

EEL 851
Biometrics

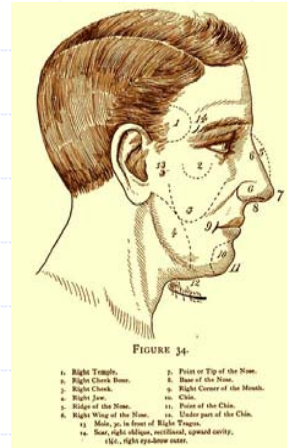
Introduction

Outline

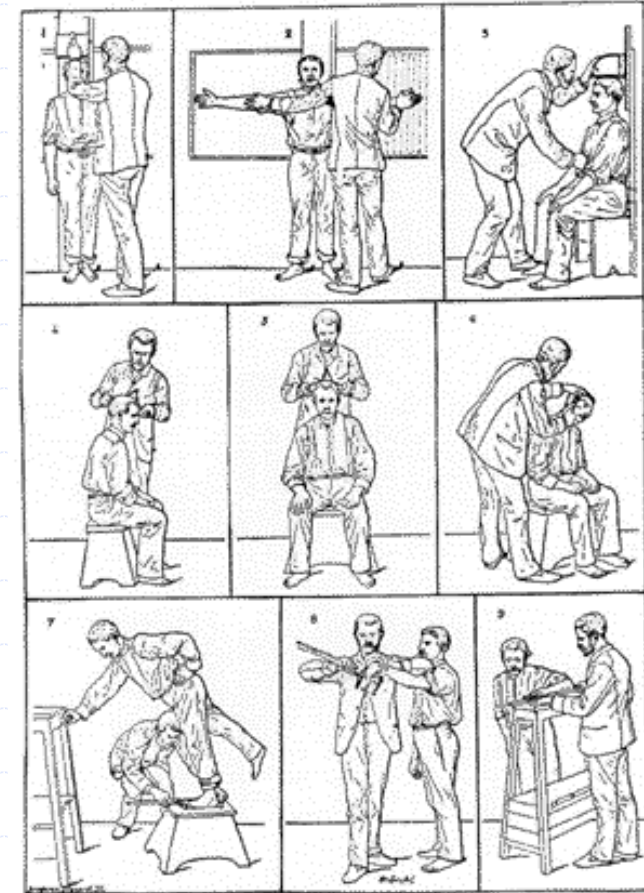
- ❑ History
- ❑ Biometric Characteristics
- ❑ Biometric Systems
- ❑ Operating Modes
 - Verification
 - Identification
- ❑ Biometric System Errors
 - False Match Rate
 - False Non-Match Rate
 - Equal Error Rate
 - Failure to Compute/Enroll
- ❑ Receiver Operating Characteristics
- ❑ Introduction to Various Biometric Modalities
- ❑ Comparison of Various Biometrics

History

- Human Identification
- Bertillon System
 - Alphonse Bertillon (1853–1914)
 - Physical Measurements



- Formula → 241 Offenders (1884)
- Quickly → American, British Police Forces



History



"One can only see what one observes, and one observes only things which are already in the mind"
- Alphonse Bertillon

- Flawed System
 - Age
 - Two officers made their measurements in slightly different ways

- Discredited (1903) → *Will West* case

- Evolution of Fingerprinting

Characteristics

➤ Biometrics

- Ancient Greek, *bios* → life, *metron* → measure
- “the study of automated methods for uniquely recognizing humans based upon one or more intrinsic physical or behavioral traits”

➤ What Measurements?

- **Physiological**
- **Behavioral**

➤ Desired Properties

- **Universality**
- **Distinctiveness**
- **Permanence**
- **Collectability**
- **Performance**
- **Users Acceptability**
- **Robustness against Circumvention**

Biometric System

➤ Human Identification

➤ Biometric System

- **Biometric acquisition**
- **Feature extraction**
- **Matching against the template in database**
- **Decision**

