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1st Israeli Biometrics Winter School, Haifa

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Biometrics: 2020 Vision

Outline

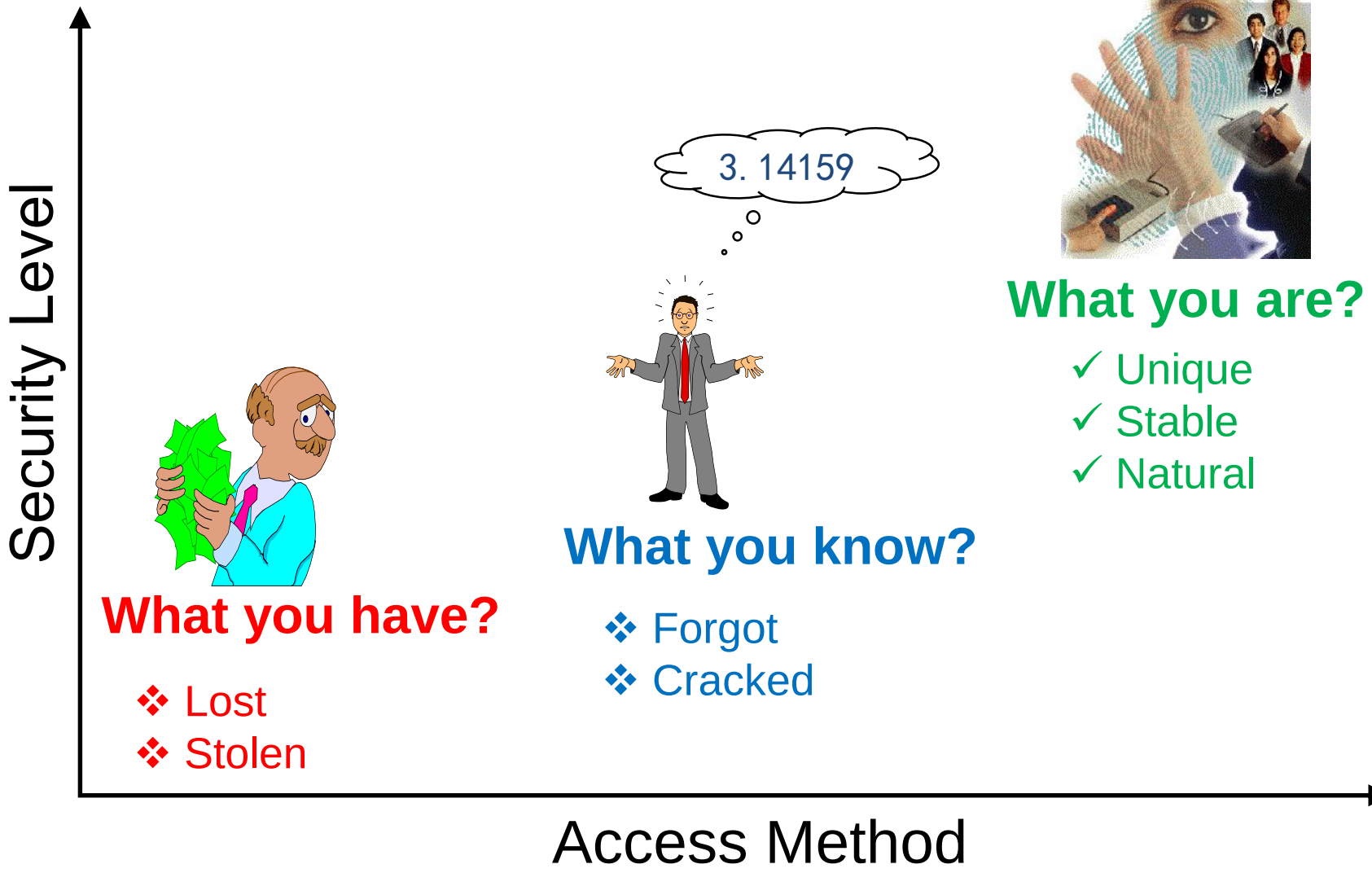
- Background and milestones
- Drivers (applications) and enablers
- State-of-the-art
- 2020 Vision
- Summary

Security Concerns

We now live in a society where individuals cannot be trusted based on their ID documents and PIN/passwords

