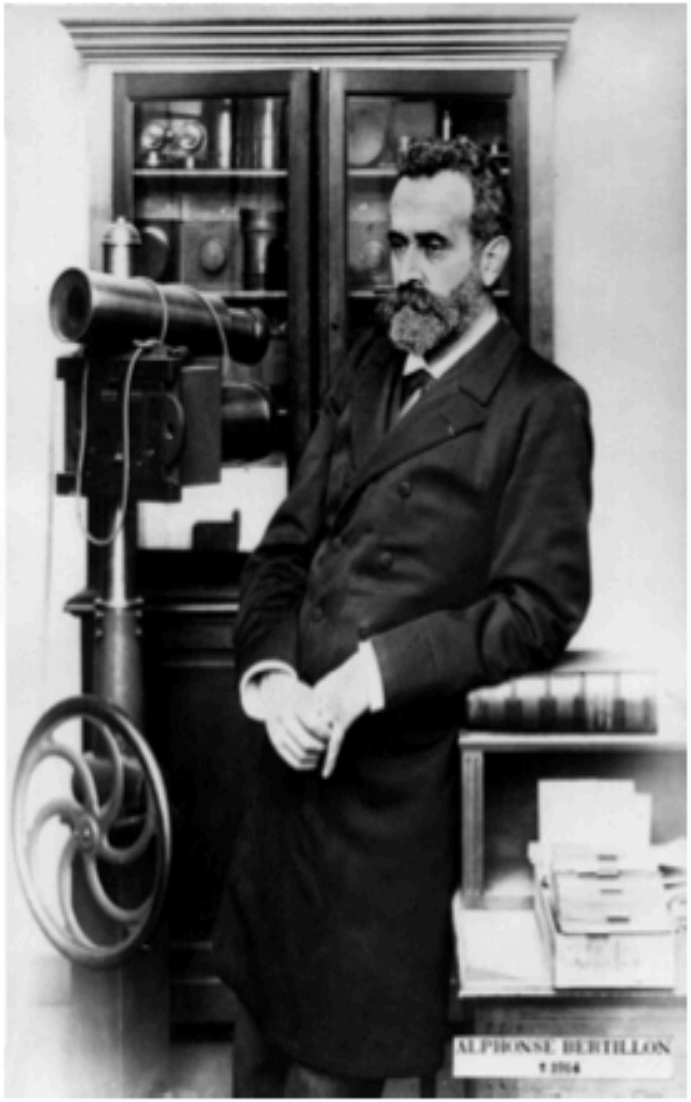


# Alternativní úvod

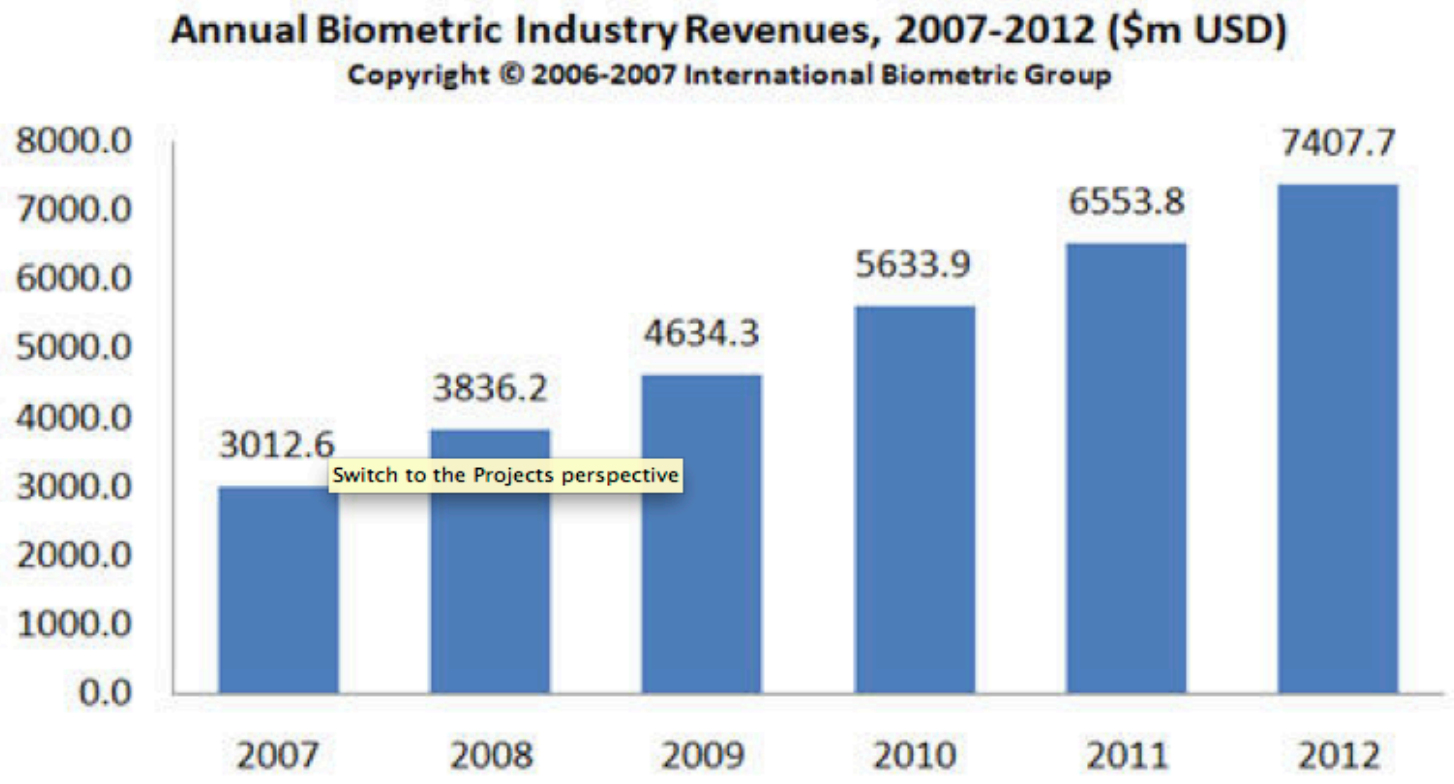
- Dobrodužství kriminalistiky na csfd
- Dobrodužství kriminalistiky na CT



# Alphonse Bertillon: Forensic Anthropometry

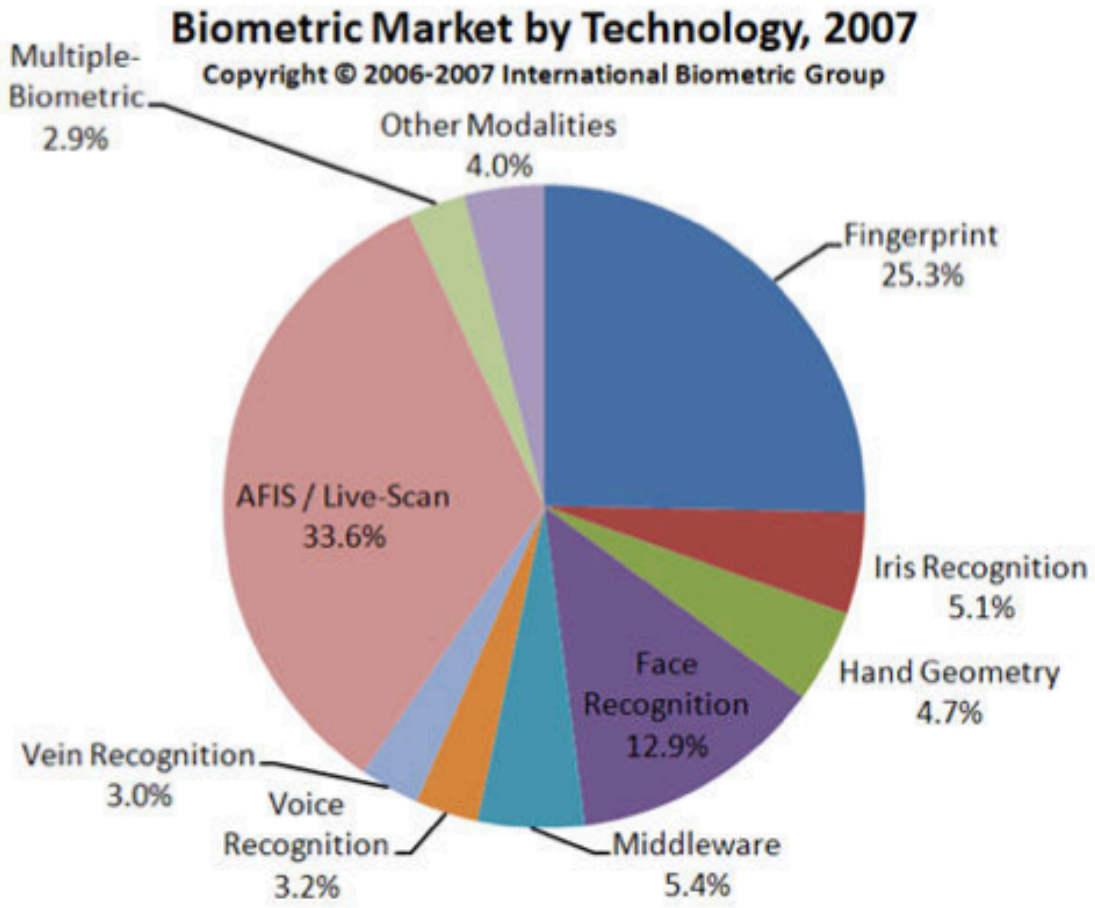


# Trend




"A Touch of Money"

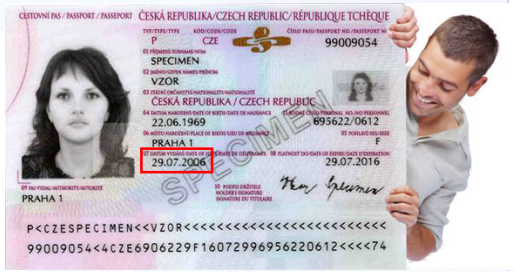
# Market Share



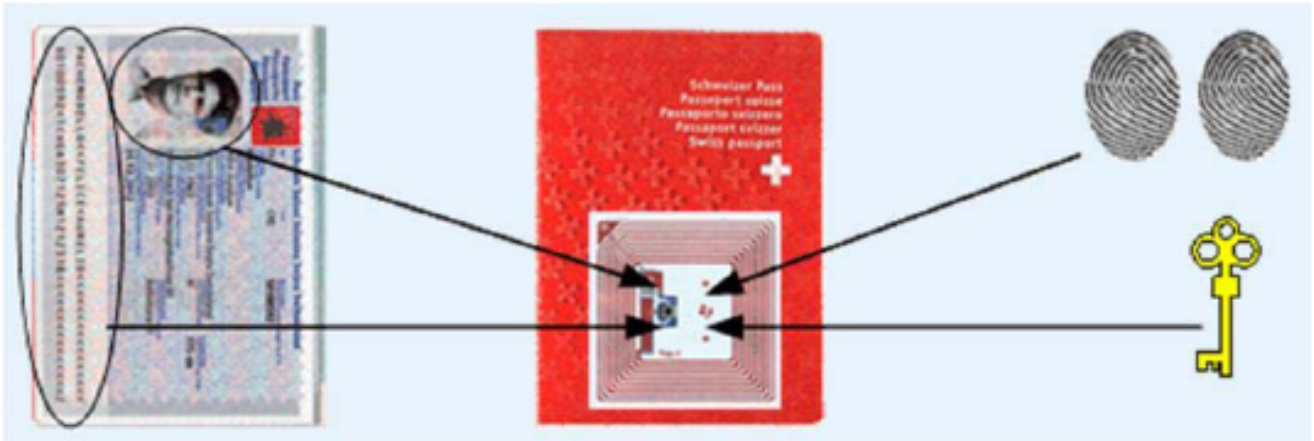
# ePassport – Biometricky pas

**Nutná podmínka pro výjezd do USA+ESTA, v ČR od roku 2006, od dubna 2009 s 2 otisky prstů**

http://czech.prague.usembassy.gov/biometricky_pas.html
http://www.youtube.com/watch?v=ptb_nxCpgYQ




In accordance with ICAO and EU specifications, the data of the machine readable zone, the facial image and two fingerprints plus electronic signatures will be stored in the chip.



**Integration of Technologies**: chip card (smart card), radio-frequency identification (RFID), electronic signatures and public key infrastructure (PKI), back-office systems (databases), biometrics

# Today: eBorders in the United Arab Emirates (UAE)

- Iris recognition system
- Fully operational since April 2003
- 36 land, air and sea ports
- 12,000 passengers each day

- 1 central database
  - Watchlist application
  - Fully networked
  - Enrolment centres: prisons and deportation centres
  - More than 1 million enrolments (150+ nationalities)
  - Exhaustive search takes <2 seconds

- 12 billion comparisons each day (12,000 passengers against 1 million enrolments)
- About 50,000 persons caught since launch

# Ukradená identita

Článek v NY times a v Telegraph, zodpovědný byl MOSAD

- February 2010: Dubai Hamas murder: Fraudulent foreign passports were used by the alleged killers of a Hamas commander in Dubai

- One of the victims of the identity theft was British-Israeli Paul John Keeley (picture right). The passport used by one of the suspected assassins bore his name, but featured a photograph of another man (pictured left)

# Další krádež identity

- DU – Unknown podívat se a ohodnotit na CSFD (71%)

# What is Biometrics?

The term "biometrics" is derived from the Greek words bio (life) and metric (to measure)

- **Biometrics** – automated recognition of individuals based on their biological and behavioral characteristics
  - *Scientific follow-on to Bertillon's body measurements of the late 1800s*
- **Biometry** – statistical and mathematical methods applicable to data analysis problems in the biological sciences
- **Biometric system** – essentially an automatic pattern recognition system that recognizes a person by determining the authenticity of a specific biological and/or behavioral characteristic (biometric modality) possessed by that person
- **Anthropometry** – measurement techniques of human body and its specific parts
  - ***Forensic (judicial) anthropometry*** *– identification of criminals by these measurement techniques*

laboratory
erstner

versity

# Historie Biometrie

- **Pěkné shrnutí** http://www.biometrics.gov/documents/biohistory.pdf
- **Nejstarší kresby v jeskyni Chauvet, otisk dlaní – To jsem namaloval já! (dokument od Herzoga)**

- Ancient civilisations practised biometric techniques routinely.

Sumerians considered a hand print and outline of a hand on a clay tablet a good identifier.

- Egyptians brought the concept of biometric identity verification into the mainstream, in many various ways:
  - From discrete anatomical measurements, e.g., distance between the individuals outstretched thumb and the tip of the elbow
  - To more general notification of individual features, e.g., Nechutes, son of Asos, aged 40, of middle size, sallow complexion, cheerful countenance, long face with straight nose and a scar upon the middle of his forehead.

# Identity Verification by Animals - Examples

- Penguins - by voice recognition to locate their offspring within a population sometimes numbering hundreds of thousands
- Frogs – discriminate between neighbours and strangers by voice recognition
- Hawks and other birds – by using visual information
- Wolves – by voice at a distance and corroborate this information by visual cues and scent at shorter distances
- Insects (bees, wasps, ants, etc.) – practice identity verification routinely

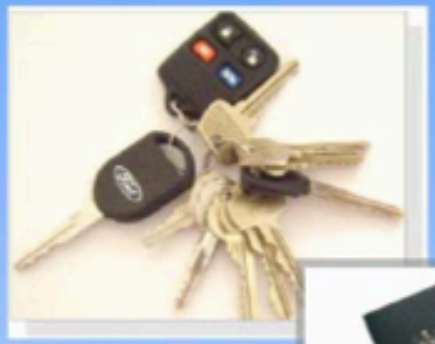
# Traditional modes of authentication



- Possession-based schemes

  Based on ID cards, tokens, keys, etc.