➤ Operating Modes

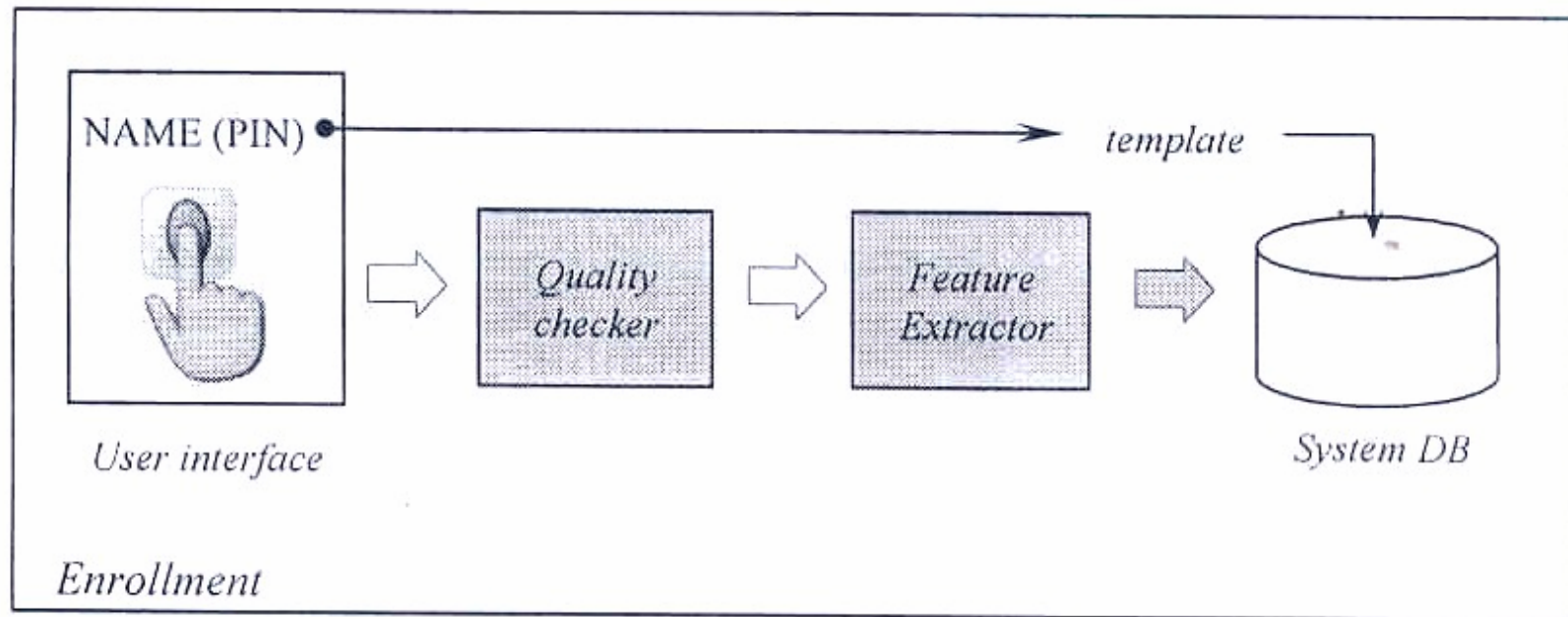
■ **Verification Mode**

- ◆ Claims an Identity → PIN, User Name, Smart Card, etc.