CARIBBEAN AIRPORT SECURITY

Methods of Person Recognition



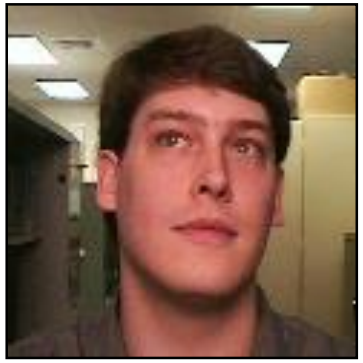
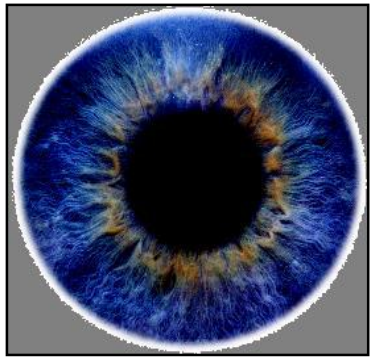
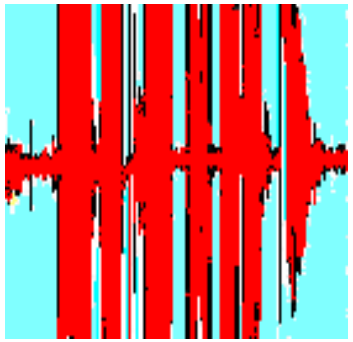
Biometrics

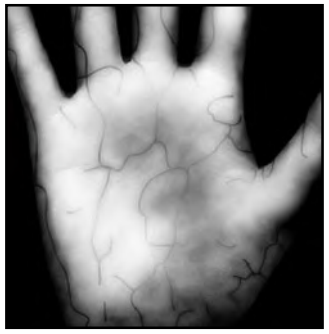
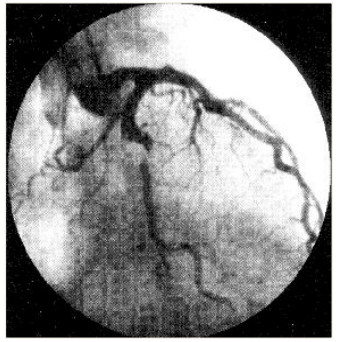
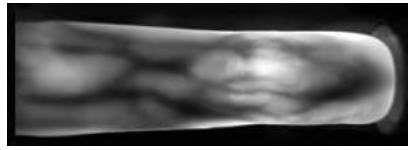
- Morris (1875): ***Bios:*** **life** and ***Metron: a measure***
- Pollack (1981): ***What makes each person unique?***
- *ISO/IEC JTC1 2382-37:2012:* ***"Automated recognition of individuals based on their behavioral and biological characteristics"***
- ***Foundation of biometrics laid over 150 years back***

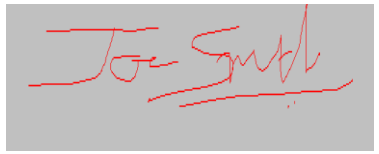
Stigler, "The Problematic Unity of Biometries", BIOMETRIC5, S6 , Sept. 2000
Pollack, "Technology: Recognizing the Real You", NYT, Sep. 24, 1981

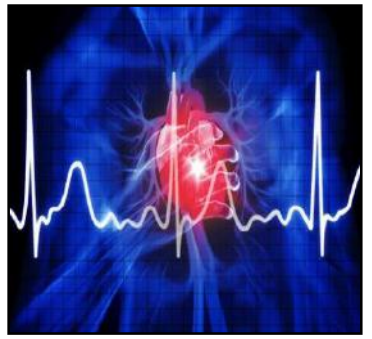
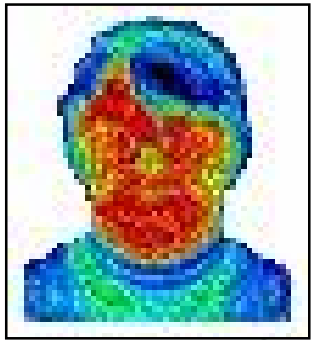
Biometric Milestones

Biometric Characteristics (Traits)