  **WHAT YOU HAVE**

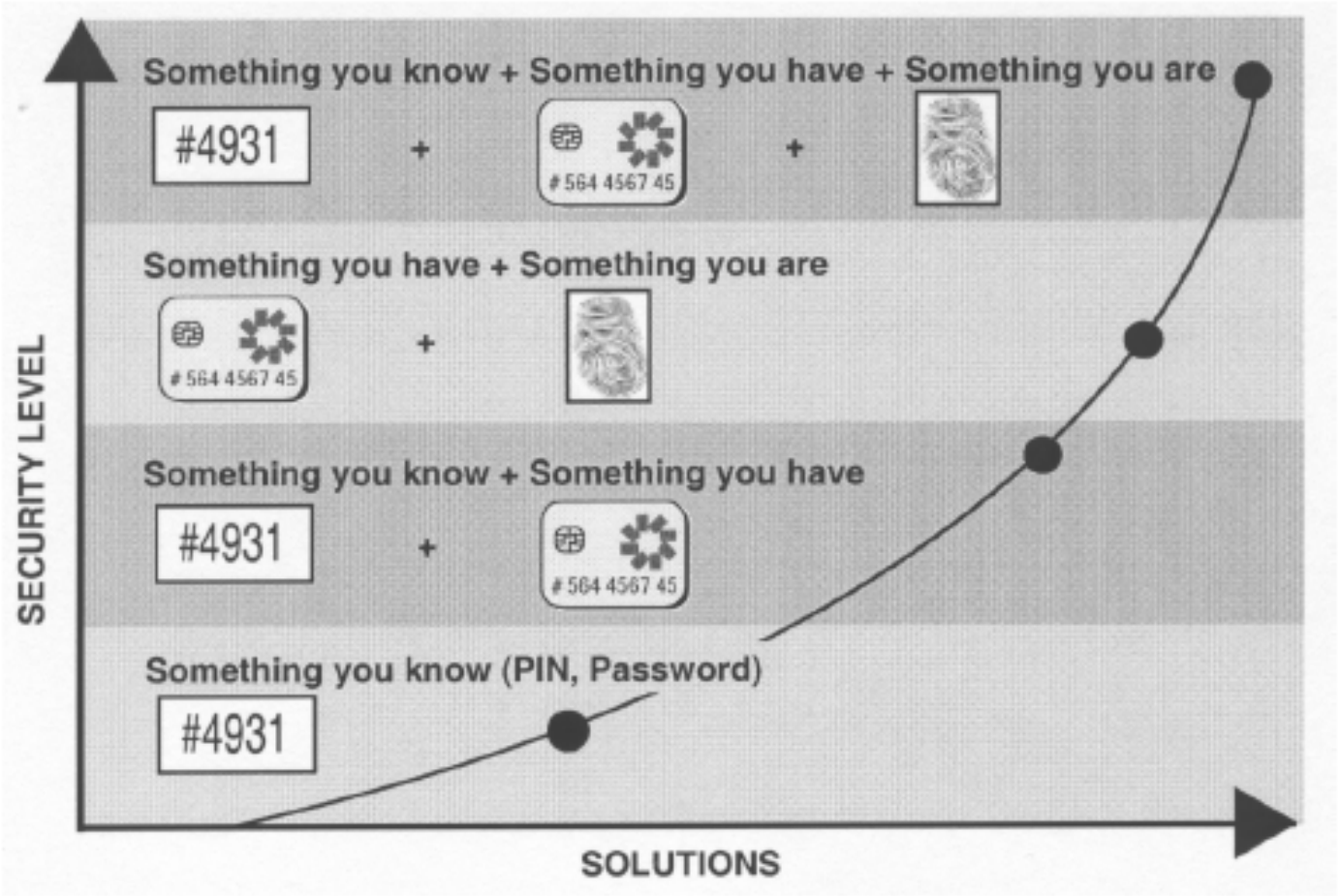


- Knowledge-based schemes

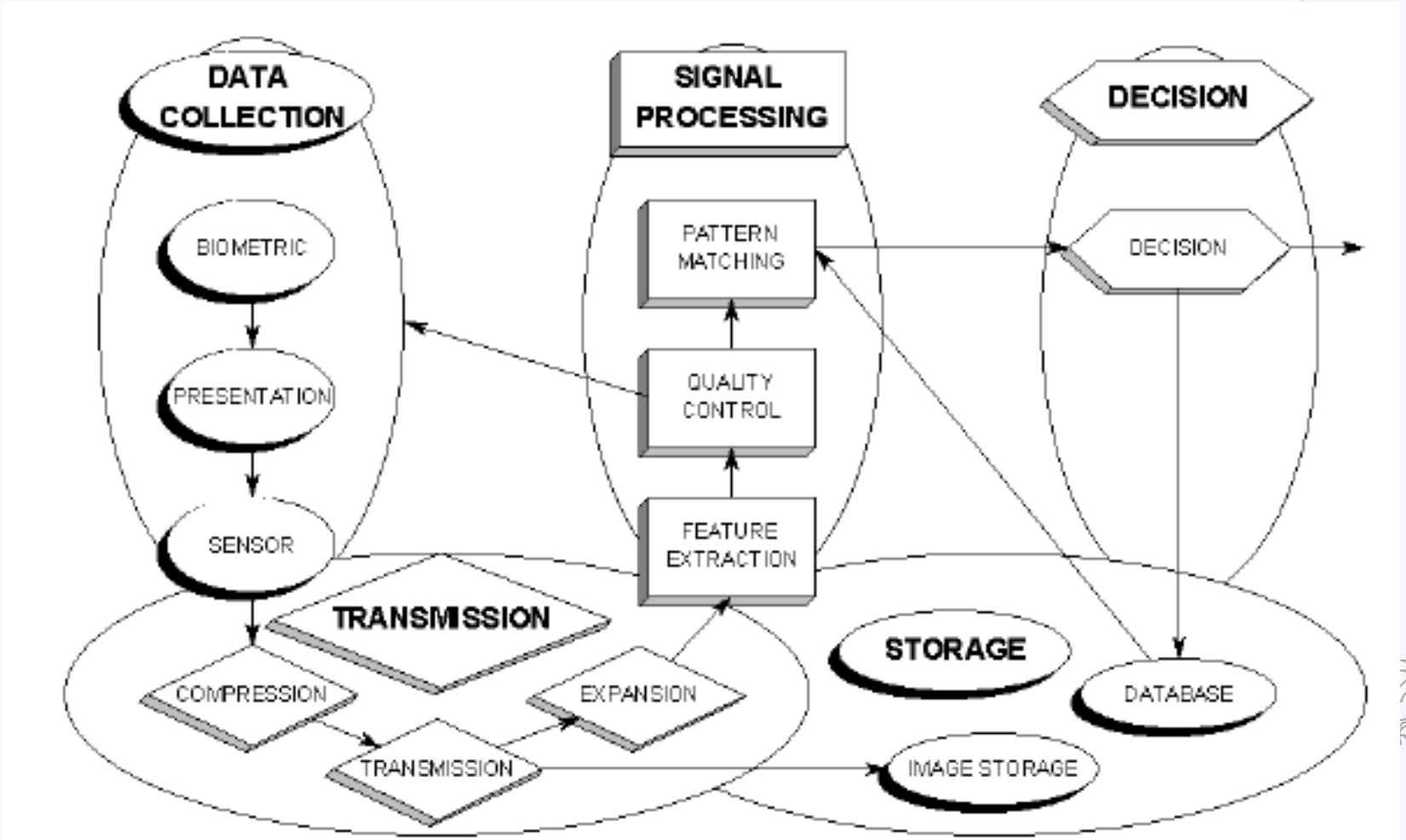
  Based on passwords, PINs, etc.

  **WHAT YOU KNOW**

# Three basic means



# Generic Biometric System

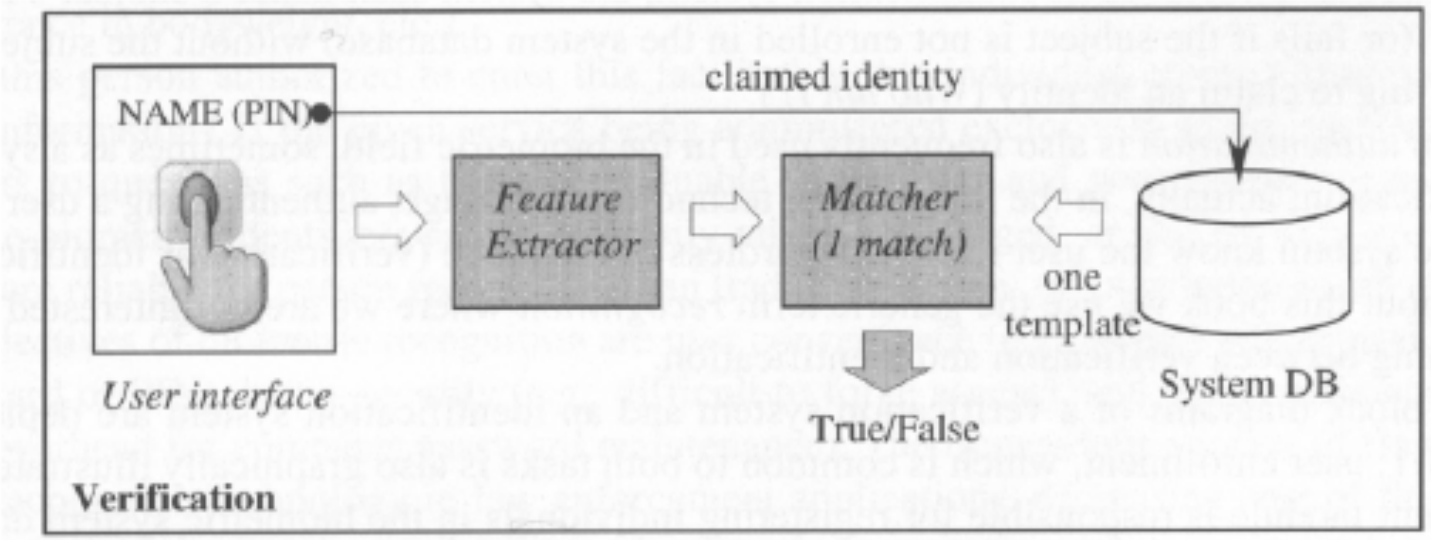


# Pattern Recognition System

Two patterns are similar, if an appropriately defined distance measure between their feature vectors is small

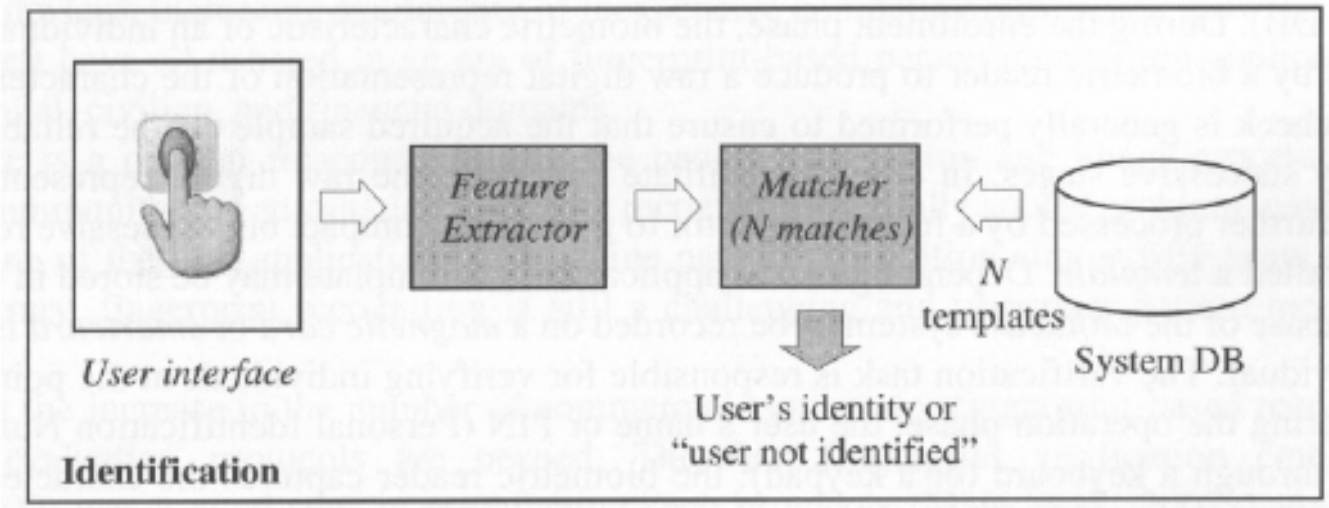
# Person recognition

- Verification – biometric system function that performs a one-to-one comparison of a submitted biometric characteristic (sample) set against a specified stored biometric references, and returns the comparison score and decision.
- "Is this person who he claims to be?"

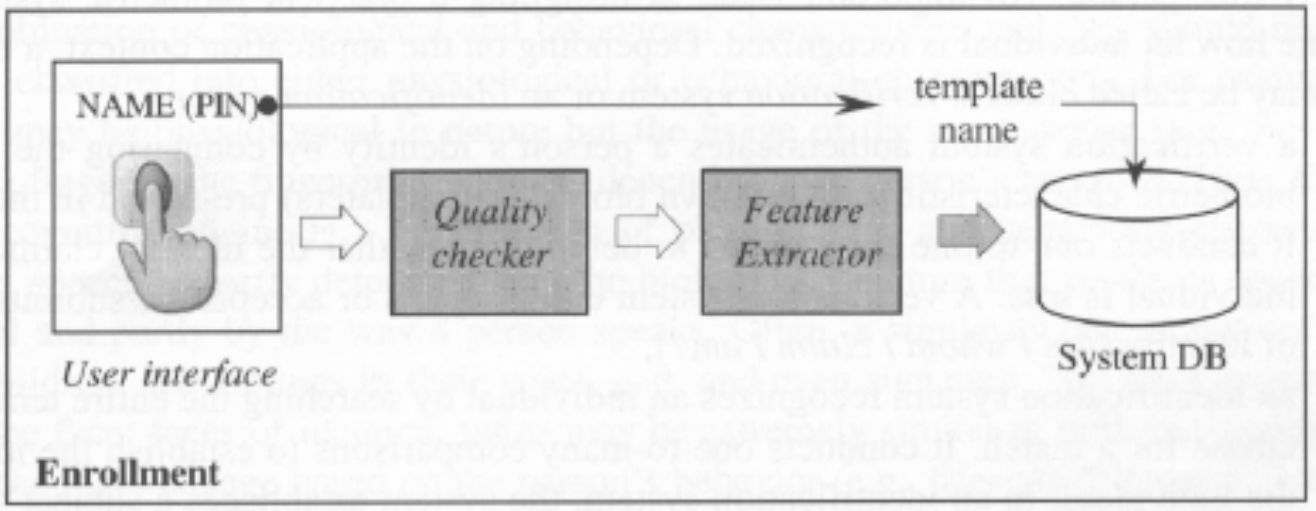


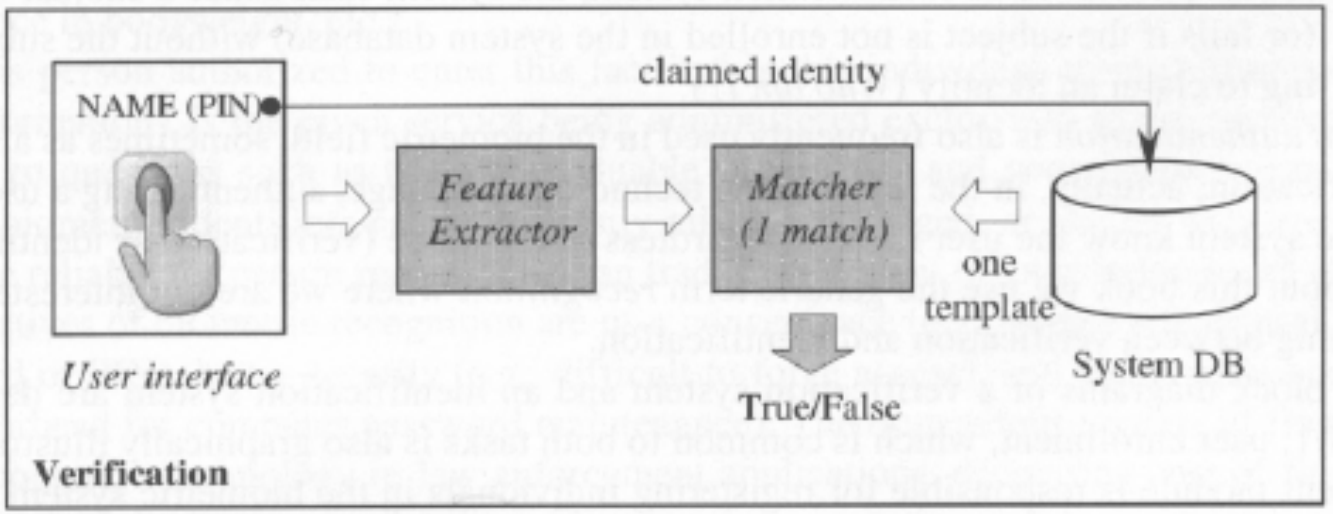
# Identification

- Identification – biometric system function that performs a one-to-many comparison/search process in which a biometric characteristic set is compared against all or part of the database to find biometric references with a specified degree of similarity.
- "Who is this person?"



# Enrollment


NAME (PIN)
template name
Quality checker
Feature Extractor
System DB
User interface
Enrollment


claimed identity
NAME (PIN)
Feature Extractor
Matcher (1 match)
one template
System DB
User interface
True/False
Verification

# Some statistics of Mobile devices

Nice example – Motorola Atrix 4G using swipe fingerprint AuthenTec sensor
Company was bought by Apple in July 2012 for 356$ mil (8$ for share – cutrent value: 5$)

- Some statistics:
  - 35,000 laptops reported stolen in the UK each year
    (Times Online's estimate: 110,000 stolen laptops/year)
  - only 3% ever retrieved

- Several million biometrically enabled phones, PDAs and peripherals now on the market

SecurePhone

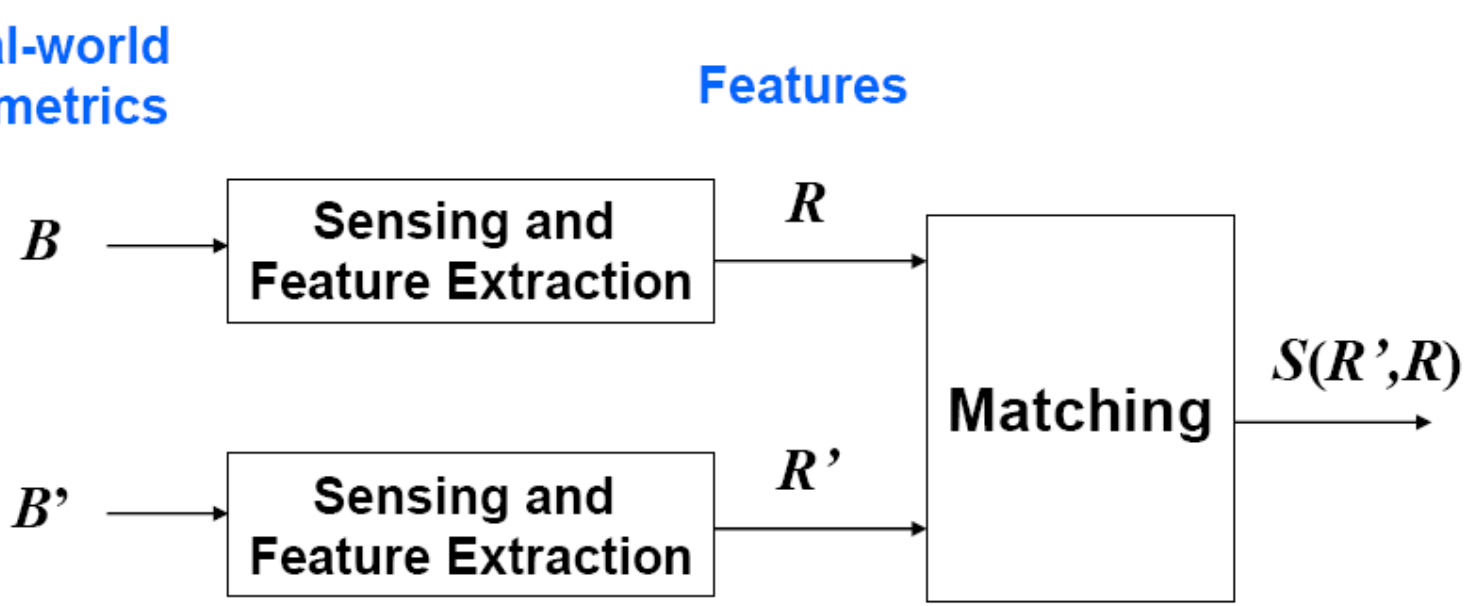
# Mobile phone apps

- DU: vyzkouset a vyvesit na facebook ci Twitter¨
- BioLock, youtube video:

# Example Iris & Speech

- Example
  - Assume 10'000 customers are signed up for biometric authentication and 1'000 transactions are done weekly
  - Assume best-case biometric verification error of 1 in 1 million (iris)
  - Assume best-case speaker verification error of 1 in 1 hundred
  - How often are customers falsely billed?
- Answer
  - On average 10 people are falsely billed each week
  - On average 100 000 people are falsely billed each week