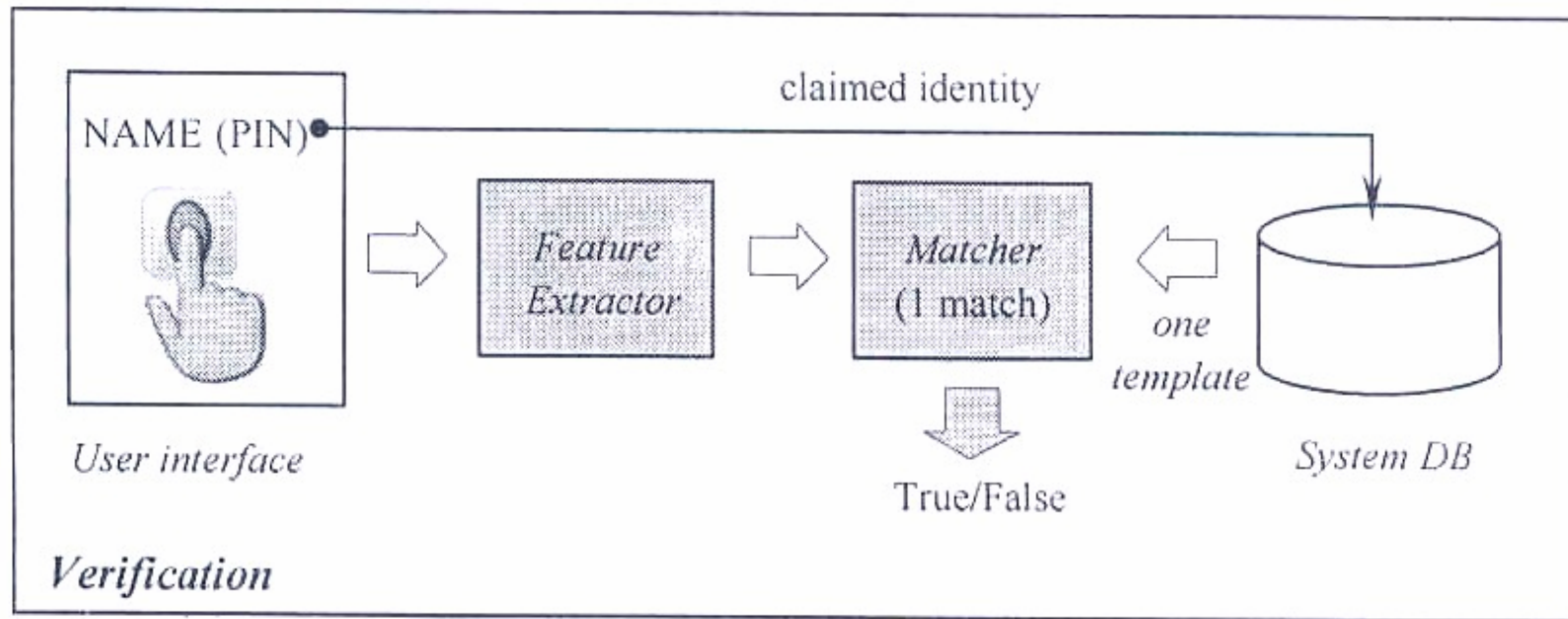
■ **Identification Mode**

- ◆ Negative Recognition → Only through Biometrics

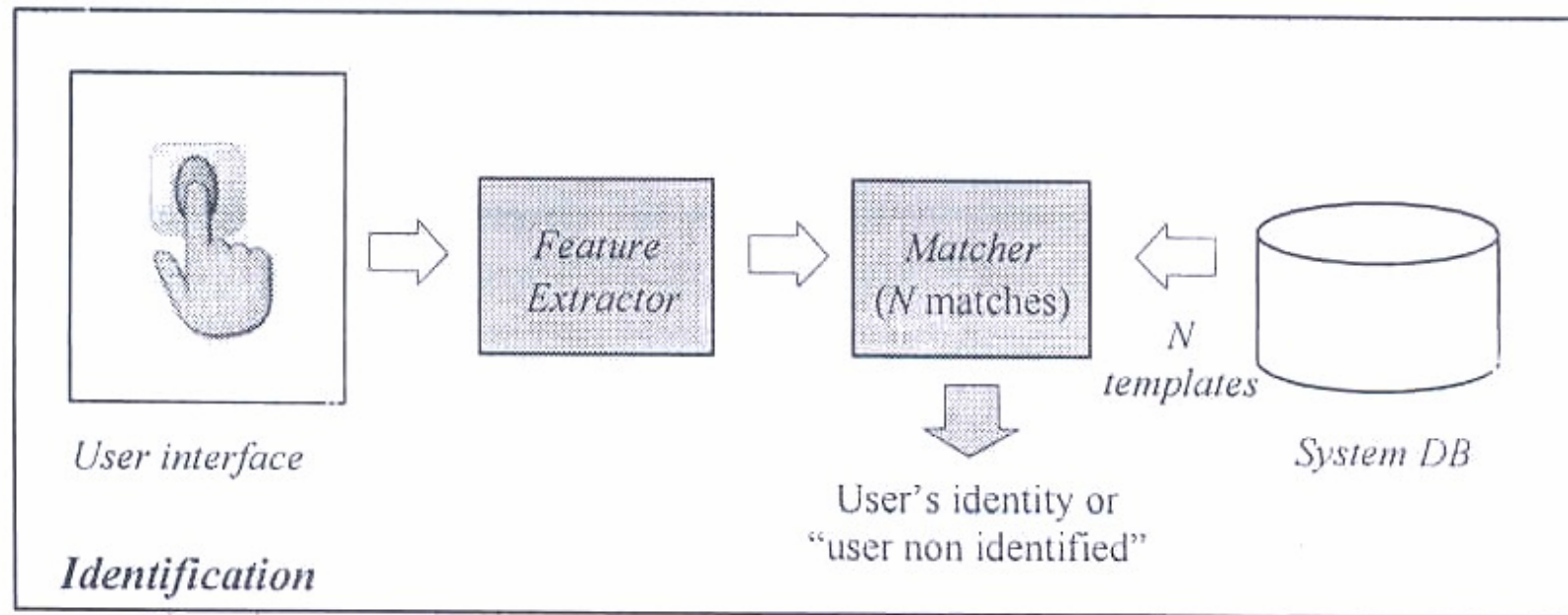
Biometric System



Biometric System



Biometric System



Biometric Verification

- The claimed identity I has feature vector F_q from his/her biometric data
- Task → Determine if (I, F_q) belongs to class C_1 or C_2
- Typically the decision is based on $D(F_q, F_I) \rightarrow$ Similarity or Matching Distance

$$(I, F_q) \in \begin{cases} C_1 & \text{if } D(F_q, F_I) \geq t \\ C_2 & \text{otherwise} \end{cases}$$

where t is a predefined threshold

- Why threshold is needed?

Biometric Identification

➤ Problem

- Given the feature vector $F_q \rightarrow$ determine the identity I_k
where $k \in \{1, 2, 3, \dots, N, N+1\}$
- I_1, I_2, \dots, I_N are the enrolled identities
- $I_{N+1} \rightarrow ?$

➤ Typically the decision is based on $D(F_q, F_l) \rightarrow$ Similarity or Matching Distance

$$F_q \in \begin{cases} I_k & \text{if } \max_k \{D(F_q, F_{I_k})\} \geq t, \quad k = 1, 2, \dots, N \\ I_{N+1} & \text{otherwise} \end{cases}$$

where t is a predefined threshold

$F_{I_k} \rightarrow$ biometric template corresponding to I_k

Biometric System Errors

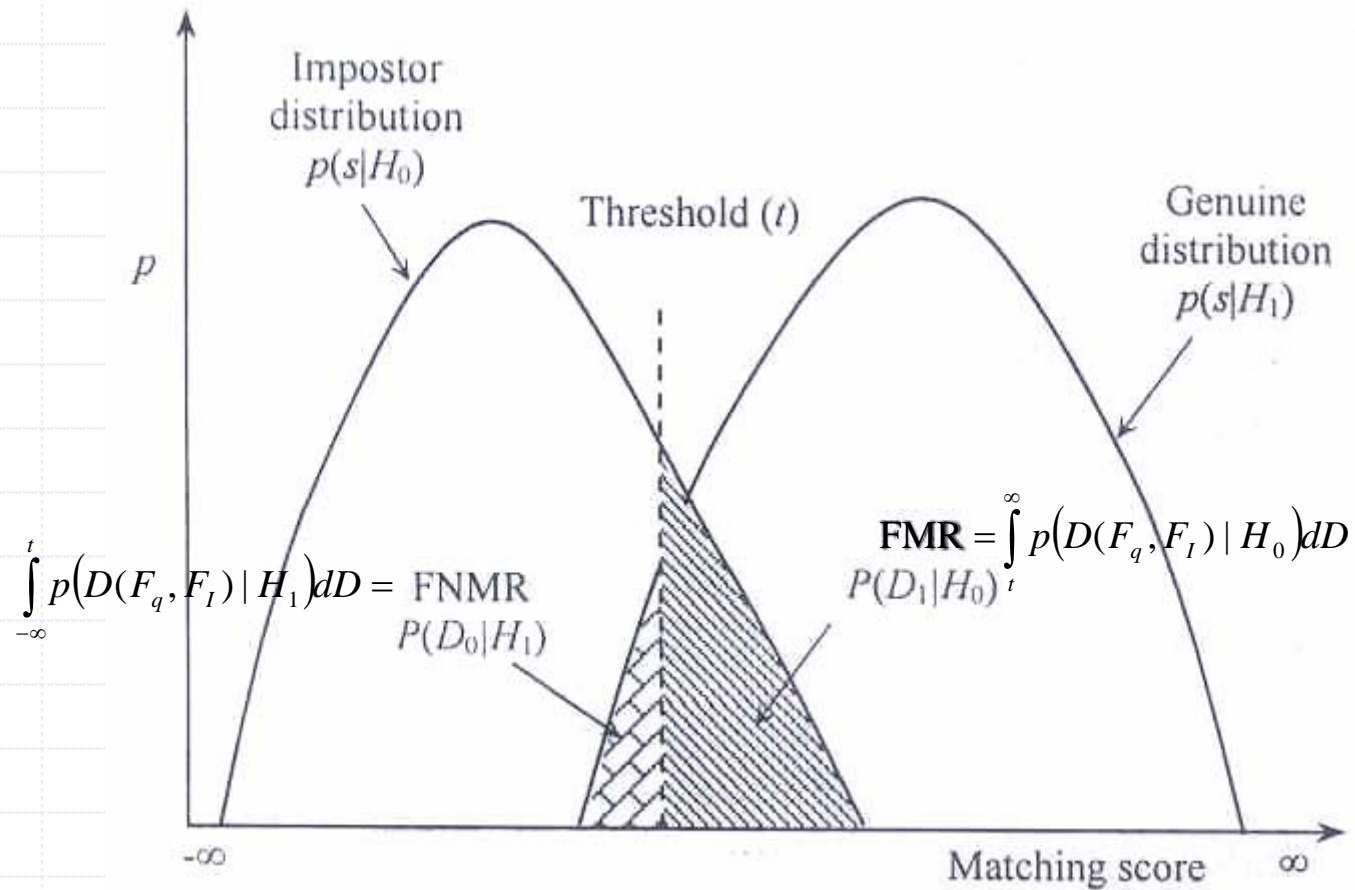
- Variation in biometric characteristics
 - Imperfect Imaging Conditions
 - ◆ Sensor Noise, Alcoholic, Dry Fingers,
 - Changes in physiological/behavioral characteristics
 - ◆ Cuts/bruises, ambient conditions
 - Users interaction with sensor

