Bridging The Gap:
From Biometrics to Forensics

Anil K. Jain

Michigan State University

http://biometrics.cse.msu.edu

February 2, 2015
Outline

• Questions about identity
• What is biometrics?
• Why biometric recognition?
• Automatic biometric recognition
• Challenges
• Bridging the gap
Bridging The Gap

- Uncooperative subjects
- Incomplete and poor quality information
- Fusion of information
- Capacity (distinctive) of body traits
- Persistence of body traits
- Probabilistic models (confidence, reject option)
  - Data to learn the models?
Questions About Identity

• Is Steve authorized to access the website?
• Is Cathy the owner of the bank account?
• Is the visa associated with John?
• Is Mary authorized to enter the building?

We rely on credentials: documents & secrets
Stolen passports are routinely used for illegal activity. Two Iranians boarded flight MH370 using passports stolen in Thailand.

160,050 U.K. passports were either lost or stolen abroad (2008-2013)

INTERPOL has data on 40M lost/stolen travel documents
Driver Licenses

Beta test of face-based scrubbing of 13.5M records in Michigan DMV database shows photos of different subjects in some records!

Courtesy: Pete Langenfeld, MSP
Too Many Passwords!

“Sorry about the odor. I have all my passwords tattooed between my toes.”

Most common passwords: 123456, password, qwerty
Bank ATM

Input to ATM:
- Card
- 4-digit PIN

• Machine does not know who is inputting the card and PIN
• Estimated no. of unauthorized transactions in 2012: 31M with $6B value

Biometric Recognition

Automated recognition of individuals based on their behavioral and biological characteristics
[ISO/IEC JTC1 2382-37:2012]

– Recognition of individuals
– Use of automated methods (no human in loop)
– Context (application)
Bank ATM With Biometrics

Biometric ATM in Lanzhou

Three-factor authentication: Card, PIN and Finger Vein
Origin of the Term Biometrics

- First use of **Biometry** attributed to William Whewell, FRS (1831); used for “calculations on lives” or demography; analysis of biological data using mathematical & statistical methods

- Morris (1875): “… a word whose precise derivation illustrates its intended meaning- from the Greek words **Bios**, life; **Metron**, a measure”

- Pollack (1981): “What makes each person unique?” Introduced biometrics in the context of access control

Bertillon System (1882)

H.T. F. Rhodes, Alphonse Bertillon: Father of Scientific Detection, Harrap, 1956
Fingerprints

“Perhaps the most beautiful and characteristic of all superficial marks (on human body) are the small furrows with the intervening ridges and their pores that are disposed in a singularly complex yet even order on the under surfaces of the hands and feet.”  

Francis Galton, Nature, June 28, 1888
Biometric Traits

Not all of these used in forensics
Biometric Recognition System

Yes: score > T
No: score < T

Matcher (similarity score)
Preprocessor
Feature Extractor

Template Database

Recognition

Enrollment

T: threshold or system operating point

Verification: 1:1 matching; Identification: 1:N matching
Biometric Systems Make Errors

T = 0.18

Score: 0.10
False Reject

Score: 0.21
False Accept
Designing Biometric Systems

• Purpose, target population, system requirements

Texas Health hospital system has 2,488 patients named Maria Garcia; 231 have the same date of birth.

Coal miner identification for safety and T&A; “Anti-Black-Face” Technology.
Drivers of Biometric Technology

- **Security**: Does the person have a prior criminal record?
- **Convenience**: No need to remember *password*
- **Audit trail**: Who accessed the bank vault?
- **Fraud detection**: Is the card holder the rightful owner?
- **De-duplication**: One person, one passport!

Enablers: Processor, storage, sensor technology
Processor & Storage Technology

Enrollment of 724K subjects; average of 400 tenprint search/day @15K comparisons/sec.

Enrollment of 3.0M; 2K tenprint search/day, 35 latent search/day, 5 latent palm search/day @25M comparisons/sec.

Courtesy, Scott Blanchard, MSP
Biometric Sensing Technology

Identix
12.5cm x 18cm x 6cm; 1 lb.
Cost: ~$1,500 (1995)

Digital Persona
(Optical)

Morpho “Finger on the Fly”
(Contactless)

Lumidigm
(Multispectral)

Authentec, Swipe sensor
(Capacitive)

Morpho “Finger on the Fly”
(Capacitive)

96x96 pixels
(500PPI)

Goodix
(Capacitive)
Game Changer

Game Changer

Walt Disney Theme Park (2005)
Game Changer

FBI Next Generation Identification (2008)

First AFIS in 1980; IAFIS launched in 1999

http://www.fbi.gov/about-us/cjis/fingerprints_biometrics/ngi/ngi2/
Basic demographic data and biometrics stored centrally

UID = 1568 3647 4958
10 fingerprints, 2 irises & face image

Central UID database

India’s Aadhaar Program (2009)

https://portal.uidai.gov.in/uidwebportal/dashboard.do
World’s Largest Biometric Database