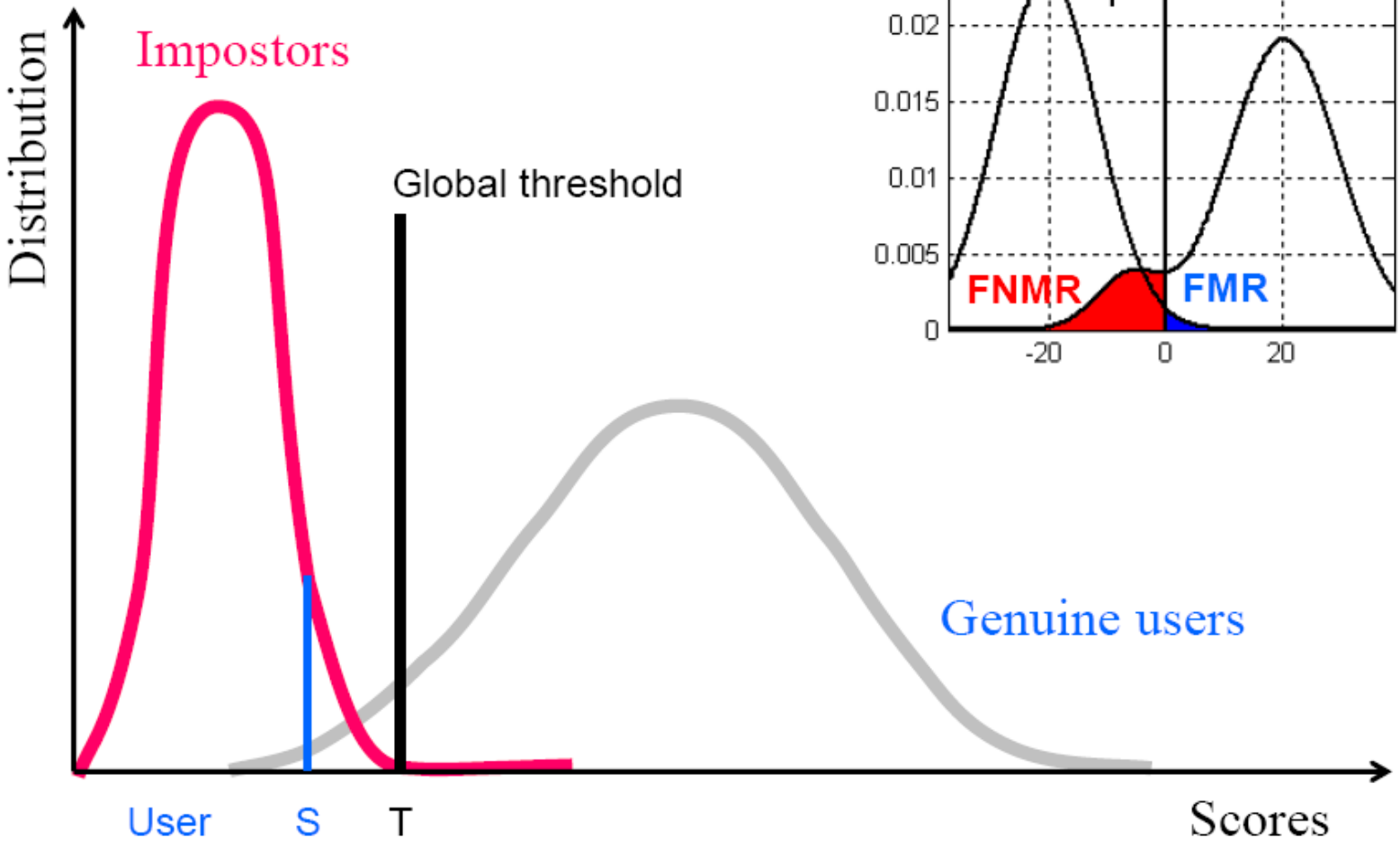
# Matching

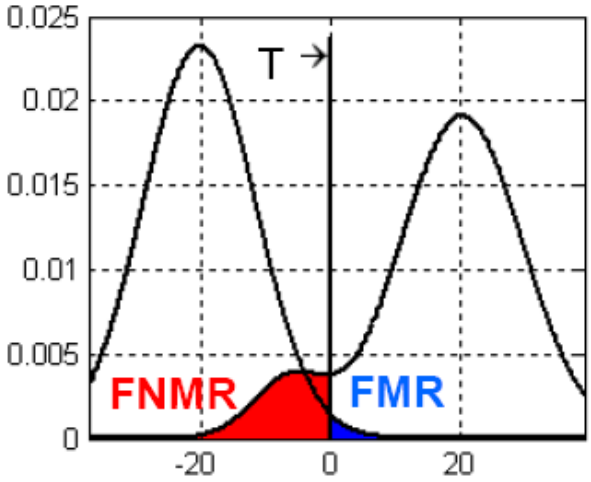



$$s(R', R) = s(f_{t'}(B'(t')), f_t(B(t)))$$

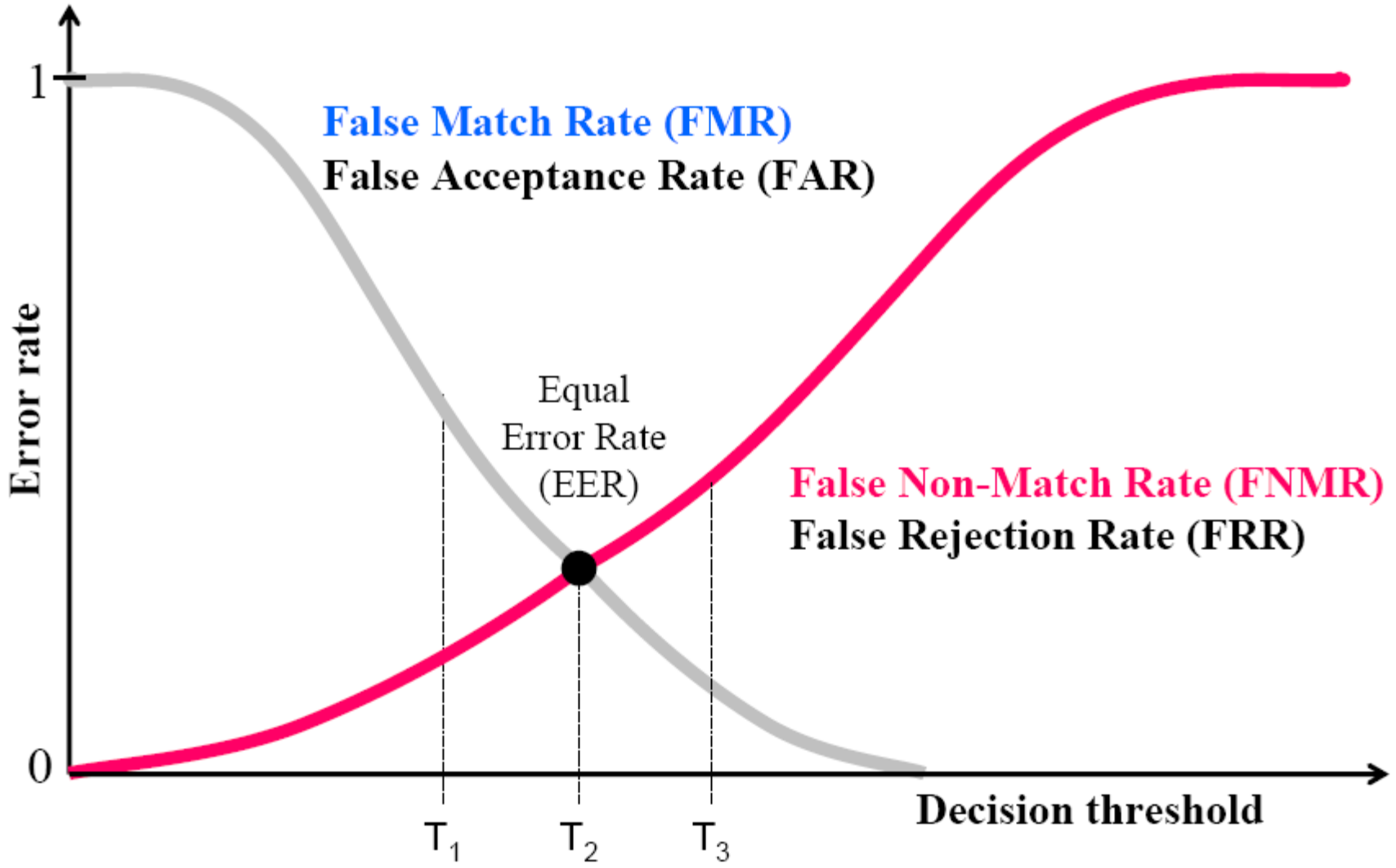
Biometric matching makes a decision by computing a measure of the likelihood that the two input samples from two persons are the « same » and hence that the subjects are the same real-world identity.

# Performance evaluation



# FMR and FNMR

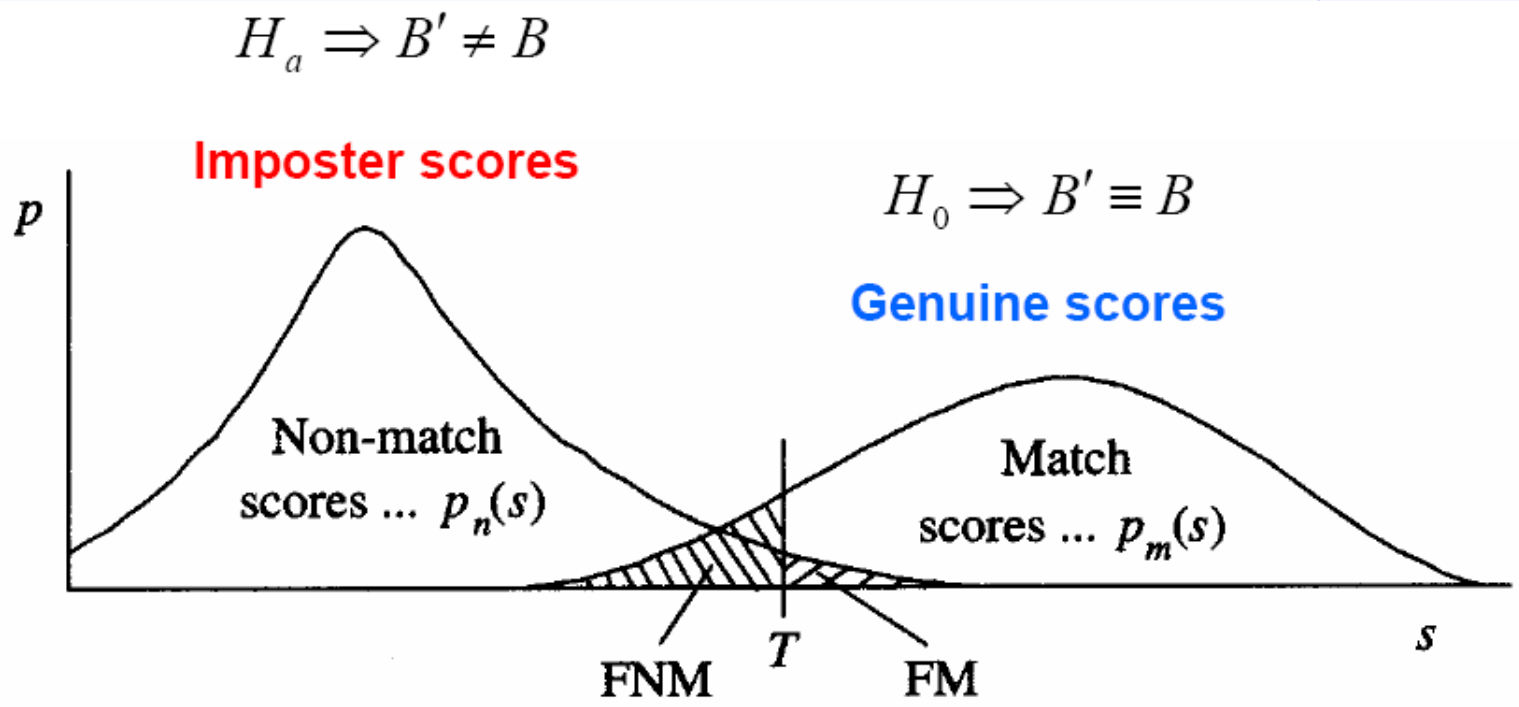

1
0
Error rate
False Match Rate (FMR)
False Acceptance Rate (FAR)
Equal
Error Rate
(EER)
False Non-Match Rate (FNMR)
False Rejection Rate (FRR)
T1
T2
T3
Decision threshold

# FA & FR

- **False Accept (FA):** Deciding that a (claimed) identity is a legitimate one while in reality it is an imposter; False Accept Rate (FAR)
- **False Reject (FR):** Deciding that a (claimed) identity is not legitimate when in reality the person is genuine; False Reject Rate (FRR)

- A **FA** results in security breaches, with an unauthorized person being admitted
- A **FR** results in convenience problems, since genuinely enrolled identities are denied access to the application

# Scores distribution




Given two biometric samples, we can construct two possible hypotheses:

| | | |
|---|---|---|
| The null hypothesis: | $H_0 \Rightarrow$ | the two samples match |
| The alternate hypothesis: | $H_a \Rightarrow$ | the two samples do not match |

# Two kinds of error

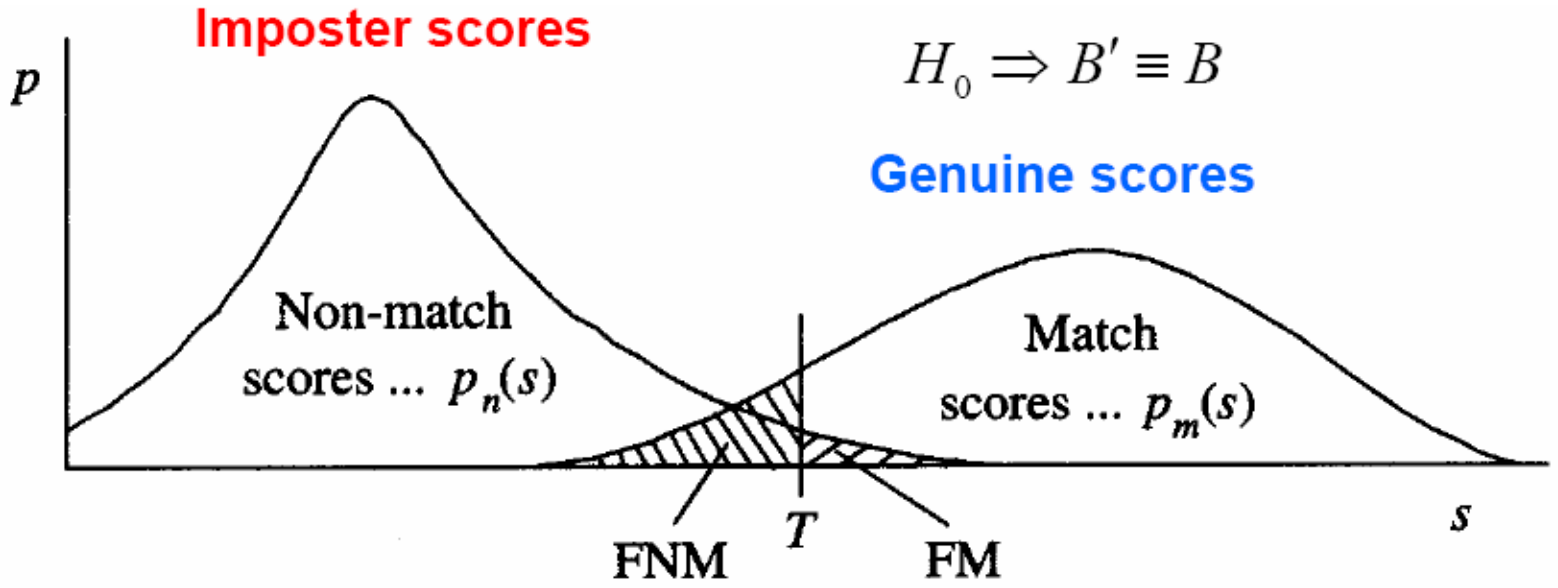
- Verification:

$$\text{Decide } H_0 \text{ is true: if } s > T,$$
$$\text{Decide } H_a \text{ is true: if } s \leq T.$$

- Type I Error - False Match (FM): Deciding that two biometrics are from the same identity, while in reality they are from different identities; the frequency with which this occurs is called the False Match Rate (FMR)
- Type II Error – False Non-Match (FNM): Deciding that two biometrics are not from the same identity, while in reality they are from the same identity: the frequency with which this occurs is called the False Non-Match Rate (FNMR)
- Correct Match: correctly deciding that two biometric samples match
- Correct Non-Match: correctly deciding that the samples do not match