- Genuine Distribution
- Imposter Distribution
- False Match, False Accept
 - Mistaking biometric measurements from **two different persons** → **same person**
- False Non-Match, False Reject
 - Mistaking biometric measurements from **same person** → **different persons**

Errors in Verification

- Let user I has template F_I and the acquired one is F_q
 - $H_0 \rightarrow$ Input F_q does NOT come from same template as F_I
 - $H_1 \rightarrow$ Input F_q does comes from same template as F_I
- Associated Decisions
 - $D_0 \rightarrow$ NOT the one that is claimed
 - $D_1 \rightarrow$ persons is the one as claimed
- Decision Rule, $D(F_q, F_I) < t \rightarrow D_0$ else D_1
- FAR/FMR \rightarrow False match (D_1 is decided when H_0 is true)
 - $FMR = P(D_1 | H_0)$
- FRR/FNMR \rightarrow False non-match (D_0 is decided when H_1 is true)
 - $FNMR = P(D_0 | H_1)$
- Multiple samples from the same person, Genuine Distribution $\rightarrow p(D(F_q, F_I) | H_1)$
- Multiple samples from the different person, Imposter Distribution $\rightarrow p(D(F_q, F_I) | H_0)$

Errors in Verification



Biometric System Errors

➤ Decidability Index

- Normalized distance between means of Genuine and Imposter distributions

$$d' = \frac{|\mu_G - \mu_I|}{\sqrt{(\sigma_G^2 + \sigma_I^2)/2}}$$

- Problem → Works best for Gaussian type distributions

➤ Failure to Compute (FTC)

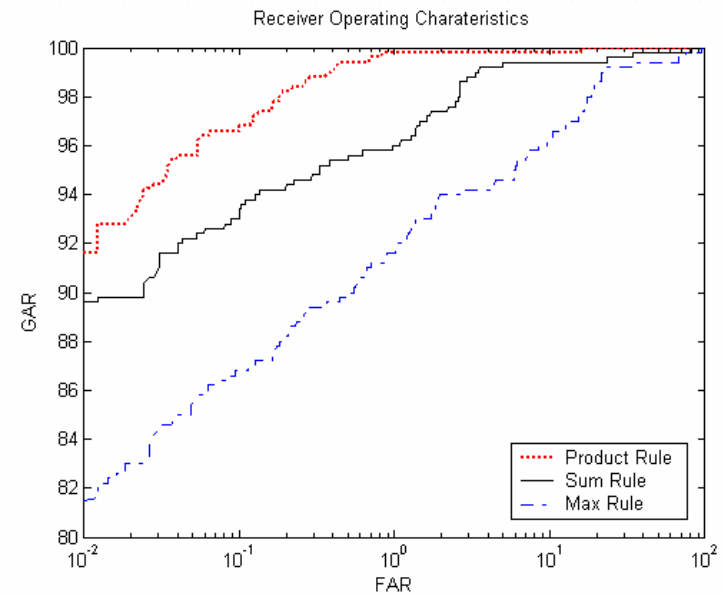
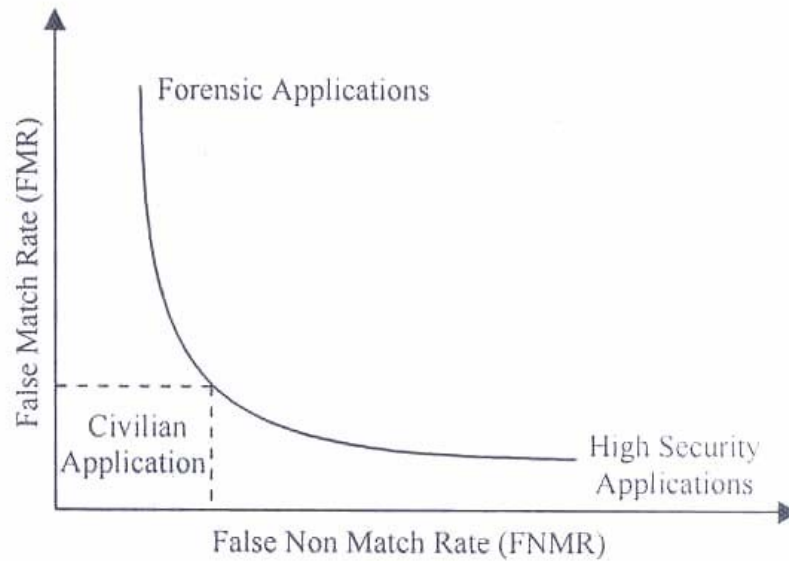
- Device not able to locate good quality biometric