~730 million unique 12-digit ID numbers have been issued as of January 2015
Game Changer

Apple Pay (2014) with NFC device; 2-factor authentication
State of the Art Performance

Unconstrained

Cooperative

Constrained

Imaging Conditions

MBGC FVC2004 CASIA.v4-distance

100% TAR @ FAR=0.1%
92.2% TAR @ FAR=0.01%
95% Rank-1 accuracy

FRGC, Exp. 1 FVC2002 IREX III

100% TAR @ FAR=0.1%
99.4% TAR @ FAR=0.01%
97.8% TAR @ FAR=0.01%

FVC2002 FRGC, Exp. 1 IREX III

80% TAR @ FAR=0.1%
72% Rank-1 accuracy

76% TAR @ FAR=0.1%

FVC2004 MBGC CASIA.v4-distance

100% TAR @ FAR=0.1%
92.2% TAR @ FAR=0.01%
95% Rank-1 accuracy

FVC2004 MBGC CASIA.v4-distance

80% TAR @ FAR=0.1%
72% Rank-1 accuracy

76% TAR @ FAR=0.1%

FRGC, Exp. 1 FVC2002 IREX III

100% TAR @ FAR=0.1%
92.2% TAR @ FAR=0.01%
95% Rank-1 accuracy

FRGC, Exp. 1 FVC2002 IREX III

80% TAR @ FAR=0.1%
72% Rank-1 accuracy

76% TAR @ FAR=0.1%

FVC2004 MBGC CASIA.v4-distance

100% TAR @ FAR=0.1%
92.2% TAR @ FAR=0.01%
95% Rank-1 accuracy

FVC2004 MBGC CASIA.v4-distance

80% TAR @ FAR=0.1%
72% Rank-1 accuracy

76% TAR @ FAR=0.1%

FVC2004 MBGC CASIA.v4-distance

80% TAR @ FAR=0.1%
72% Rank-1 accuracy

76% TAR @ FAR=0.1%

FVC2004 MBGC CASIA.v4-distance

80% TAR @ FAR=0.1%
72% Rank-1 accuracy

76% TAR @ FAR=0.1%

FVC2004 MBGC CASIA.v4-distance

80% TAR @ FAR=0.1%
72% Rank-1 accuracy

76% TAR @ FAR=0.1%
Bridging The Gap

Forensic Science
- Latent fingerprint
- Latent palmprint
- Fibers
- Explosive residue
- Paint chips
- DNA
- Tire marks
- Shoe prints
- Bite marks
- Handwriting
- SMT

Biometrics
- 2D Face
- 3D Face
- Fingerprint
- Iris
- Speech
- Signature
- Gait
- Ear
- Palmprint
- Keystroke

- Distinctiveness
- Minimize human bias and sources of error
- Probabilistic models of similarity score; degree of uncertainty
- Fusion of evidence
Probabilistic Matching of Ballistics Images

Toolmark types: breech face impression (BF); firing pin impression (FP); ejector mark (EM)
Distinctiveness of a Biometric Trait

• Given a 10-digit PIN, no. of unique identities that can be resolved = 10 billion
• But, what can we say about a biometric trait?
• How many traits needed to recognize 7B individuals?
• Biometric trait vs. representation
Distinctiveness of Face Representation
(Intra-person Variability)

Same woman arrested at different times
Does the fingerprint matching accuracy decrease with time lapse?

Biometrics For Lifetime

Fingerprint capture of a baby at a health clinic in Cotonou, Benin

Inked finger of an Afghan woman after voting in Bamiyan, Afghanistan
A Case Study on the Boston Bomber

(Gallery of *one million* mug shots)

**Race:** White
**Gender:** Male
**Age:** 20 to 30

<table>
<thead>
<tr>
<th>Race</th>
<th>Gender</th>
<th>Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>White</td>
<td>Male</td>
<td>20-30</td>
</tr>
</tbody>
</table>

![Images of Tamerlan Tsarnaev]

<table>
<thead>
<tr>
<th>(b) WITH DEMOGRAPHIC FILTERING (white male, 20-30)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td><strong>lx</strong></td>
</tr>
<tr>
<td><strong>ly</strong></td>
</tr>
<tr>
<td><strong>lz</strong></td>
</tr>
<tr>
<td>mean</td>
</tr>
</tbody>
</table>

Tamerlan Tsarnaev
Soft Biometrics: Scars, Mark & Tattoos

http://wtvr.com/2012/05/04/pictures-investigators-seek-shirtless-heavily-tattooed-suspect/
Confidence in Latent Comparison

Similarity score = 6.54; retrieval rank = 1; score range: [0, 13.29]
Attacks on Biometric Systems

Natural Fingerprint

Minutiae

Minutiae Density Map

Altered Fingerprint
Summary

• Biometrics deals with real-time, automatic recognition of a person based on body traits

• Biometric has its origins in forensics; current challenges in biometrics have forensics flavor

• Synergy between forensic science (data and domain expertise) and biometrics (models, learning algorithms and computing) is needed to put forensics science on a firm footing