# Two kinds of error

$$H_a \Rightarrow B' \neq B$$

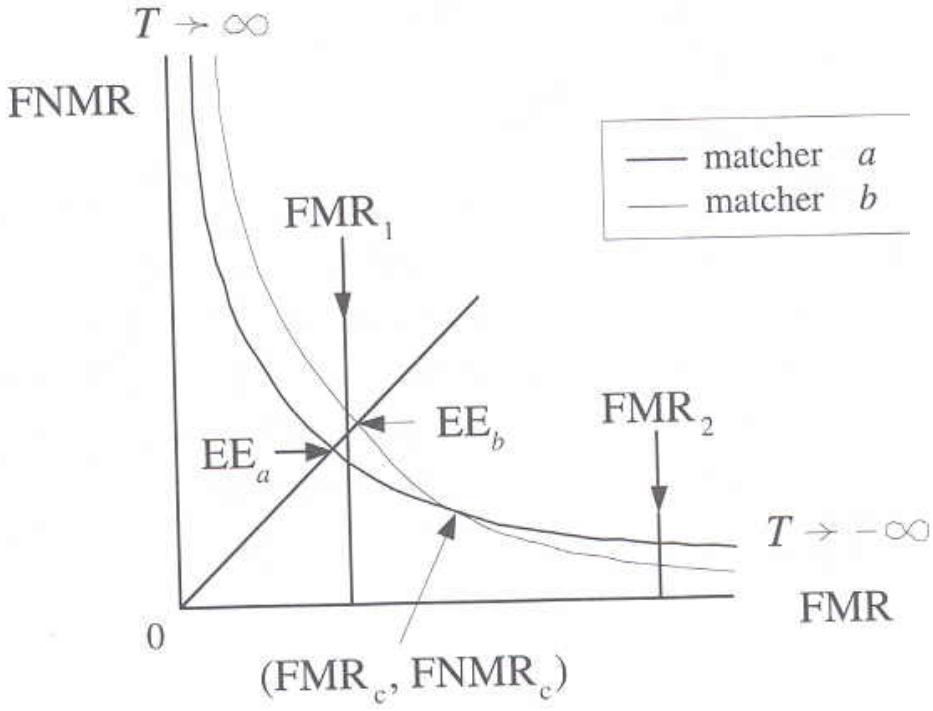


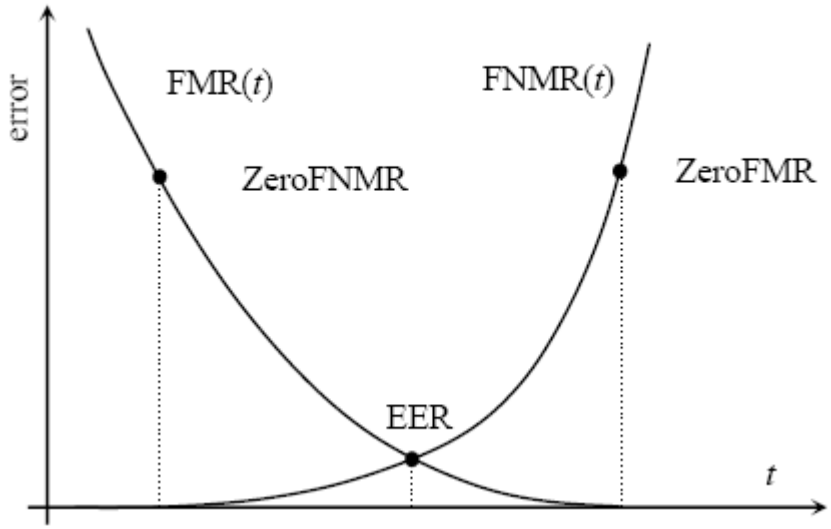

$$\mathrm{FNMR}(T) = \int_{s=-\infty}^{T} p_m(s)ds$$

$$\mathrm{FMR}(T) = \int_{s=T}^{\infty} p_n(s)ds$$

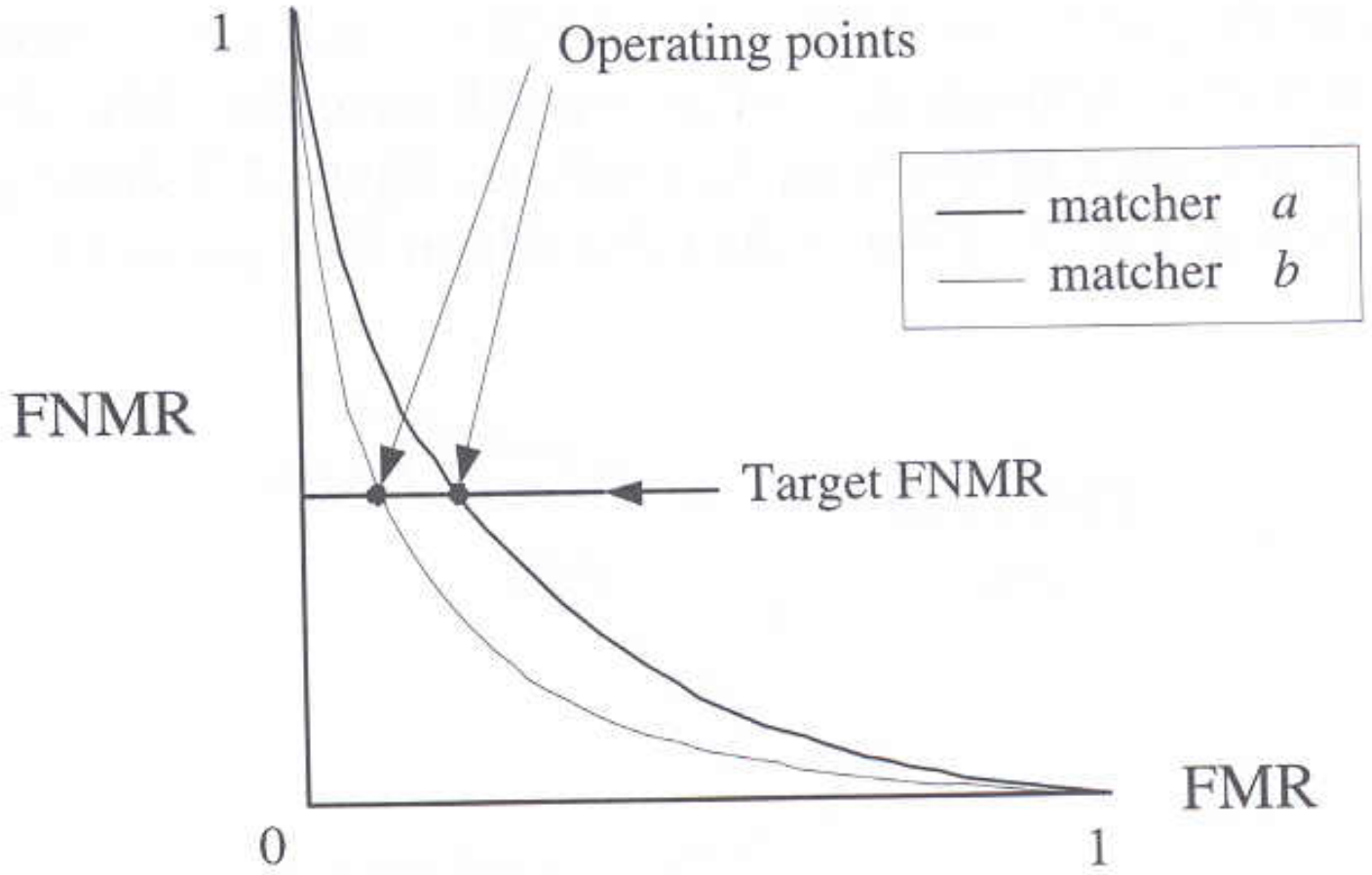
# The Equal Error Rate

- ROC:



# Using the ROC Curve




Matcher *b* is always better than matcher *a* since for every possible FNMR, its FMR is lower

# Main Sorting

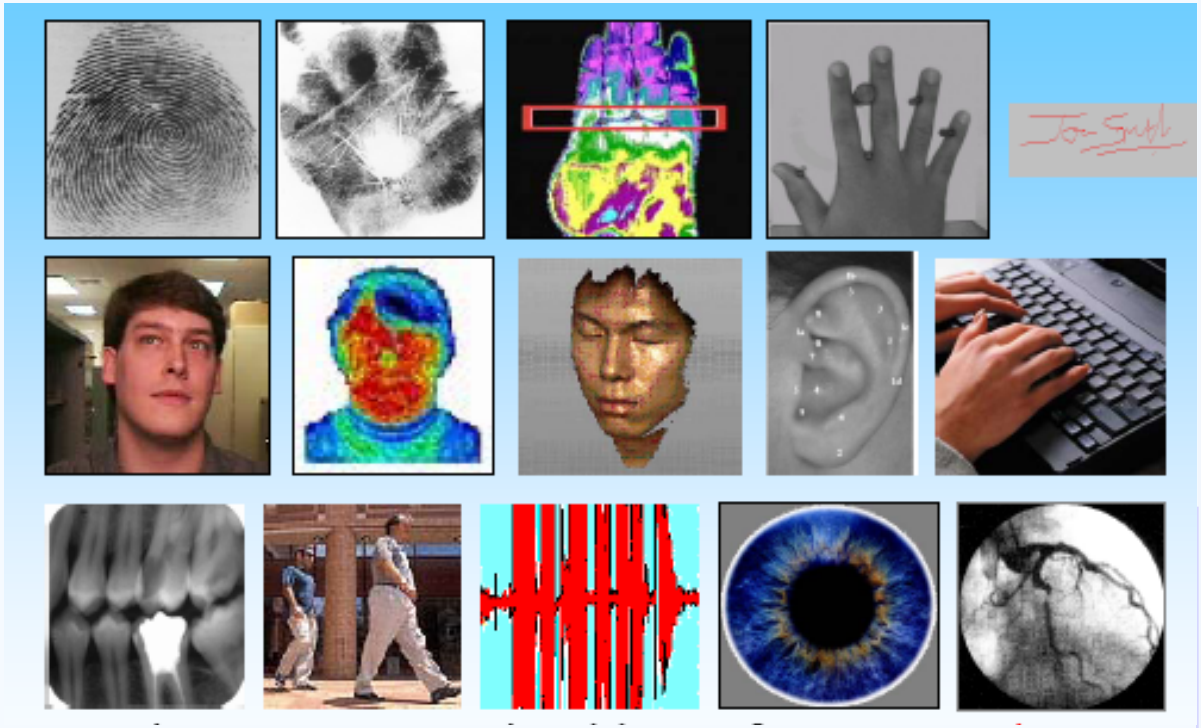
Biometrics can be sorted into two classes:

- Physiological

  ***Examples:*** ***face, fingerprint, hand geometry and iris recognition***

- Behavioral

  ***Examples:*** ***signature and voice***



# Biometric Identifiers

Common:

- *Fingerprint Recognition*
- *Face Recognition*
- *Speaker Recognition*
- *Iris Recognition*
- *Hand Geometry*
- *Signature verification*

Others:

- DNA
- Retina recognition
- Thermograms
- Gait
- Keystroke
- Ear recognition
- Skin reflection
- Lip motion
- Body odor

laboratory Gerstner

# Some More* …

| Vein Pattern |
| --- |
| Sweat Pores |
| Fingernail Bed |
| Hand Grip |
| Brain Wave Pattern |
| Footprint and Foot Dynamics |

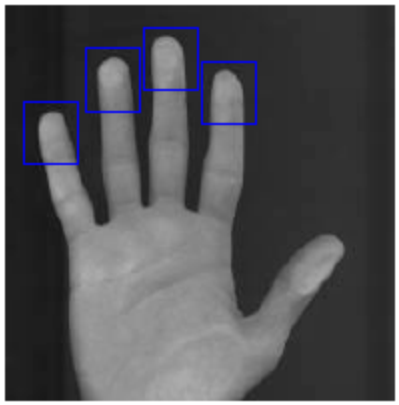
•*See details in ***Chapter 7 Esoteric Biometrics*** of ***Biometrics*** by John D. Woodward, Nicholas M. Orlans, Peter T. Higgins, New York : McGraw-Hill/ Osborne, c2003

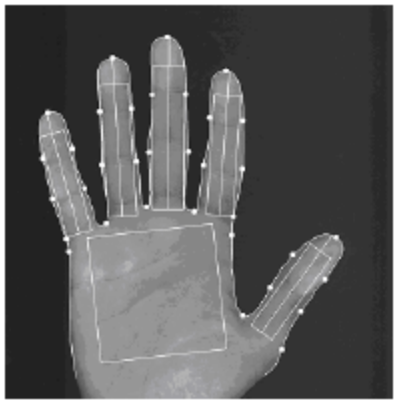
# 1. Fingerprint Recognition (D.Novak)

- An extremely useful biometrics technology since fingerprints have long been recognized as a primary and accurate identification method.

Hand shape

Fingerprints





Palm print

Finger strips
(digitprints)

Palmar veins

# Acquisition Devices

- ✓ Ink & paper – the oldest way
- ✓ Ink-less Methods - sense the ridges on a finger

– "Livescan" fingerprint scanners

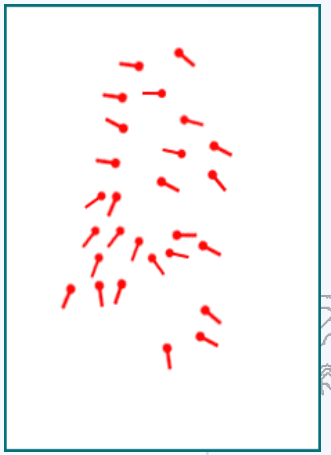
- ➢ Optical methods (FTIR)
- ➢ CMOS capacitance
- ➢ Thermal sensing
- ➢ Ultrasound sensing

## Minutiae

- Uses the ridge endings and bifurcation's on a persons finger to plot points known as Minutiae
- The number and locations of the minutiae vary from finger to finger in any particular person, and from person to person for any particular finger

•Finger Image

•Finger Image + Minutiae



•Minutiae

Capture

Extraction

Comparison

Verify individual?

No

Access denied cannot sign record

Yes

Access to application sign records

Scan left index finger

Thin image to a single pixel

Sample minutia graph

Acceptable score

?

Identify minutiae

ending minutiae

bifurcation minutiae

Reference minutia graph for individual

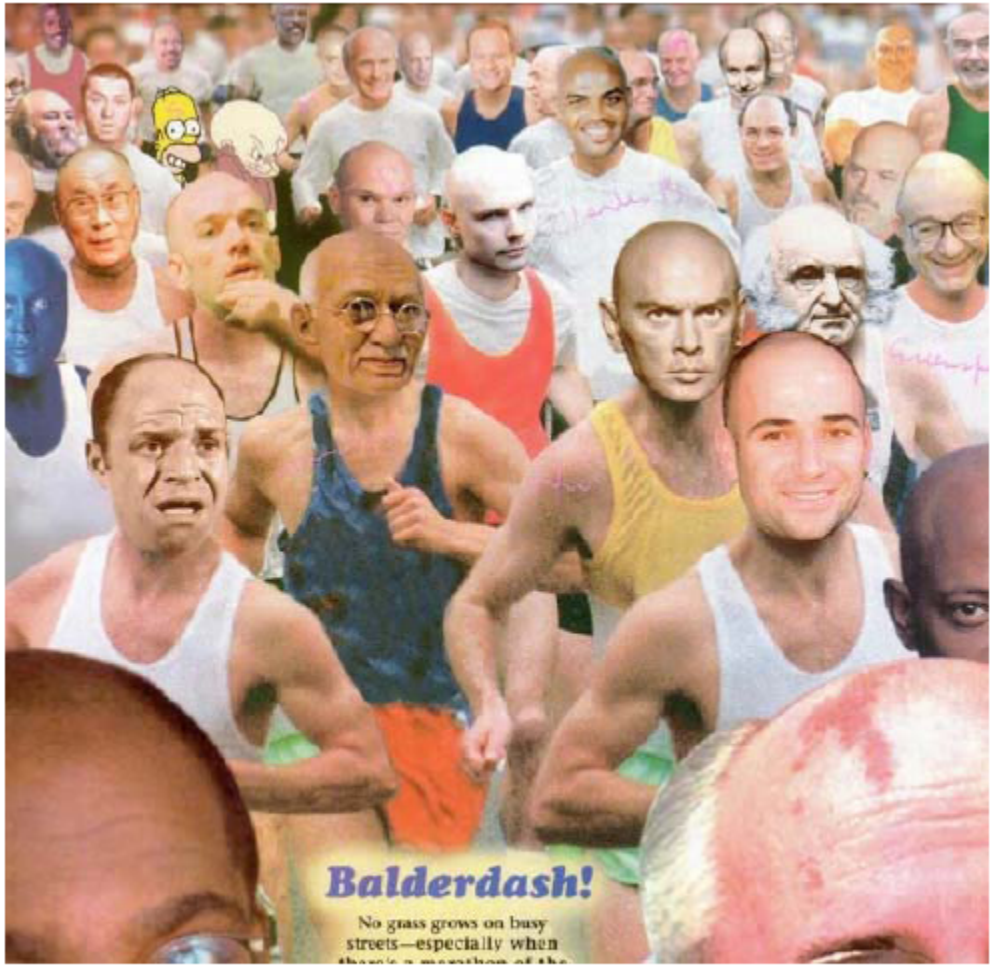
Minutia graph

## 2. Face Recognition (V. Franc)

- Uses an image or series of images either from a camera or photograph to recognize a person.
- Principle: analysis of the unique shape, pattern and positioning of facial features.

laboratory Gerstner

# Who is there??




Games Magazine, September 2001

# Why face?

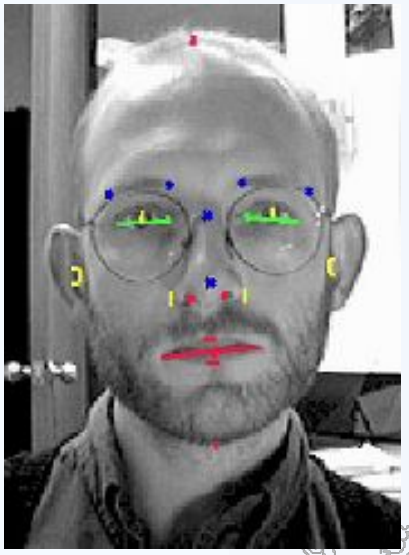
- Face is the most common biometric characteristic used by humans
- Sensing at a distance
- Easy to capture from low-cost cameras
- Non-contact data acquisition (free from contagious disease)

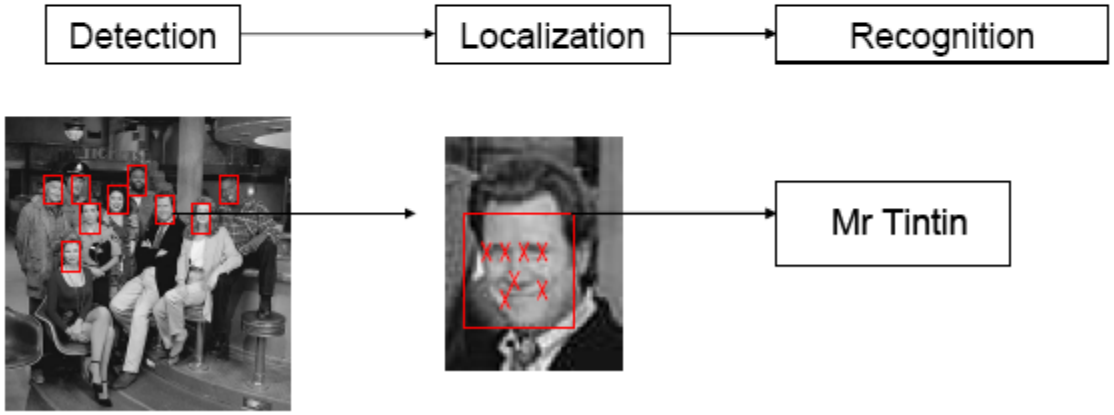
- Non-intrusive technique which people generally accept as biometric characteristic
- Overt (user aware) and covert (user unaware, e.g. ubiquitous surveillance cameras) applications
- Legacy databases (passport, visa and driver's license)

# Details

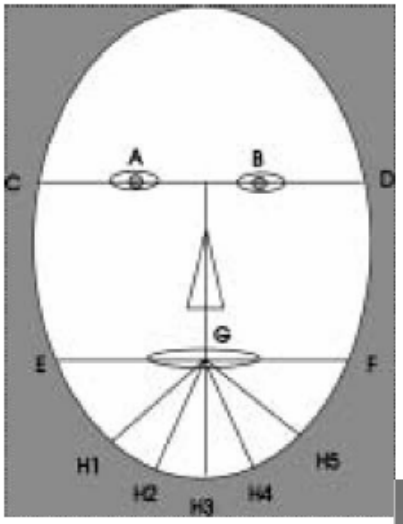
- Source of data: Single image, video sequence, 3D image and Near Infrared
- Models: weak models of the human face that model face shape in terms of facial texture

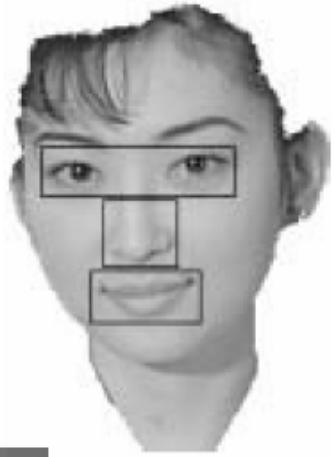
- **Face detection** – discriminating faces from all other possible images. This is 2-class classification task of assigning an image to the face class or the non-faces class.
- **Face localization** – finding precisely the position of one face, whose presence is already known in a single image