➤ Failure to Enroll (FTE)

- Percentage to time user is not able to enroll in system

Errors in Verification

➤ Receiver Operating Characteristics



Errors in Recognition

- Test Samples
- Training Samples
- Recognition Accuracy
- Confusion Matrix

Example: Confusion Matrix of a Face Recognition System
Total Accuracy 81%

Number of Training Pixels 408 Verification Set 1000

Recognized as

		Recognized as							
True ID		Reject	A	B	C	D	E	F	ACCURACY %
A	6		168	1	8	17	8	5	78
B	7		1	154	1	10	1	0	88
C	17		1	0	77	0	10	1	72
D	13		5	2	2	215	7	1	87
E	22		1	0	3	5	64	0	67
F	2		2	1	9	3	11	139	83

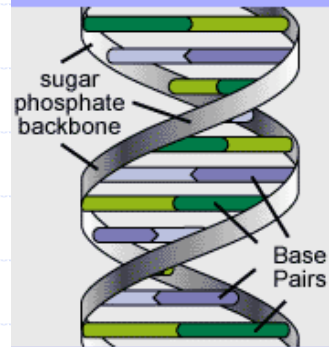
DNA

- Every Human Cell → Deoxyribo Nucleic Acid, Double helix structure
- Only portions of the DNA sequence that vary most among humans
 - Only one-tenth of a single percent of DNA (about 3 million bases) differs from one person to the next
 - DNA profile, Forensic scientists → 13 regions are scanned
 - Samples from blood, bone, hair, and other body tissues/products
 - two DNA samples are alike at four or five regions, odds are great that the samples are from the same person
- Advantages
 - Permanence of DNA is incontestable, Does not change throughout persons life
 - Cannot be altered by surgery
 - Statistical testing → One in six billion chance (Burgess, 2004), Twins 0.4%

DNA

- Bases → A (adenine), C (cytosine), T (thymine), G (guanine)
- Pairing (always) → A+T; C+G

The DNA molecule consists of two ribbon-like strands that wrap around each other resembling a twisted ladder.



The rungs of the ladder are Nucleotide Base Pairs that always combine in this way:
C with G and A with T



DNA

➤ Privacy Issues

- DNA sequence → Information about susceptibilities of a person to certain disease
- Use of Genetic Code in discrimination
- Origin → Where their ancestors came from

➤ Problems

- Easy to steal
- Real time Recognition?
 - ◆ Cumbersome chemical methods, experts skill
 - ◆ Time required today 4-5 hours, May be reduced by half as per recent claims
- Impossible to distinguish identical twins

Ear



- Rich and Stable Structure → Preserved from birth into old age
- Problems
 - Ear features are not expected to be very distinctive
 - Hair, May be solved → Infrared images
- Advantages
 - Decidability Index > Face (< Iris)
 - No problem with expression/pose, 3D structure,
- Ear Print → Conviction of *Mark Dallagher* (1998) for murdering, overturned in Jan 2004
 - The uniqueness of earprints inconclusive?, Alfred Iannarelli (1989) → 10,000 ear samples were different

Thermogram



- Pattern of heat generated by body → Unique characteristics, IR camera
- Heat patterns created by branching of blood vessels and emitted from skin

- Advantages
 - Highly distinctive, Identical Twins → Different thermograms
 - Non-evasive, Contactless

- Problems
 - Presence of heat emitting surfaces in vicinity of body
 - Requires Infrared Sensors, Cost ↑

- Identification systems using facial thermograms in 1997, the effort was suspended → high cost of manufacturing

Fingerprint



- Pattern of ridge and valleys → Surface of a fingertip
- Patterns typically scanned with 0.05 mm (500 dpi) resolution
- Fingerprints are determined within first seven months of fetal development
 - Identical twins have different fingerprints

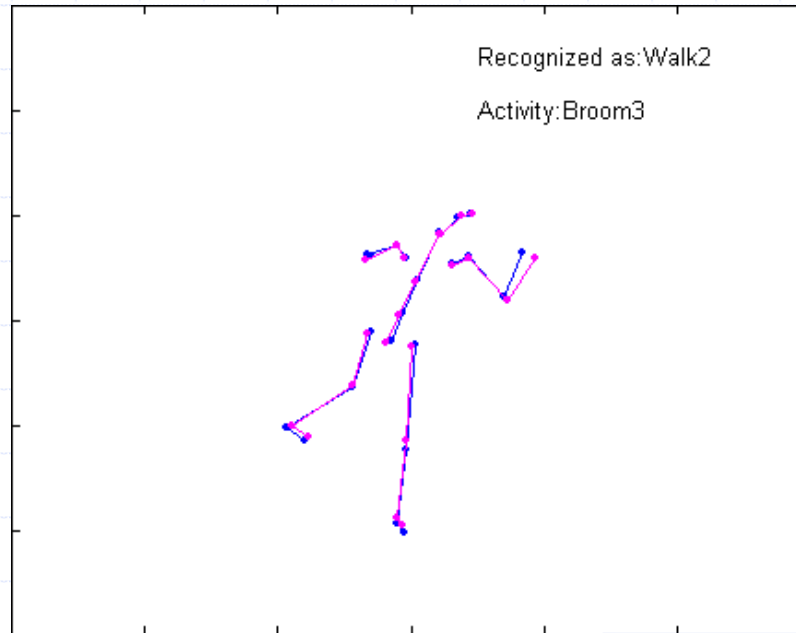
- Problems
 - Fingerprints of small fraction of population may not be suitable
 - Large computation, User acceptance ↓

- Advantages
 - Well established forensic technique, High accuracy
 - Modern fingerprint scanners → Low Cost

Gait

- Distinctive way one walks
 - Behavioral biometric → Video sequence
 - Complex spatio-temporal biometric
 - ◆ Dynamic mapping of changing relationships of points on body as one moves
- Advantages
 - Identification in adverse conditions
 - ◆ night, amid smoke, large distance → poor image quality
 - Acceptable biometric like face
- Problems
 - May not remain invariant
 - ◆ tiredness, age and health (arthritis, a twisted ankle or prosthetic limb)
 - ◆ Bad footwear, fluctuations in body weight
 - Not very distinctive → Verification in low-security
 - Can be obscured or disguised → wearing loose fitting clothes
 - Intensive input, Computationally intensive
- Military/intelligence sector
- Civilian applications
 - Identification of female shoplifters

Gait



Media Clip

Face

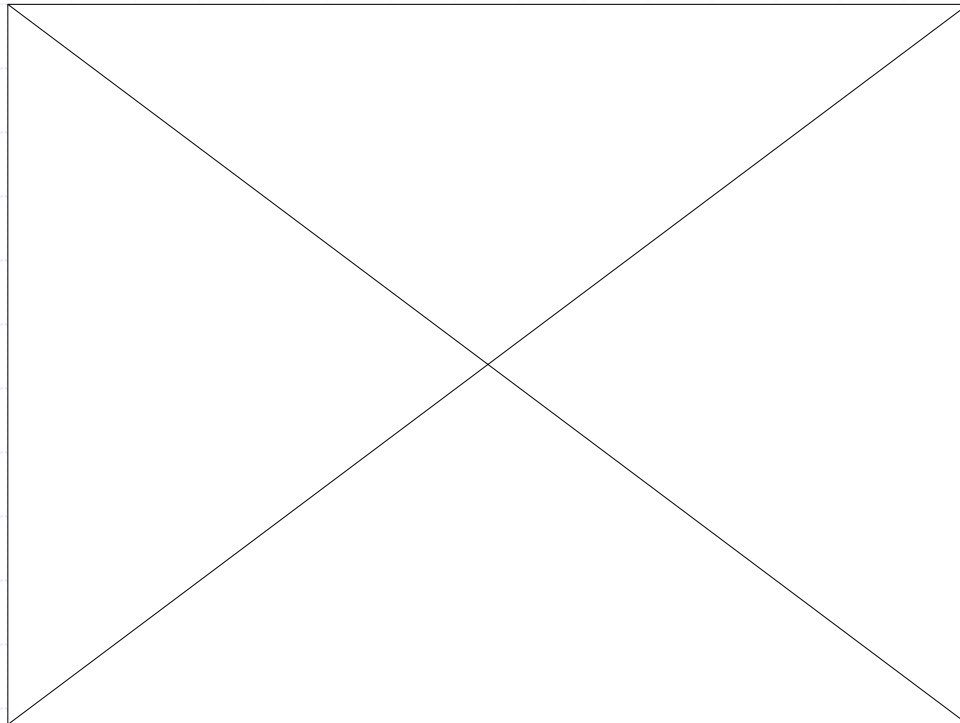


- Humans → innate ability to recognize different faces for millions of years
- Mugshots from front with good lighting
- Distinguishable landmarks as nodal points (about 80), 14-22 used
 - Distance between eyes
 - Width of nose
 - Depth of eye sockets
 - Cheekbones
 - Chin
 - Jawline

- Advantages
 - Most promising biometric for overcrowded places (airports)
 - Highest user-acceptance

- Problems
 - Surveillance
 - ◆ Animated expression, sunglasses, aging, hairstyle, weight gain/loss
 - Dynamic, Uncontrolled face identification in cluttered background
 - Identical twins

Face



Media Clip

Keystroke



- Behavioral biometric → Way the individual types at a keyboard
- Not expected to be unique to each individual but sufficient for verification
- Keystroke – ‘typing rhythm’
- Signatures based on two time-based measurements
 - Dwell time
 - ◆ time that an individual holds down a *specific* key
 - Flight time
 - ◆ time spend between keys

- Advantages
 - Can be monitored unobtrusively → Keying the information
 - Non-intrusive, may be done covertly

- Problems
 - Performance → Variations in seating, lighting, stress, health
 - Some Individual → Large variations in a typical tying patterns
 - Biased → Only those who can touch/type!
 - Requires substantial samples of text, *not just a sentence*

Odor

- Each object exudes an odor that is characteristic of its chemical composition
- Whiff of air surrounding an object is blown over an array of chemical sensors – each sensitive to certain group/aromatic compound
- An electronic nose
 - An odour sensing instrument
 - Capture the volatile chemicals that skin pores all over the body emit to make up a person's smell
- Problems
 - Invariance in body odor in presence of surrounding environment
 - Still being investigated by researchers

Voice



- Combination of Physiological and Behavioral biometrics
 - Physiological
 - ◆ Shape and size of vocal tracts, nasal, cavities, lips
 - Behavioral
 - ◆ Changes over time → age, health, emotional conditions

- Test-dependent voice recognition
- Text-independent voice recognition, more difficult

- Advantages
 - Highly suitable for phone-based applications
 - ◆ Sampling of telephone traffic