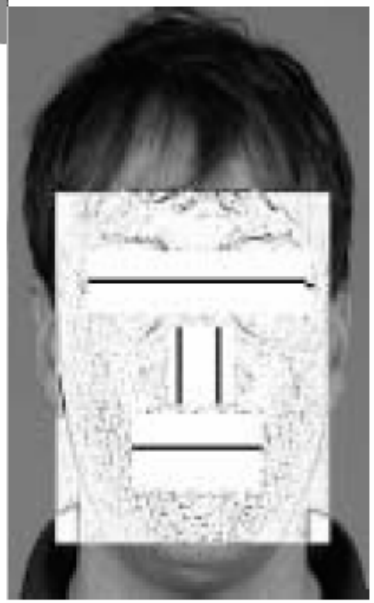


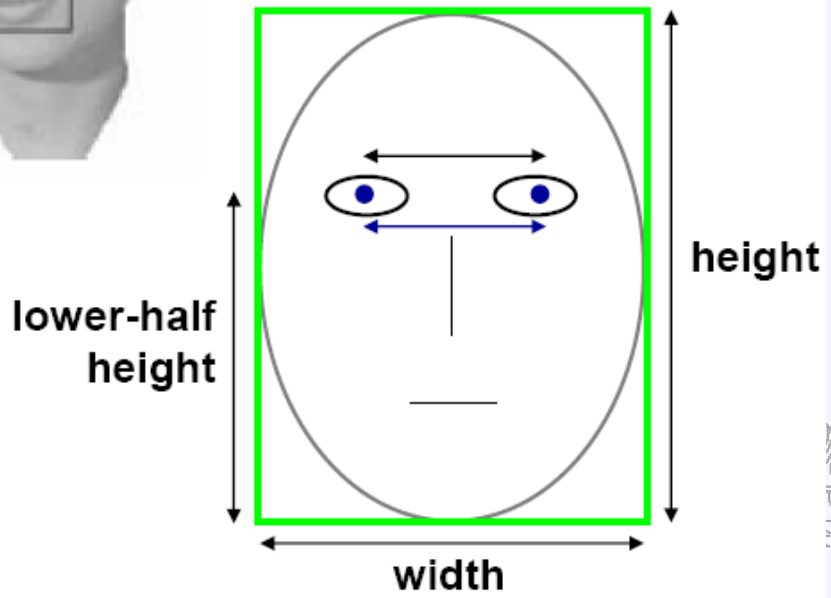


# Feature based approach

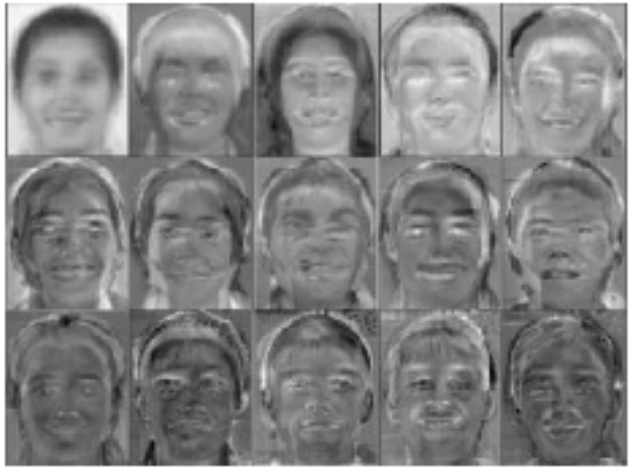






# Example: Eigenfaces

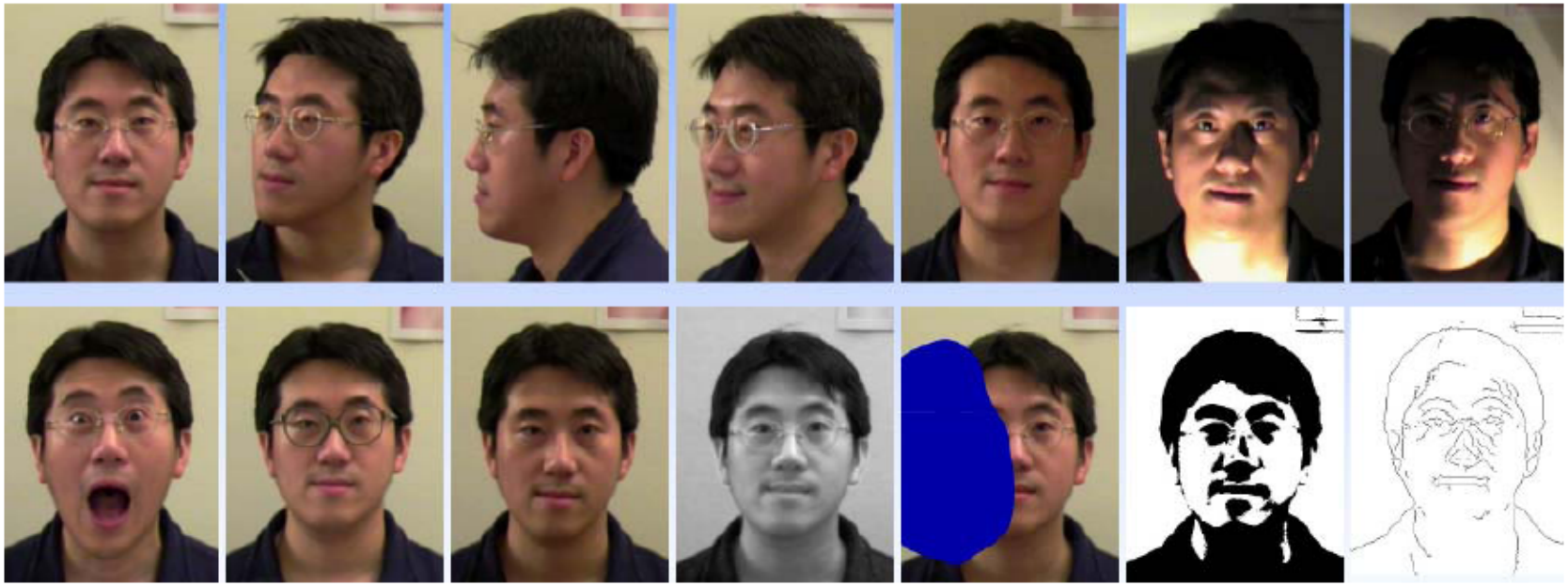


Perfect reconstruction with all eigenfaces

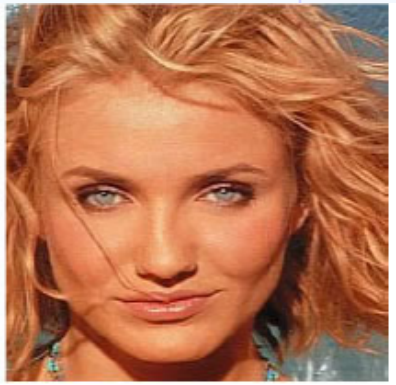
Reasonable reconstruction with just a few eigenfaces

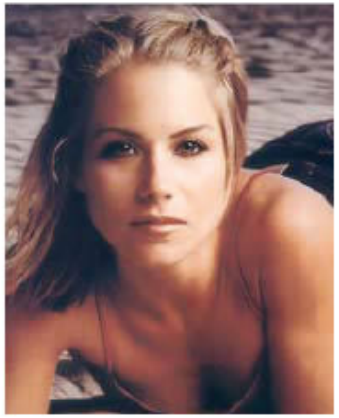
# Intra-class variability

- Faces with intra-subject variations in pose, illumination, expression, accessories, color, occlusions, and brightness



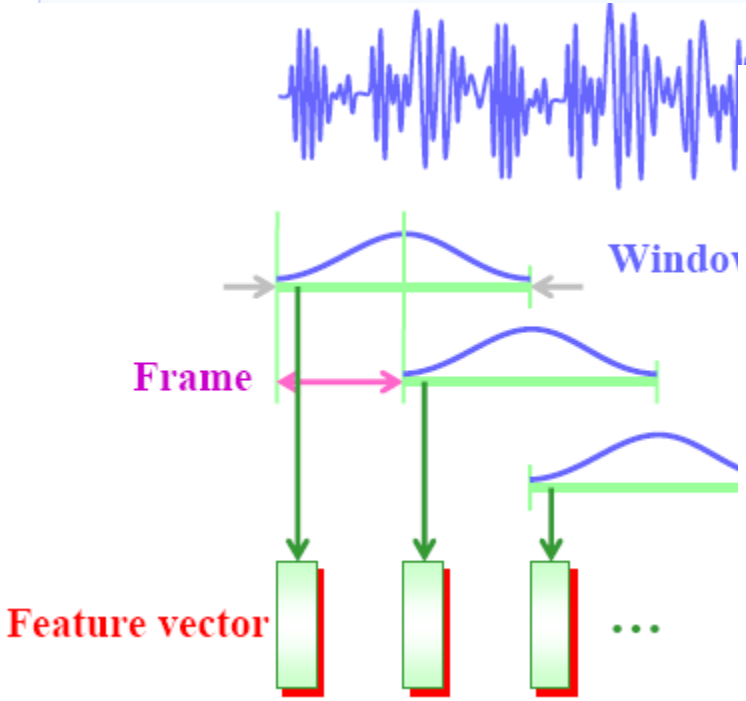
# The power of make up

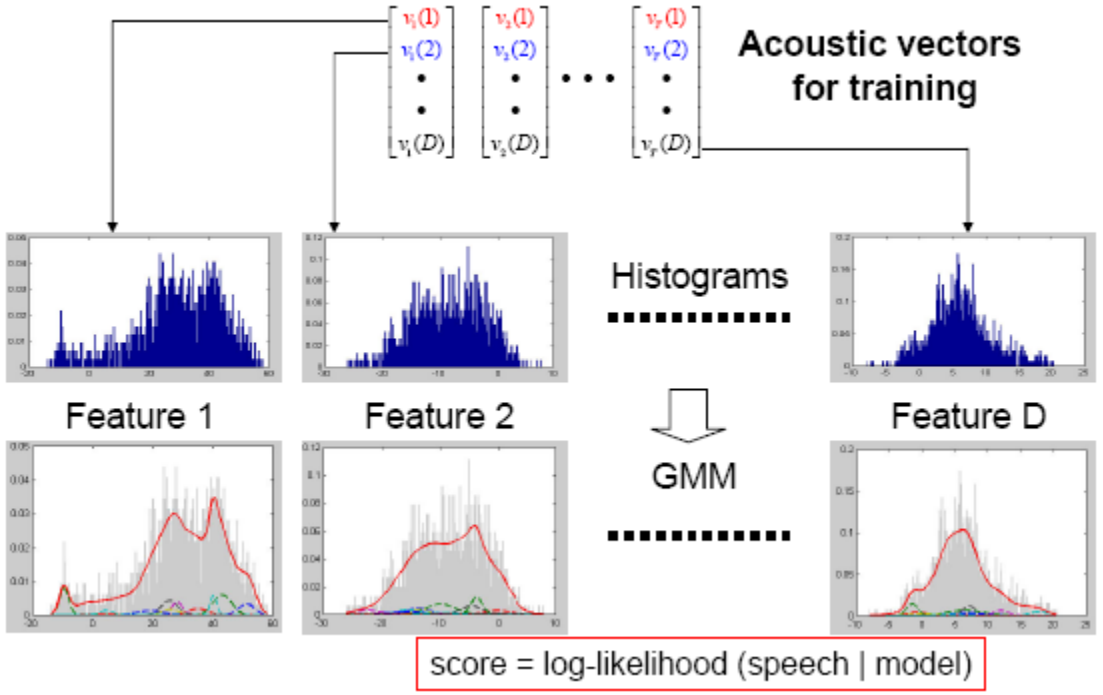




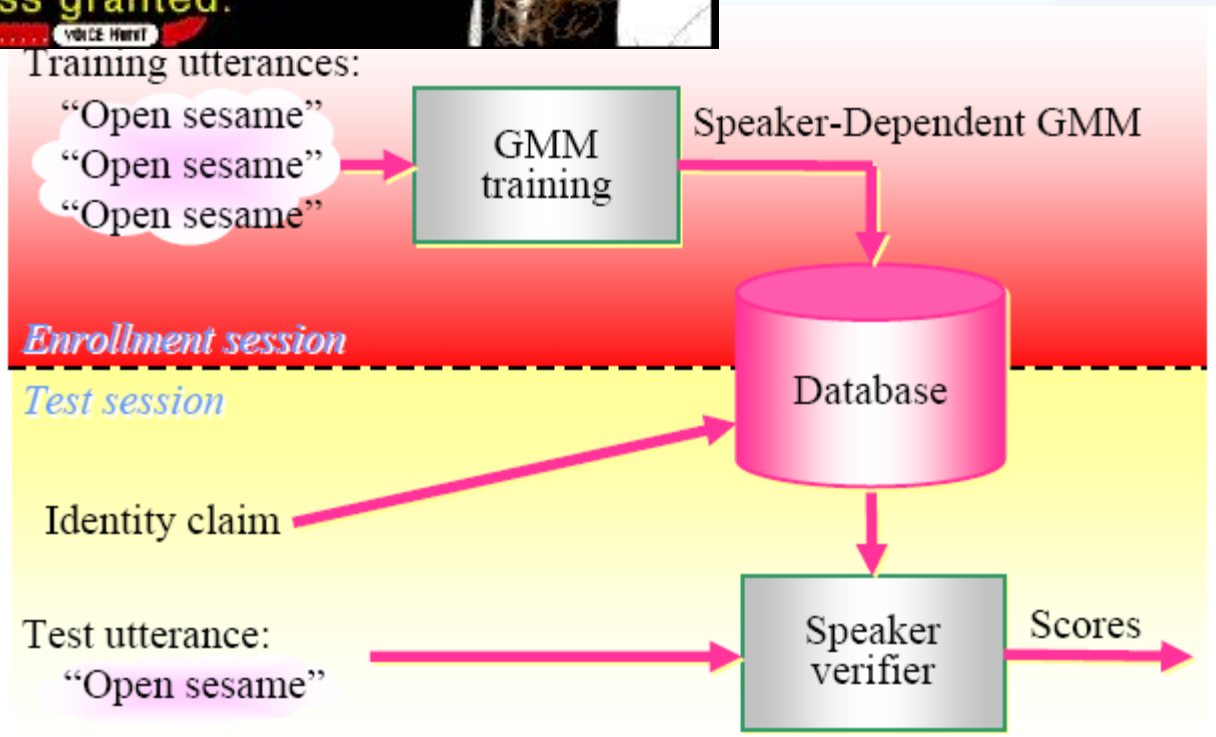
# 3. Voice Recognition (P. Polak)

- Voice recognition is not the same as speech recognition, it is speaker recognition
- Considered both physiological and behavioral
- Popular and low-cost, but less accurate and sometimes lengthy enrollment



# Application categories



# Features

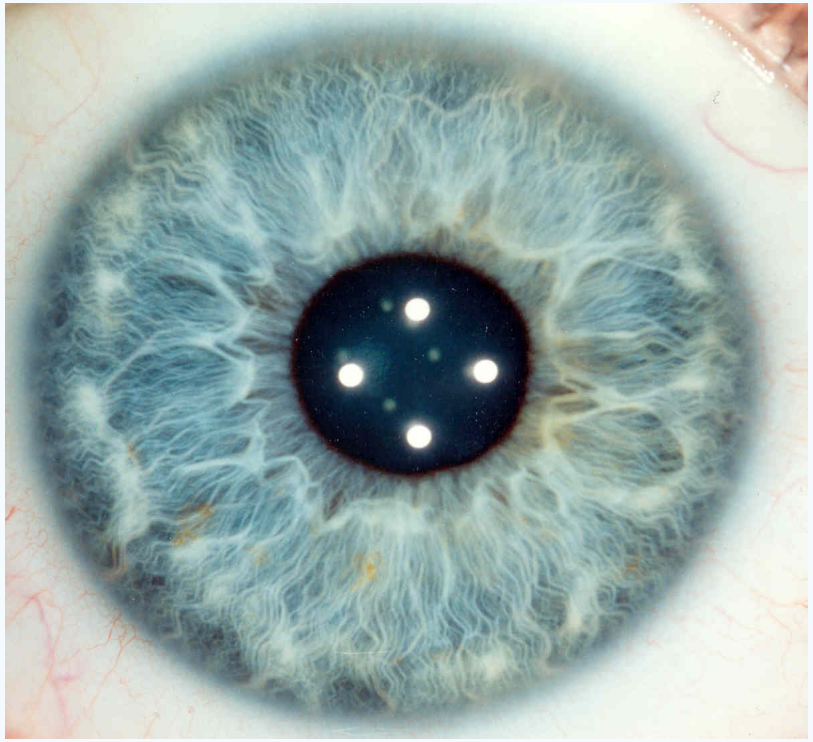
- Advantage
  - Less requirements for users, such that they do not have to go through a separate process for verification
  - Very little hardware is required, and ideally suited to **telephone-based** system for a remote identification
  - **Zero client-side cost, no special reader needs to be installed**
- Disadvantage
  - Acoustic features : 1. Misspoken or misread phrases; 2. The human voice's tremendous variability, due to colds, aging, and simple tiredness
  - Can be captured surreptitiously by a third party and replayed

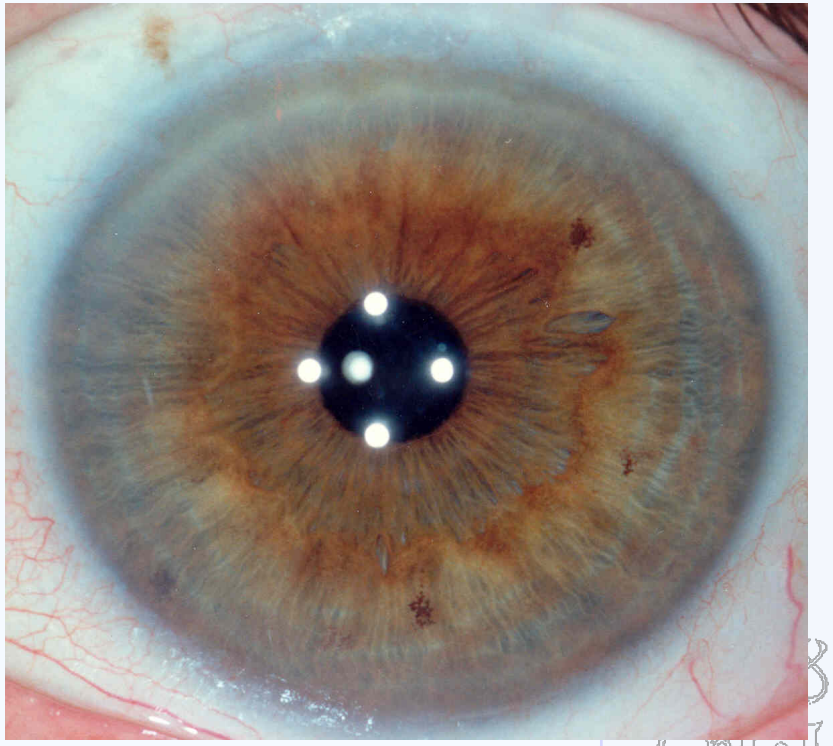
# 4. Iris recognition (E. Bakstein)

- Analysis of the iris of the eye, which is the colored ring of tissue that surrounds the pupil of the eye.
- Based on visible features, i.e. rings, furrows, freckles and the corona. Features and their location are used to form the Iriscodes, which is the digital template.
- **Widely regarded as the most safe, accurate biometrics technology and capable of performing 1-to-many matches at extraordinarily high speeds, without sacrificing accuracy**.
- VIDEO: http://www.youtube.com/watch?v=QEQEht8zloQ

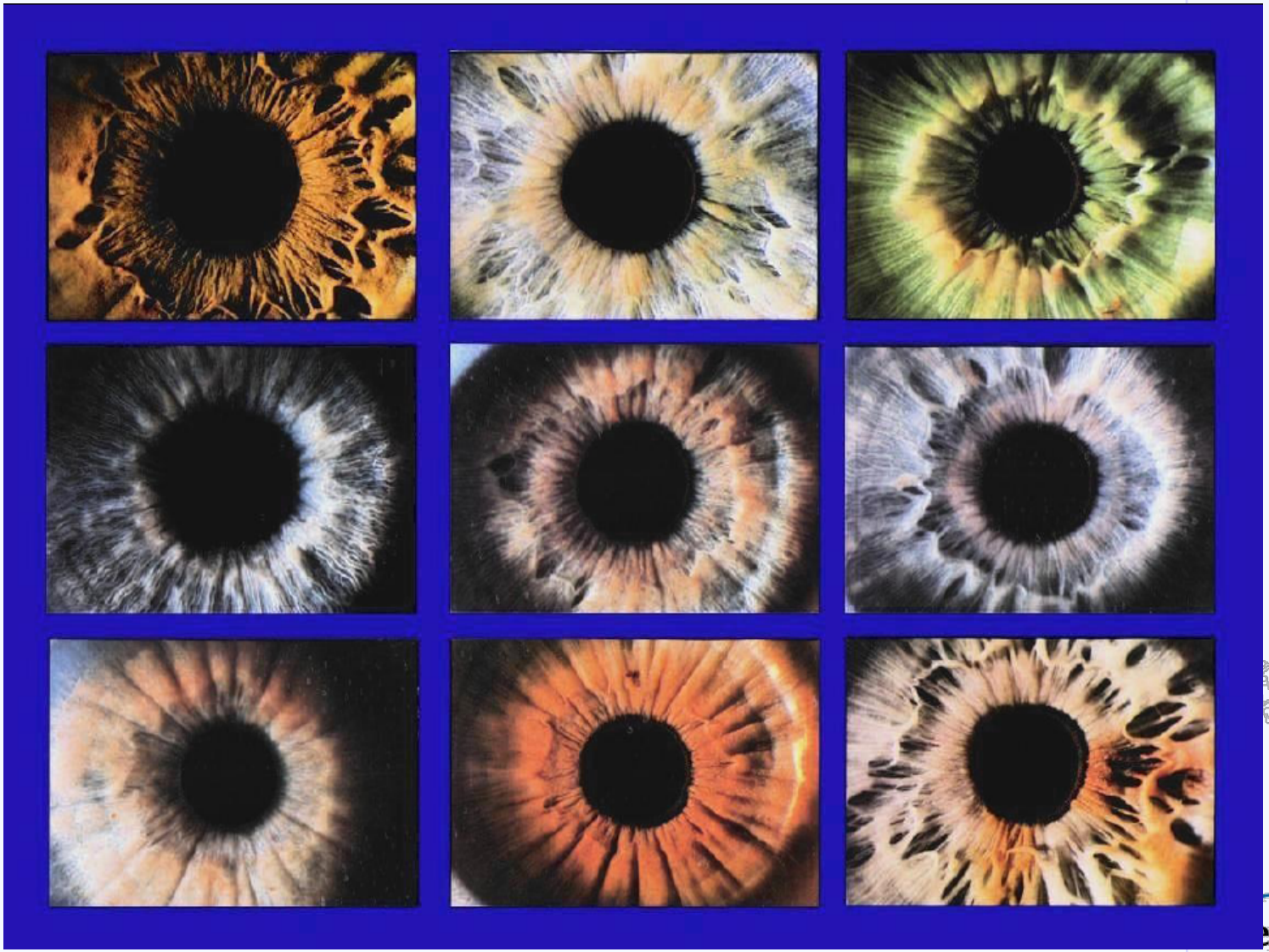
laboratory Gerstner

# Example Iris Images

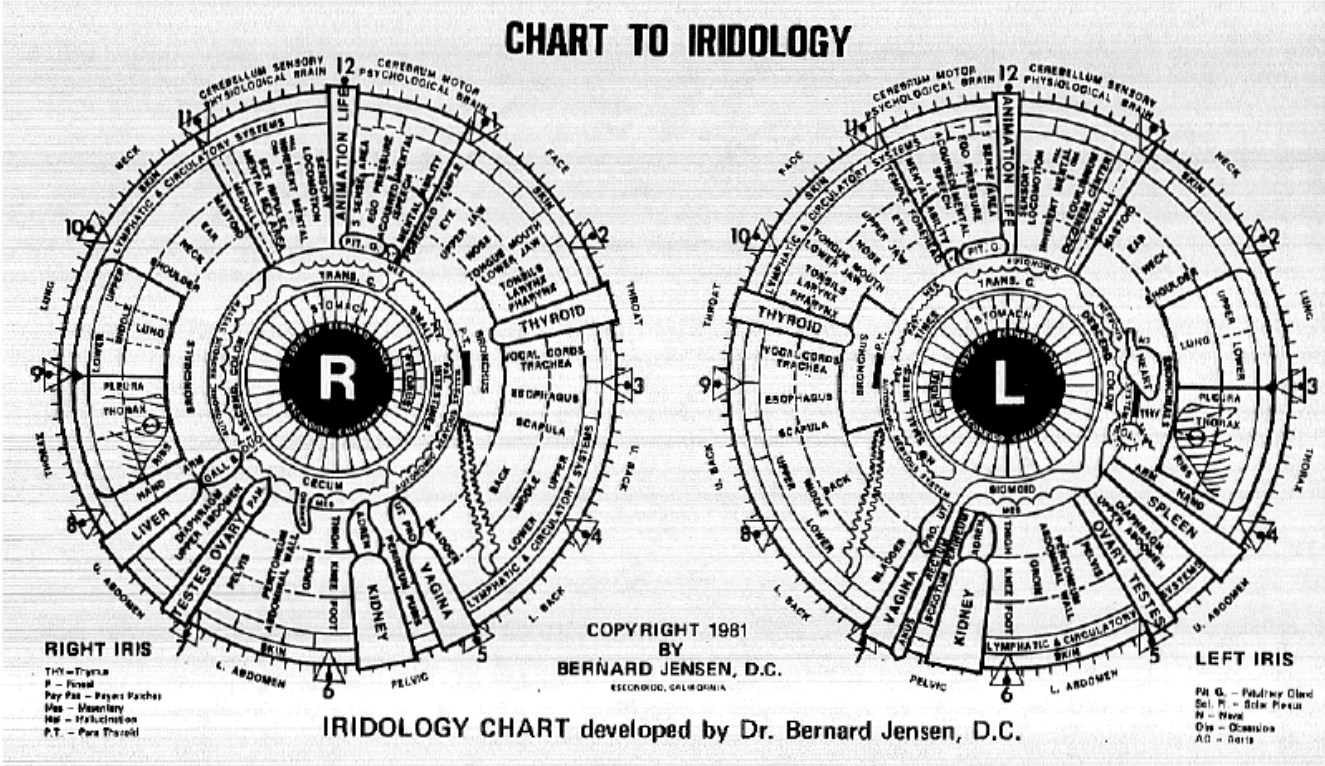




# IRISES

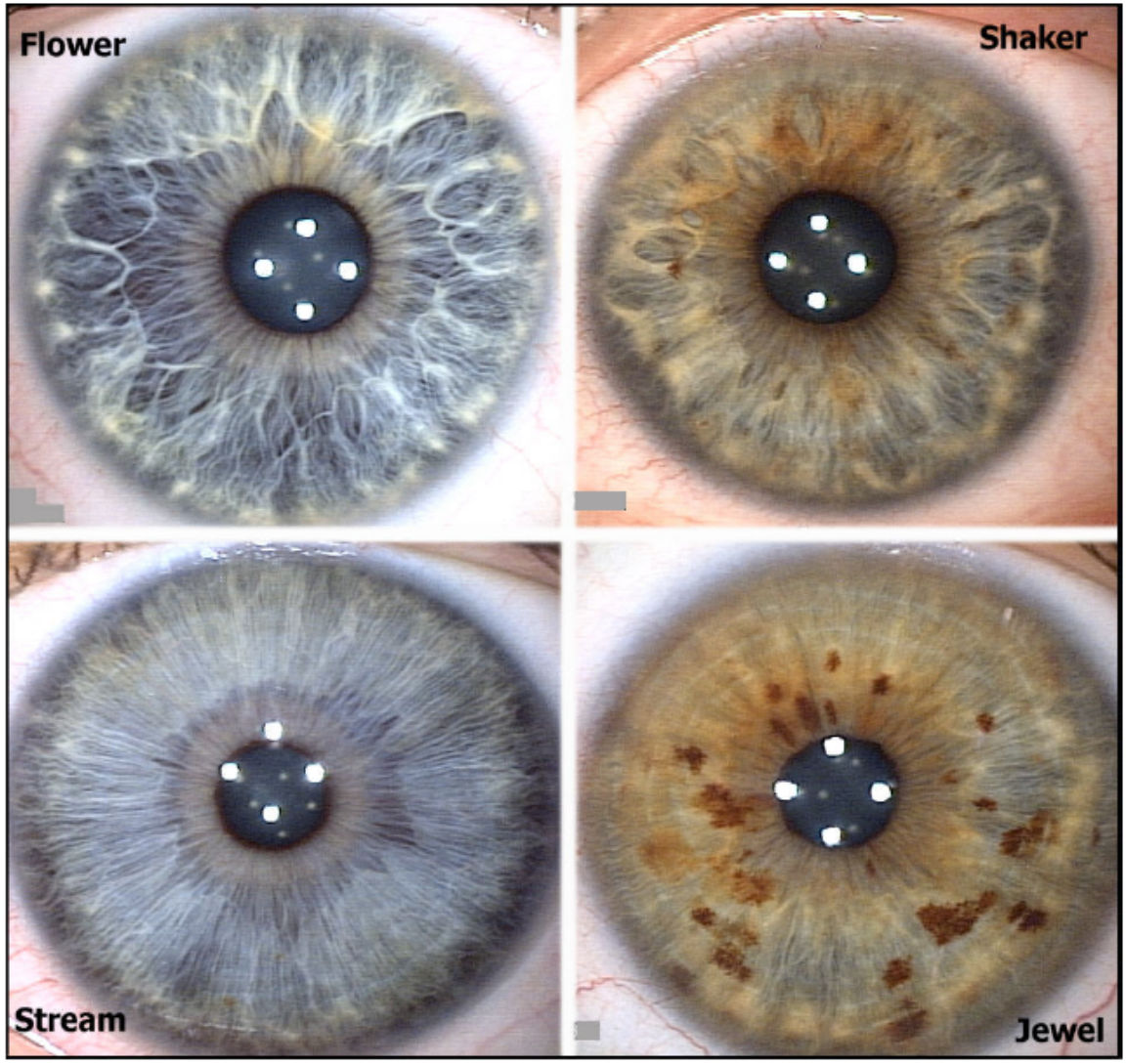


# Iridology




"Throughout the ages, the eyes have been known as the windows to the soul, and modern behavioral research is proving this adage to be true. If you look closely at the iris of the eye, you will notice small, dark dots, light streaks or rounded openings in the fibers. These characteristics provide the key to unlocking the mysteries of the personality" (Rayid International).

# Iridology



# Iris code

Iris Code

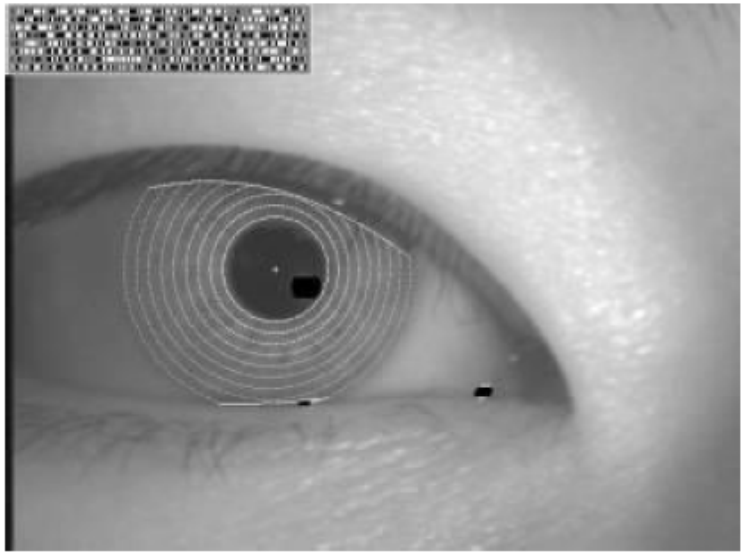
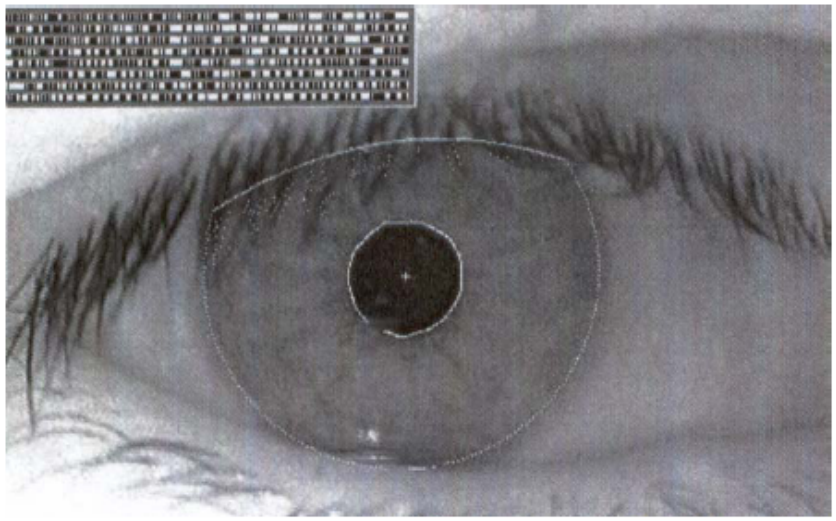
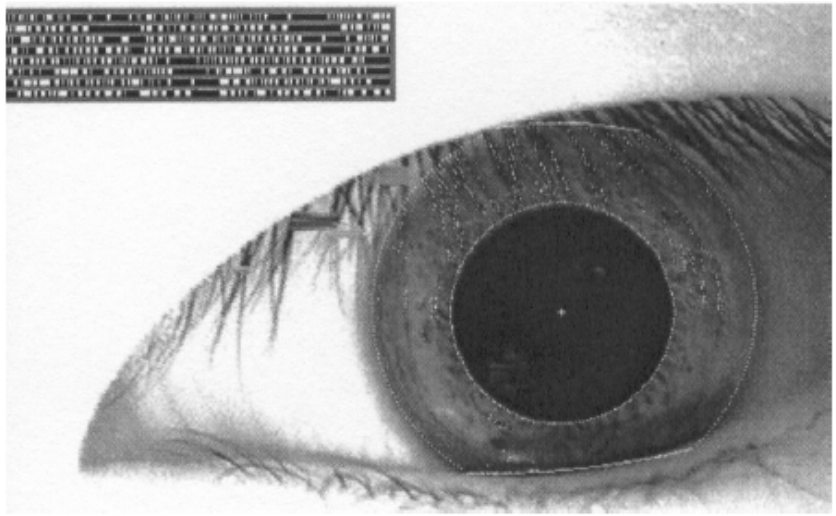
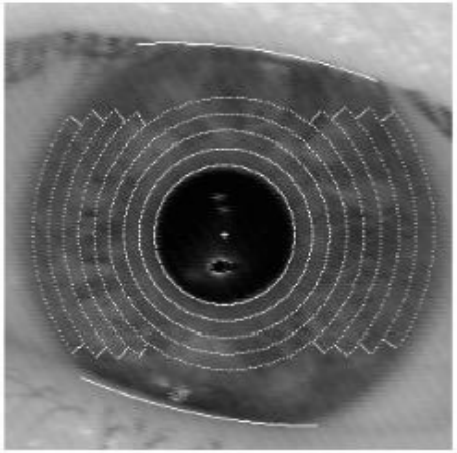


Image size is 64 x 256 bytes and the iris code is 8 x 32 bytes

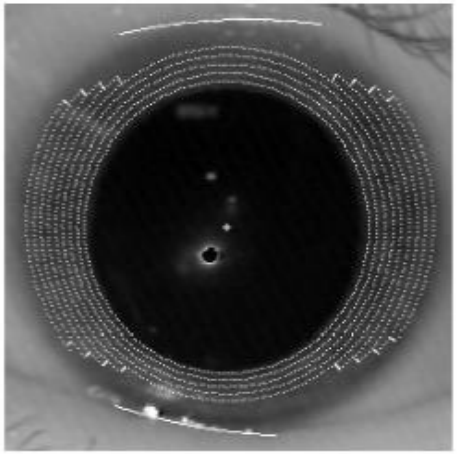
# Iris mapping







Dilatation normale



Dilatation élevée

- The iris mapping has to be invariant to shift, distance, magnification, and pupillary dilation

# 5. Signature Verification (P.Vostatek)

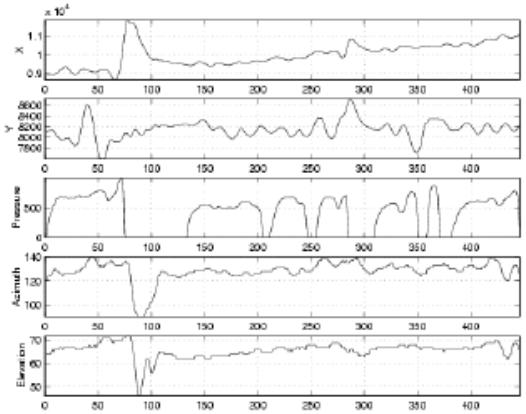
- Static/Off-line: the conventional way
- Dynamic/On-line: using electronically instrumented device