- Problems
 - Speech features → highly sensitive to background noise
 - Varying claims on performance (2-18% FAR/FRR)
 - Lack of independent large scale trials
 - Not very distinctive → *may not be suitable for large scale identification*

Retinal Scan

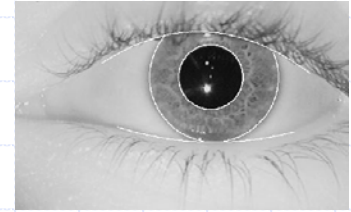


- The pattern of blood vessels that emanate from the optic nerve and disperse throughout the retina
- Unique for individuals and never changes

- Advantages
 - Identical twins
 - Highly secure → Not easy to change/replicate

- Problems
 - Acquisition
 - ◆ Requires the inner eye be subjected to intense illumination
 - ◆ Peep into eyepiece and focus on specific spot in visual field
 - ◆ User → Conscious efforts and high cooperation
 - Lower user acceptance
 - Retinal vascular → Medical conditions

Iris



- Iris → Annular region of the eye bounded by pupil and sclera
- Visual texture → During fetal development
 - Stabilizes during first two years of life
- Complex iris texture → Highly distinctive
- Advantages
 - Highly accurate
 - Identical twins
 - Easy to detect artificial irises
- Problems
 - User participation
 - User acceptance ↓
 - Iridology ?

Hand Geometry



- Hand measurements taken from hand
 - 2D → Perimeter, length and width of fingers, size of palm
 - 3D → Profile of fingers and palm

- System cannot be scaled up for identification from large population
 - Not known to be very distinctive

- Advantages
 - Simple, Easy to use, Inexpensive
 - Environmental factors
 - Low resolution imaging/processing

- Problems
 - Systems → Large physical size
 - Problems due to Jewellery, growth period of children
 - Spoofing

Signature

- Comparing new signature or signing with previously enrolled reference
- Types
 - Dynamic → How an individual signs a document
 - ◆ Speed, pen pressure, stroke direction, points in time when pen is lifted from paper – Digital pad
 - Static → Scrutiny of ink on paper
- Advantages
 - Highest user acceptance
 - ◆ Government, legal and commercial transactions
- Problems
 - Behavioral biometric → influenced by health/age/emotional conditions, can change over a period of time
 - Signatures of some people vary substantially
 - Mechanics of signing are not invariant over time
 - Professional forgers

Veins



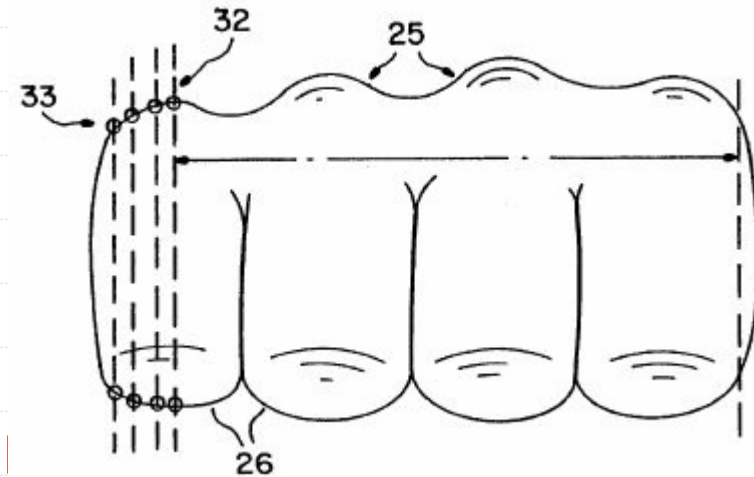
- Record subcutaneous infra red absorption patterns
 - Unique and private identification templates for users
 - Vascular "bar" code reader for users



- Subcutaneous features → Large, robust, stable and largely hidden patterns
 - Wrist, palm, and dorsal surfaces of the hand
- Advantages
 - Large, stable and hidden biometric, developed before birth
 - Low resolution IR, Simple image processing (fast)
 - Identical twins, Changes throughout ones life → overall size
 - Not intrusive, Works even if hands are not clean
- Problems
 - IR Imaging

Other Biometrics

- Otoacoustic emissions
- Skin spectrum
- Lips movement/shape
- Nailbed
- Knuckle creases articulations
- Dental radiograph
- Reflection of acoustic waves in the
- Skin impedance
- Hand pressure profile
- Bone sound transmission
- Bioelectric field champ
- Eye movement tracking
- Finger wrinkles
- Dynamic grip recognition
- Corneal surface topography
- 3D finger surface
- EEG