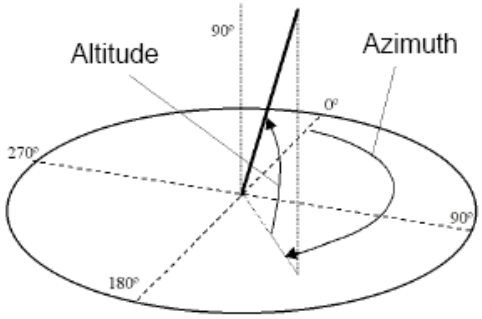
- Principle: the movement of the pen during the signing process rather than the static image of the signature.
- Many aspects of the signature in motion can be studied, such as pen pressure, the sound the pen makes

Static off-line technology – document authentication

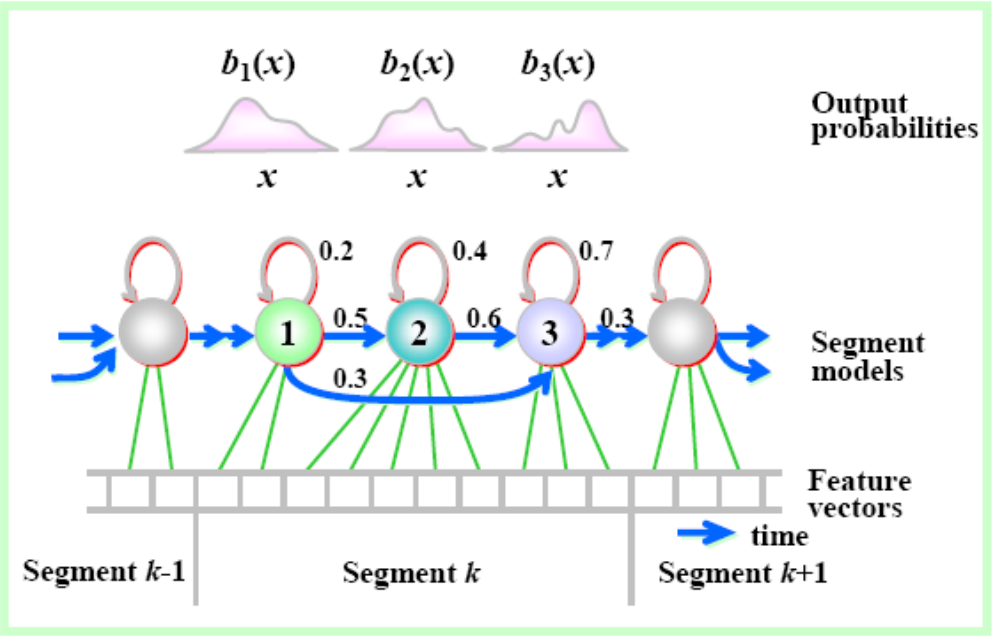
Dynamic on-line technology – signal processing and pattern recognition

# Dynamic signature

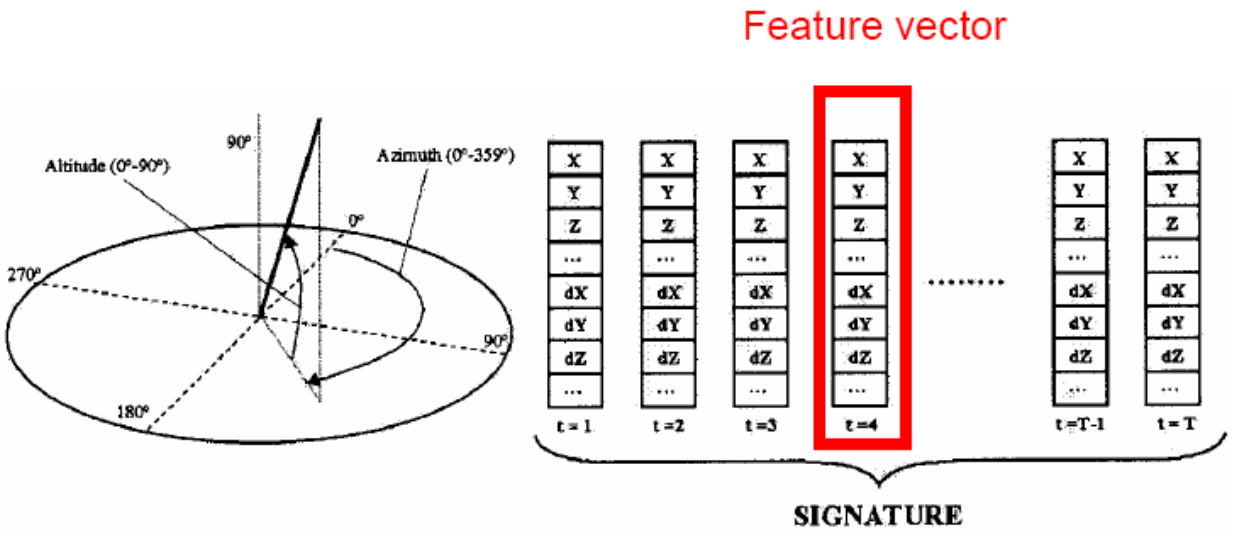





Features:
1. coordinate X
2. coordinate Y
3. pressure
4. pen azimuth (0° - 359°)
5. pen altitude (0° - 90°)



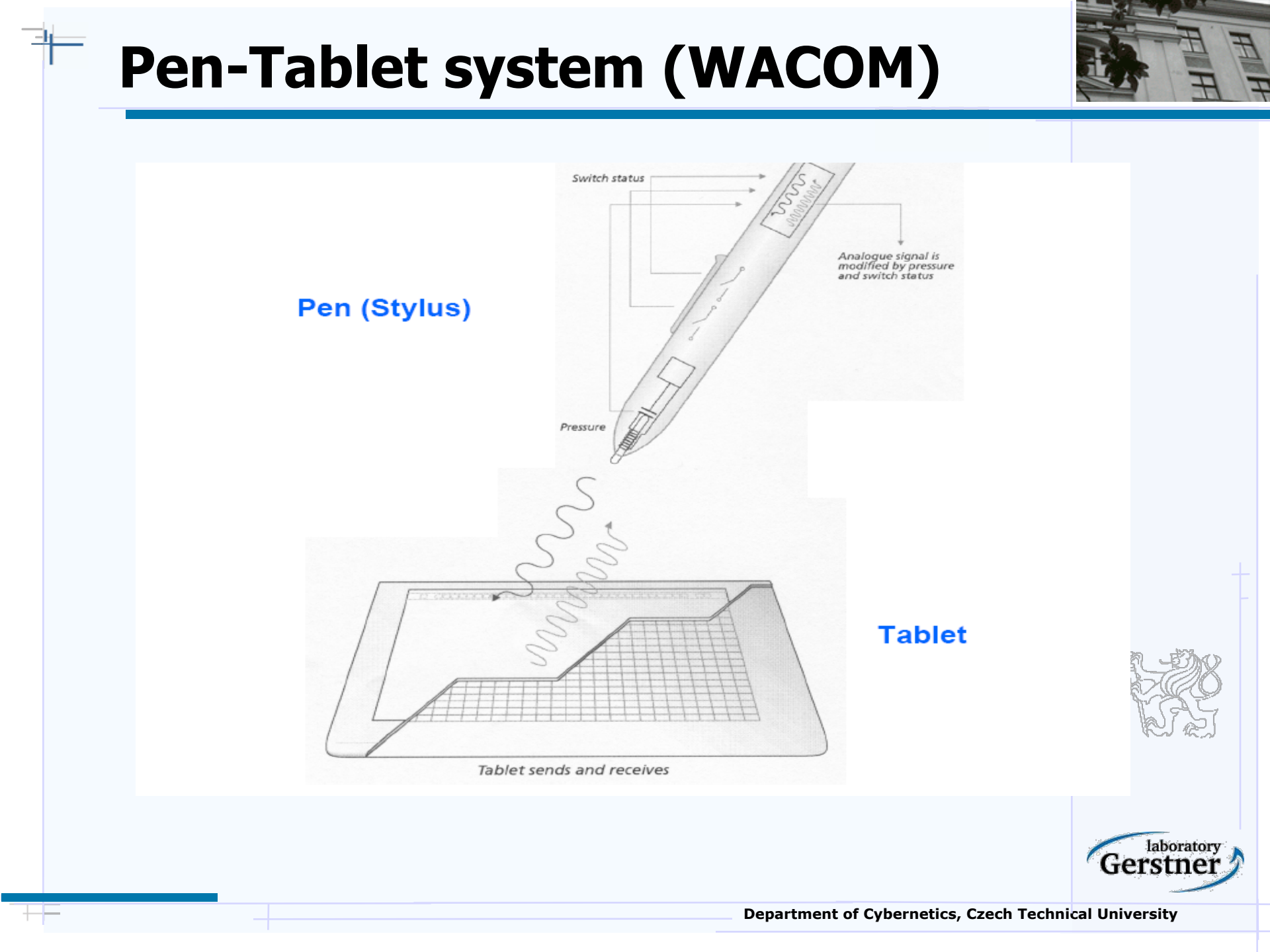
# Dynamic signature




## Acquisition:

-acquisition area: 127·106 mm
-pressure levels: 1024
-resolution: 2540 lines/inch (100 lines/mm)
-precision: +/- 0.25 mm
-detection height: 10 mm
-sampling frequency: 100 pps (points per s)

# Pen-Tablet system (WACOM)



# WACOM – How it works?

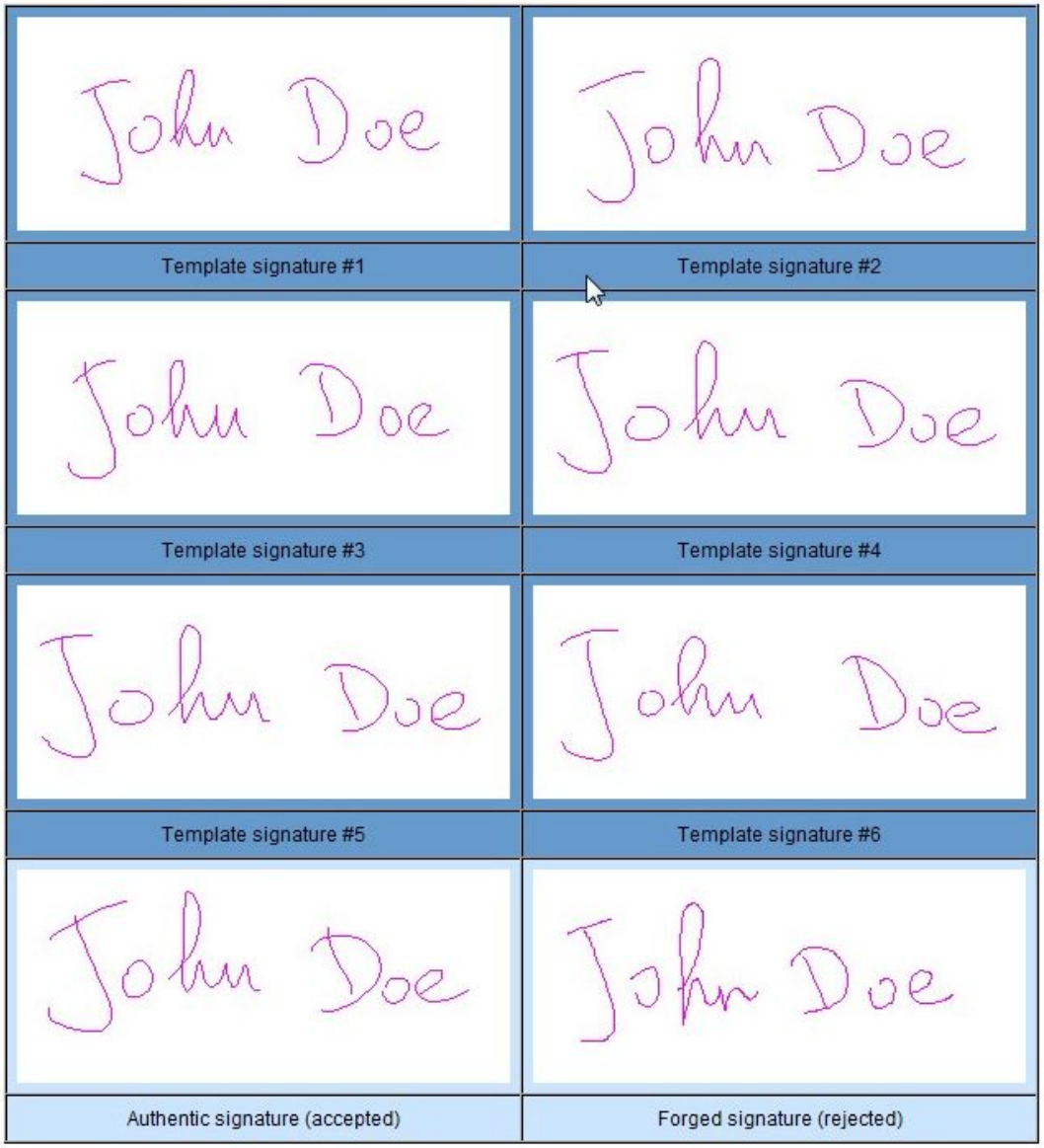
- The WACOM stylus looks and feels like a pen yet contains no batteries or magnets. Instead it takes advantage of electro-magnetic resonance technology in which radio waves are sent to the stylus and returned for position analysis.
- In operation, a grid of wires below the screen alternates between transmit and receive modes (about every 20 μs):
  - In **transmit mode**, the electro-magnetic signal stimulates oscillation in the coil-and capacitor resonant circuit in the pen
  - In **receive mode**, the energy of the resonant circuit oscillation in the pen is detected by the antenna grid. This is then analysed to determine position and other information including pressure
- Since the grid provides the power to the pen through resonant coupling, no batteries are required. Thus there are no consumables that will run down and need to be replaced or that would make the pen top-heavy.

# Dynamic signature: companies

- On-line:
  - SOFTPRO (http://www.signplus.com/)
  - CYBERSIGN (http://www.cybersign.com/)
  - CIC (http://www.cic.com/)
- Off-line:
  - APP-DAVOS (http://www.app-davos.ch/)
  - NUMEDIA (http://www.sapura.com.my/NuMedia/check.htm)

# IBM online verification

IBM online signature verification

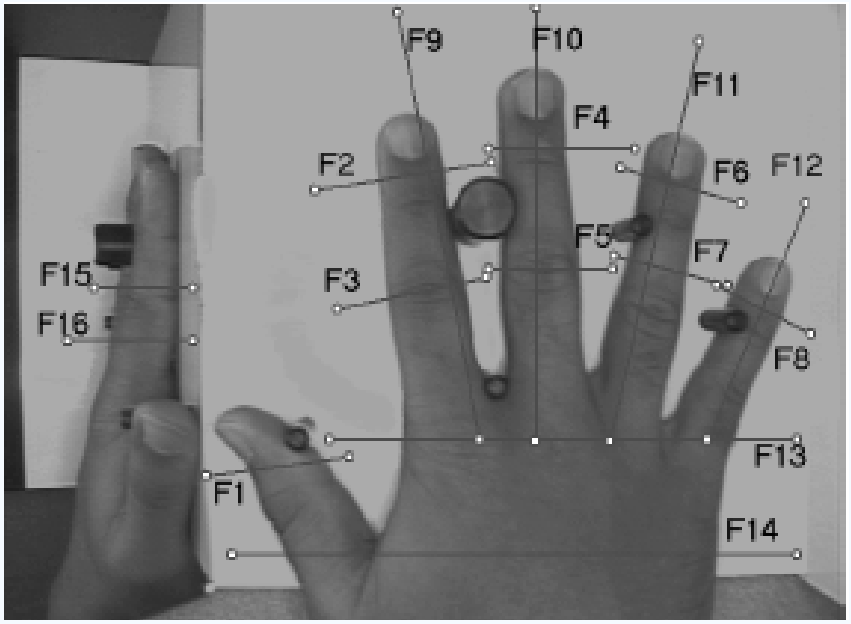


# 5. Hand geometry

- Hand geometry systems are commonly available in two main forms. Full hand geometry systems take an image of the entire hand for comparison while Two Finger readers only image two fingers of the hand.
- Hand recognition technology is currently one of the most deployed biometrics disciplines world wide

# How does it work

- A camera capture an image of the hand, with the help of a mirror to get also the edge. The silhouette of the hand is extracted, and some geometrical characteristics stored.




$$\sum_{j=1}^{d} | y_j - f_j | < \epsilon_a, \quad (1)$$

$$\sum_{j=1}^{d} \frac{| y_j - f_j |}{\sigma_j} < \epsilon_{wa}, \quad (2)$$

$$\sqrt{\sum_{j=1}^{d} (y_j - f_j)^2} < \epsilon_e, and \quad (3)$$

$$\sqrt{\sum_{j=1}^{d} \frac{(y_j - f_j)^2}{\sigma_j^2}} < \epsilon_{we}, \quad (4)$$

where $\sigma_j^2$ is the feature variance of the $j$th feature and $\epsilon_a$, $\epsilon_{wa}$, $\epsilon_e$, and $\epsilon_{we}$ are threshold values for each respective distance metric.

•( See Jain et al. A Prototype Hand Geometry-based Verification System )

# Applications

BenGurion Airport – Tel-Aviv,
Hand Geometry

JFK International Airport

1998

INSPASS - Hand Geometry

## Biometrics in Early Stages

| | | |
|---|---|---|
| DNA | Retina recognition | Thermograms |
| Gait | Keystroke | Ear recognition |
| Skin reflection | Lip motion | Body odor |

# I. DNA

- DNA has been called the “ultimate identifier”
- Identify information from every cell in the body in a digital form
- Not yet fully automated, not fast and expensive
- Theoretical limitation: Identical twins have the same DNA
- Privacy issue – DNA contains information about race, paternity, and medical conditions for certain disease

# Comparison Chart: DNA

| DNA | Conventional Biometrics |
|---|---|
| Requires an actual physical sample | Uses an impression, image, or recording |
| Not done in real-time; not all stages of comparison are automated | Done in real-time; “lights-out” automated process |
| Does a comparison of actual samples | Uses templates or feature extraction |

## II. Retina recognition

- The pattern of blood vessels that emanate from the optic nerve and disperse throughout the retina depends on individuals and never changes.
- **No two retinas are the same, even in identical twins.**
- Commercial products: Retinal Technologies

## III. Thermograms

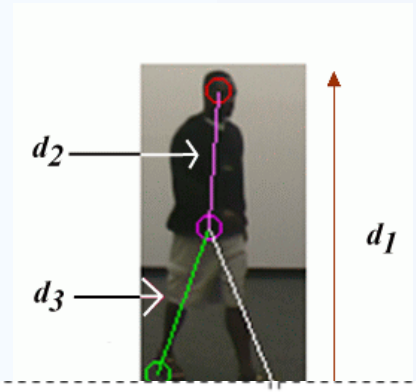
- Thermograms requires an infrared camera to detect the heat patterns of parts of the body that are unique to every human being (such as the face)

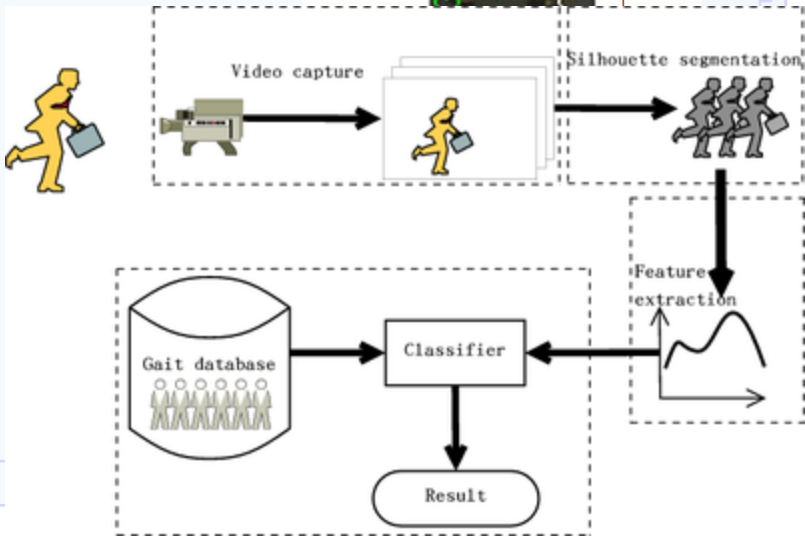
- Normally expensive because of the sensors

- Useful paper:
  Illumination Invariant Face Recognition Using Thermal Infrared Imagery (Solikinski & als)

# IV. Gait

- The final objective: to recognize persons using standard cameras in any conditions.
- Gait recognition is particularly studied as it may enable identification at distance.
- Gait video





# Češi vyhráli policejní olympiádu

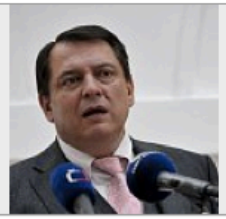
HNED.cz

ŠNÍ HN | FOTO & VIDEO | DATAROOM | KULTURNÍ TIPY | TV PROGRAM | POČASÍ | NAŠE TITULY

Vyhledat... Google

HNED.cz HNZPRÁVY HNBYZNYS HNLIFE HNTECH HNSPORT HNDIALOG

POLITIKA ČESKO SVĚT LEHKÉ ZPRÁVY ON-LINE ROZHOVORY ZPRÁVY A-Z



Paroubek by mohl být šéfem ČSNS 28. října

Sněmovna: volba prezidenta i exekuce

10 nejznámějších korupčních kauz

Pospíš vysvětl Rampu odvolá

24. 9. 2010 | poslední aktualizace: 24. 9. 2010 19:34

0 +1 velikost písma

## Čeští kriminalisté získali největší úspěch v historii. Za to, jak čtou chůzi

**Dynamiku pohybu má každý člověk unikátní, podobně jako otisky prstů.**

Čtěte více o: kriminalistika | policie

Zuzana Keményová
redaktor

REKLAMA

Hlásíme plně naloženo.

S tarifem Podnikatel Plus 1100 získát

✓ volání ve firmě zdarma

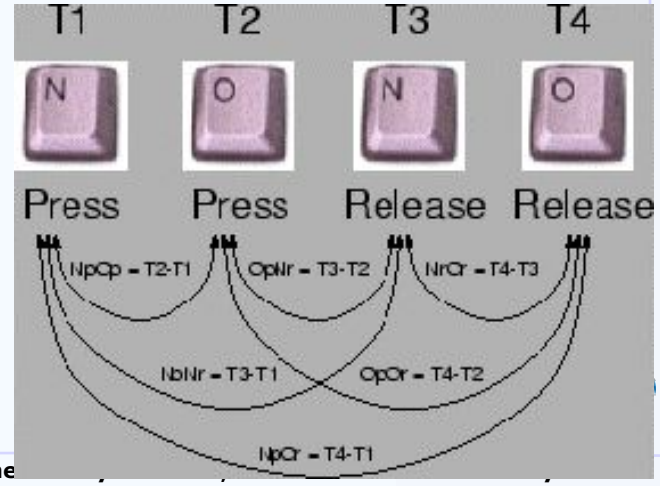
✓ volání do sousedních zemí za cenu jako v ČR

✓ nejrychlejší 3G internet

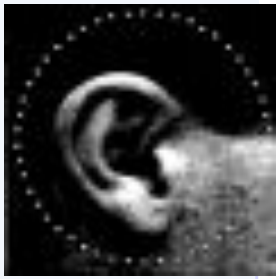
oratory Gerstner

## V. Keystroke

- The rhythms with which one types at a keyboard are sufficiently distinctive to form the basis of the biometric technology known as keystroke dynamics
- 100% software-based, requiring no sensor more sophisticated than a home computer
- VIDEO



## VI. Ear recognition



- Ear geometry recognition uses the shape of the ear to perform identification
- Suggestions have been made that the shapes and characteristics of the human ear are widely different
- **An infrared image can be used to eliminate hair**
- Might be recognized at a distance

# Example

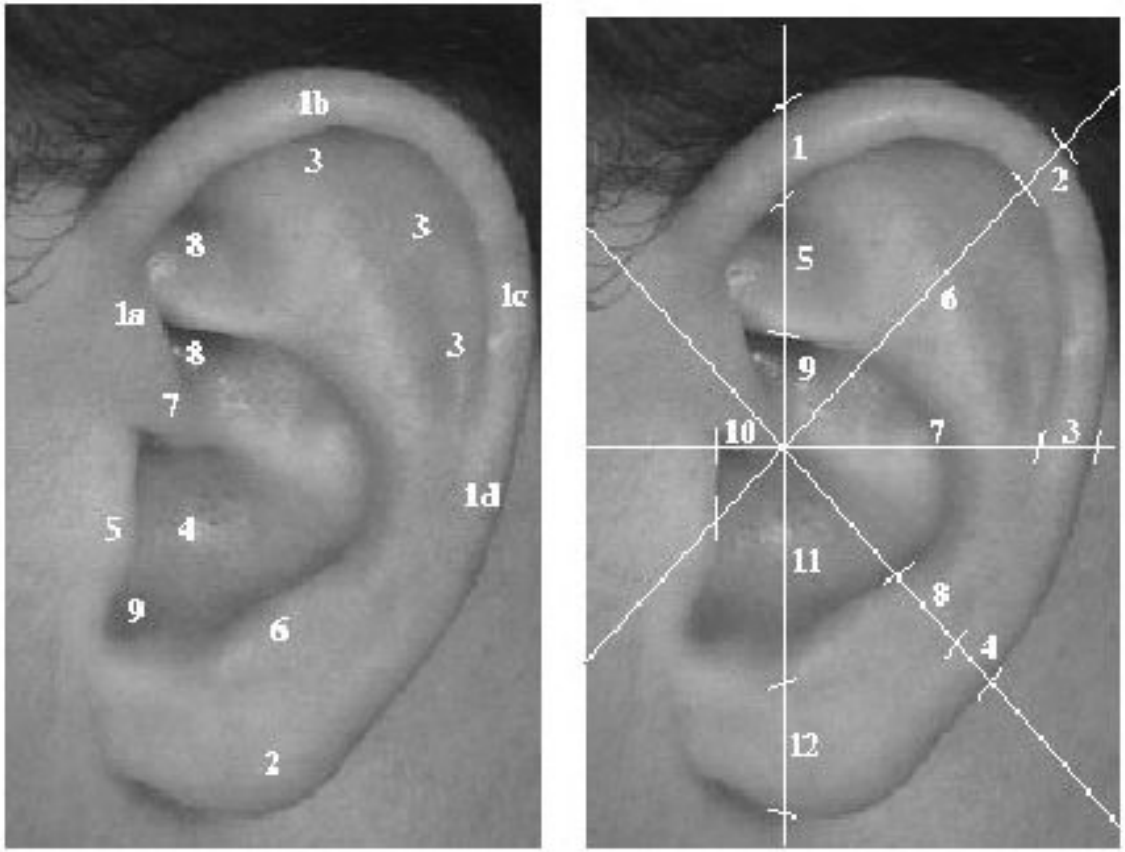
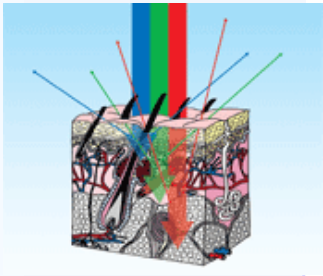



**Fig. 2.** (a) Anatomy, (b) Measurements. (a) 1 Helix Rim, 2 Lobule, 3 Antihelix, 4 Concha, 5 Tragus, 6 Antitragus, 7 Crus of Helix, 8 Triangular Fossa, 9 Incisure Intertragica. (b) The locations of the anthropometric measurements used in the "Iannarelli System". (Burge et al., 1998)

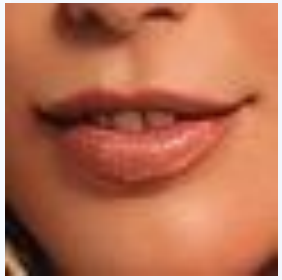
## VII. Skin reflection

- Lumidigm Inc. has established that the absorption spectrum of the skin depends on the individuals.



- In a range of wavelengths over 6mm patch, several LEDs send light into the skin, and photodiodes read the scattered light, which is analyzed to perform the authentication.

## VIII. Lip motion



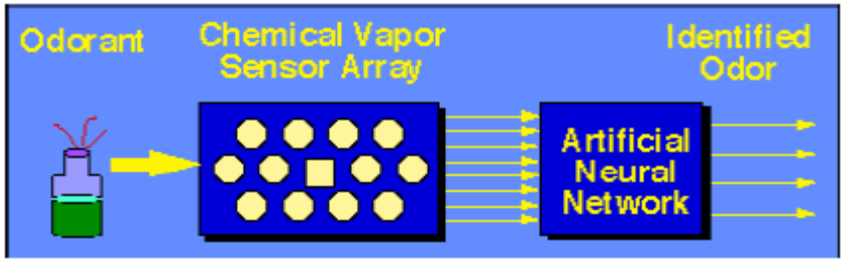
- Compares the characteristic lip motions of people while they speak.
- **Helps identification associated with speaker recognition**.
- Different imaging conditions: Infrared (high security & cost) and Near Infrared (cheap, normally used for active sensing)

# IX. Body odor

It's absolutely clear that people with differing immunity genes produce different body odors

Electronic/artificial noses: developed as a system for the automated detection and classification of odors, vapors, gases.

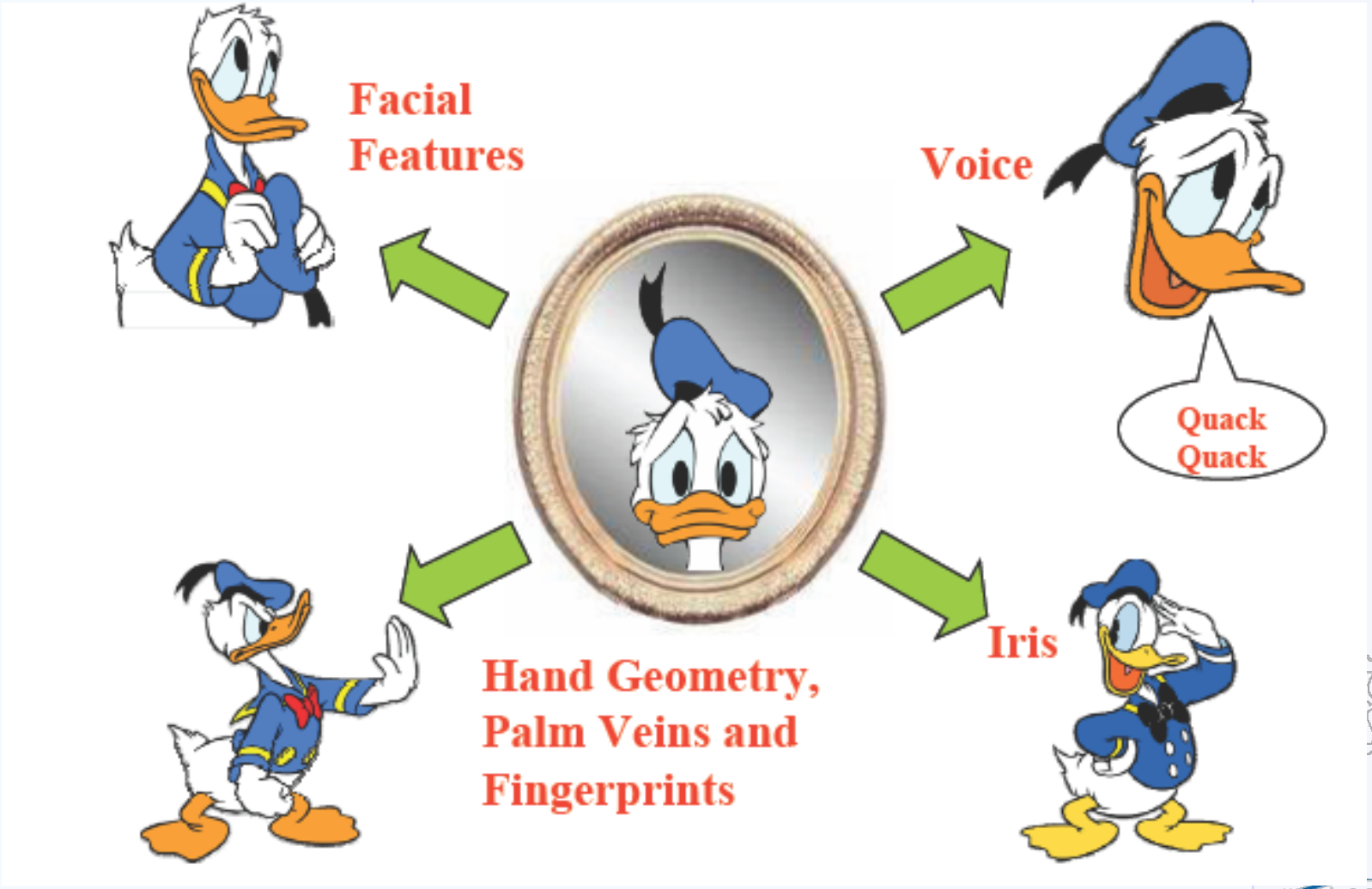
- Prometheus (Alpha Mos) ,
- an example of electronic nose



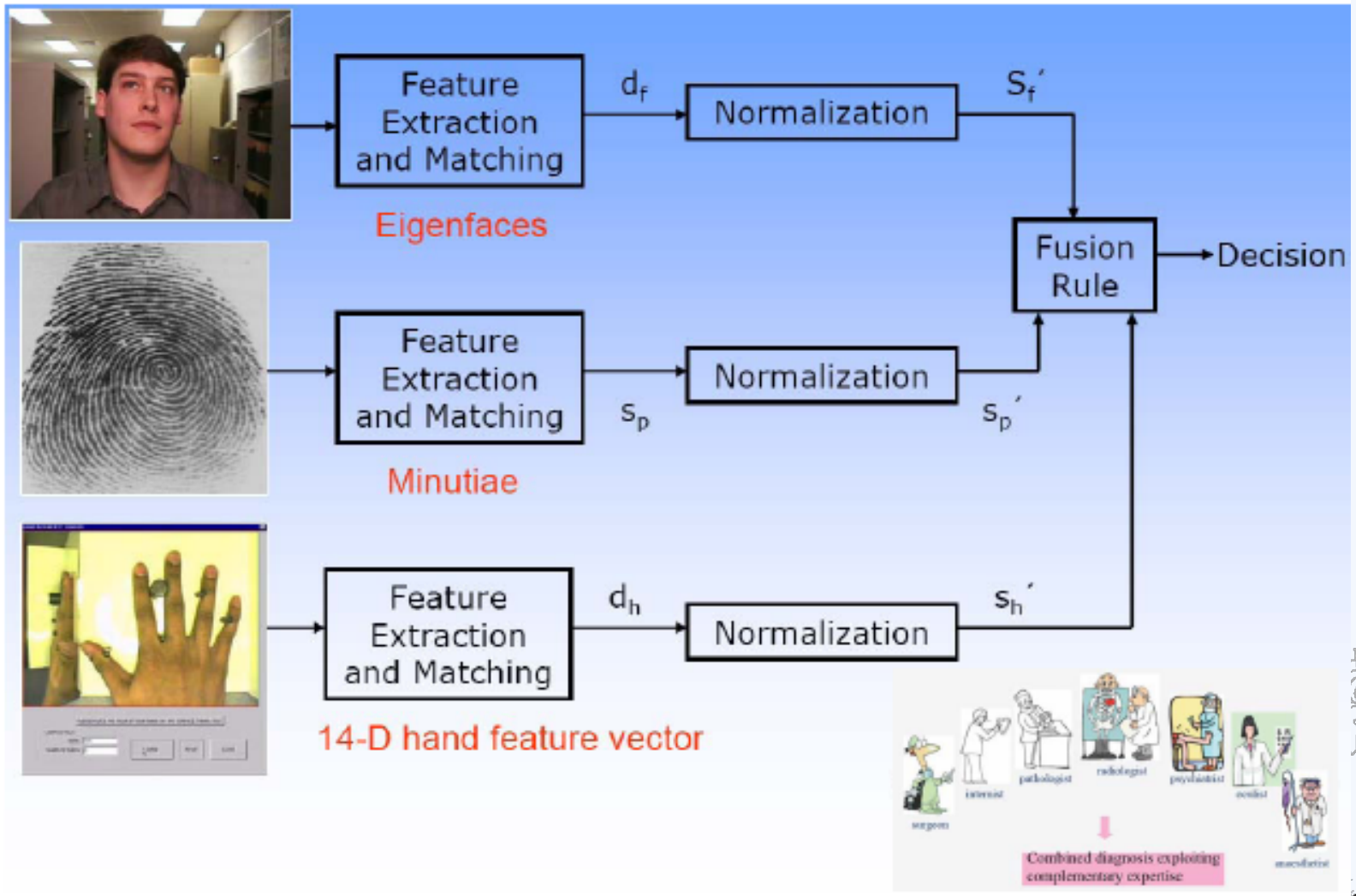

**Schematic Diagram of Artificial nose**

Artificial noses are not yet sophisticated enough to do all the job

# Multimodal Biometrics



# Fusion after normalization



# Comparision of Biometric Technologies

| Characteristic | Fingerprints | Hand Geometry | Retina | Iris | Face | Signature | Voice |
|---|---|---|---|---|---|---|---|
| **Ease of Use** | High | High | Low | Medium | Medium | High | High |
| **Error Incidence** | Dryness, dirt, age | Hand injury, age | Glasses | Lighting | Lighting, age, glasses, hair | Changing signatures | Noise, colds |
| **Accuracy** | High | High | Very High | Very High | High | High | High |
| **User Acceptance** | Medium | Medium | Medium | Medium | Medium | High | High |
| **Long-Term Stability** | High | Medium | High | High | Medium | Medium | Medium |

# Possible Future Events

Why news about iris recognition triggered an alien invasion