Comparison

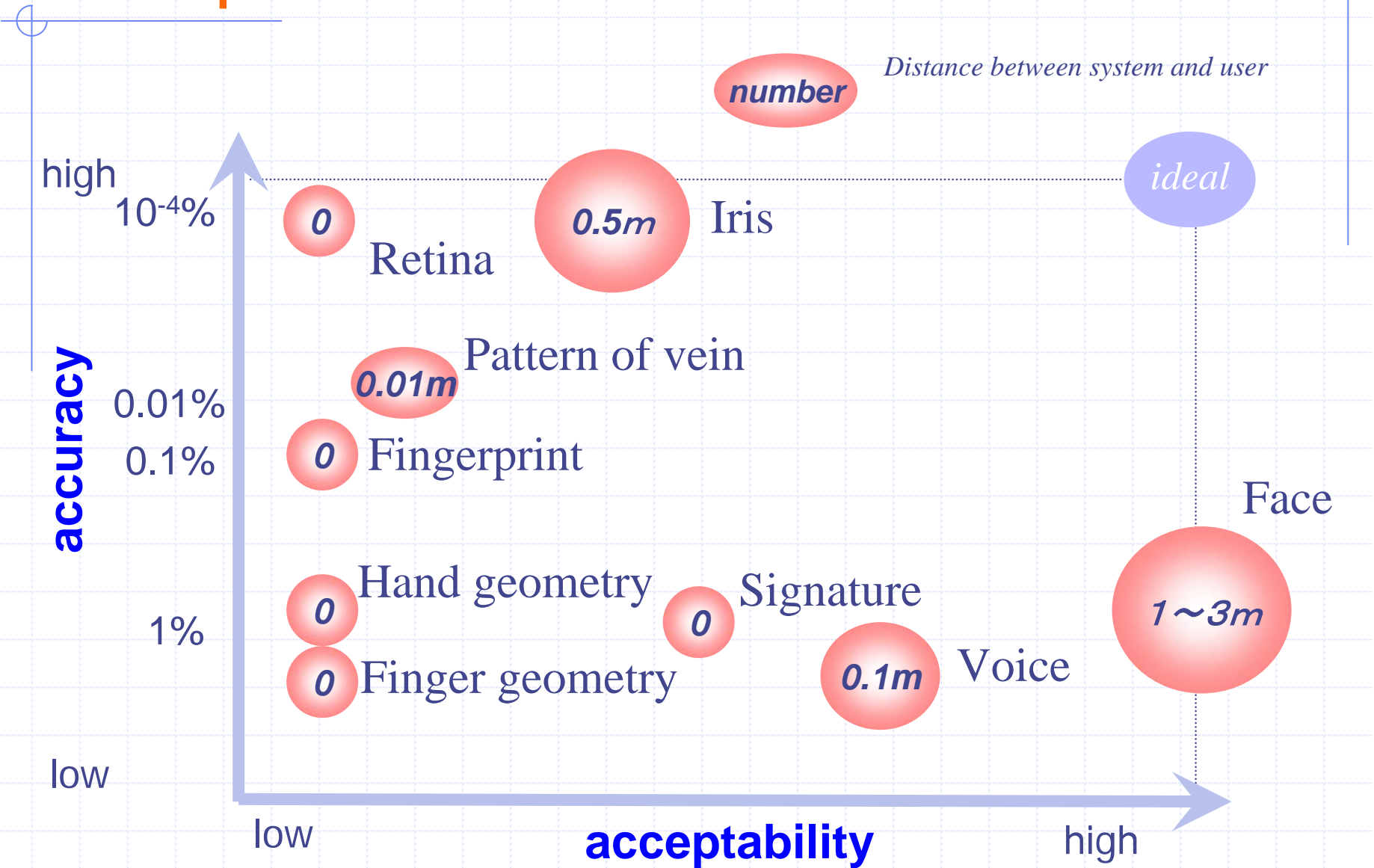
Biometric	Verify	ID	Accuracy	Reliability	Error Rate	Errors	False Pos.	False Neg.
Fingerprint	✓	✓	⊗⊗⊗⊗	▶▶▶▶	1 in 500+	dryness, dirt, age	Ext. Diff.	Ext. Diff.
Facial Recognition	✓	✗	⊗⊗⊗	▶▶	no data	lighting, age, glasses, hair	Difficult	Easy
Hand Geometry	✓	✗	⊗⊗⊗	▶▶	1 in 500	hand injury, age	Very Diff.	Medium
Speaker Recognition	✓	✗	⊗⊗	▶	1 in 50	noise, weather, colds	Medium	Easy
Iris Scan	✓	✓	⊗⊗⊗⊗	▶▶▶▶	1 in 131,000	poor lighting	Very Diff.	Very Diff.
Retinal Scan	✓	✓	⊗⊗⊗⊗	▶▶▶▶	1 in 10,000,000	glasses	Ext. Diff.	Ext. Diff.
Signature Recognition	✓	✗	⊗⊗	▶	1 in 50	changing signatures	Medium	Easy
Keystroke Recognition	✓	✗	⊗	▶	no data	hand injury, tiredness	Difficult	Easy
DNA	✓	✓	⊗⊗⊗⊗	▶▶▶▶	no data	none	Ext. Diff.	Ext. Diff.

Comparison

Biometric	Security Level	Long-term Stability	User Acceptance	Intrusive	Ease of Use	Low Cost	Hardware	Standards
Fingerprint	▶▶▶	▶▶▶	▶▶	Somewhat	▶▶▶	✓	Special, cheap	Yes
Facial Recognition	▶▶	▶▶	▶▶	Non	▶▶	✓	Common, cheap	?
Hand Geometry	▶▶	▶▶	▶▶	Non	▶▶▶	✗	Special, mid-price	?
Speaker Recognition	▶▶	▶▶	▶▶▶	Non	▶▶▶	✓	Common, cheap	?
Iris Scan	▶▶▶	▶▶▶	▶▶	Non	▶▶	✗	Special, expensive	?
Retinal Scan	▶▶▶	▶▶▶	▶▶	Very	▶	✗	Special, expensive	?
Signature Recognition	▶▶	▶▶	▶▶	Non	▶▶▶	✓	Special, mid-price	?
Keystroke Recognition	▶▶	▶	▶▶▶	Non	▶▶▶	✓	Common, cheap	?
DNA	▶▶▶	▶▶▶	▶	Extremely	▶	✗	Special, expensive	Yes

Each biometrics has its own merits or demerits. There are no ideal biometrics!

Comparison



References

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- ❑ <http://genetics.gsk.com/overview.htm>
- ❑ <http://www.luminetx.com>
- ❑ <http://ctl.ncsc.dni.us/biomet%20web/BMCompare.html>
- ❑ Colbert, *Knuckle profile indentivity verification system*, US patent 5,594,806, 1994
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- ❑ http://www.ornl.gov/sci/techresources/Human_Genome/elsi/forensics.shtml
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- ❑ <http://homepage.ntlworld.com/joseph.rice>