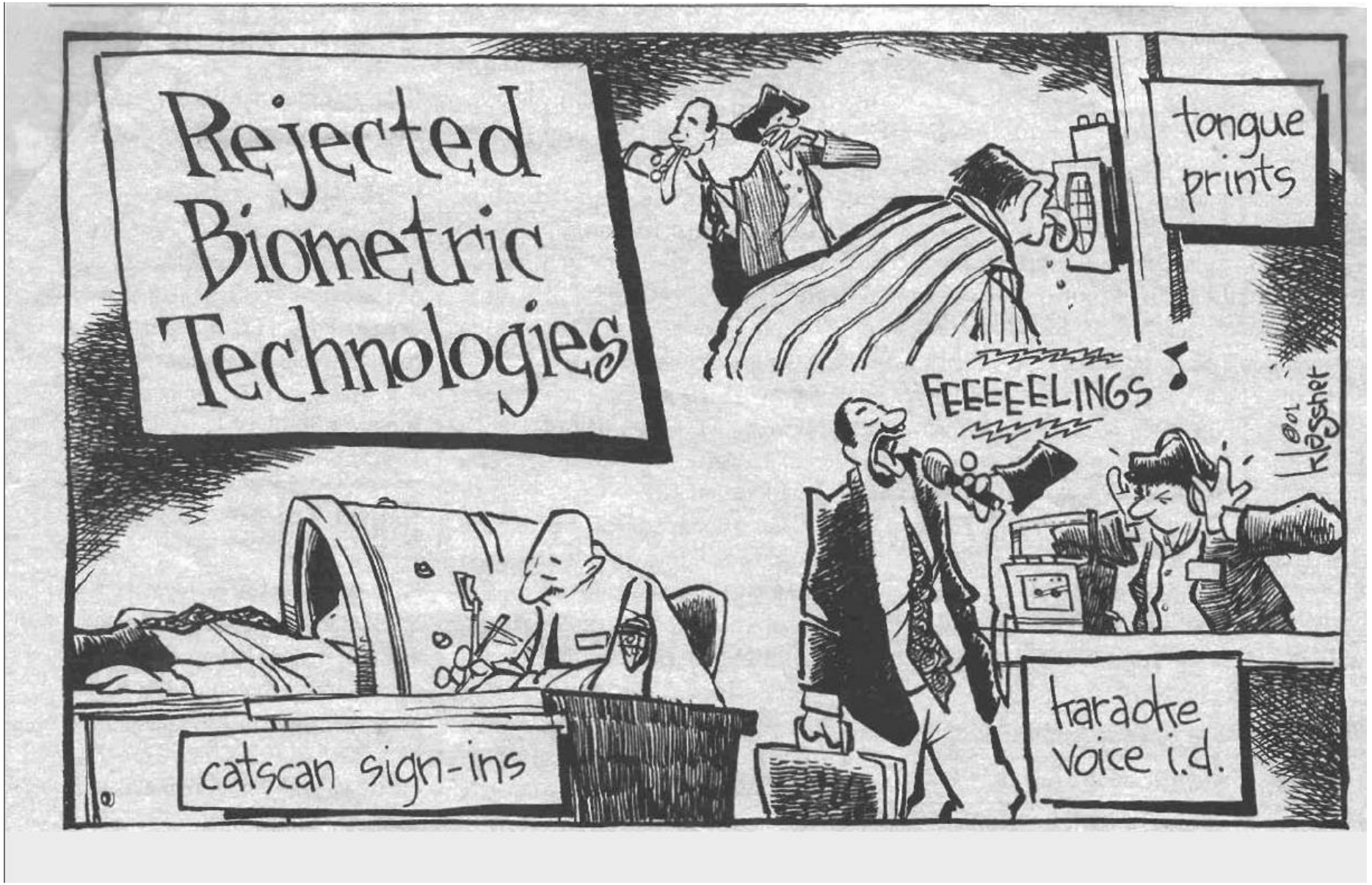





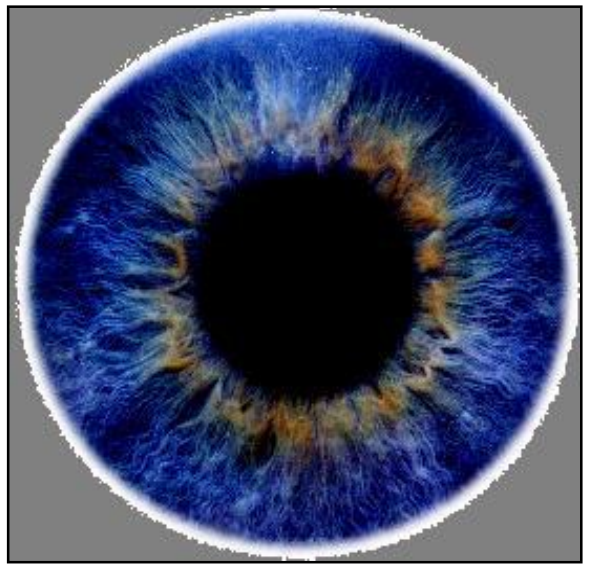
Rejected Traits



Which Biometric Trait?

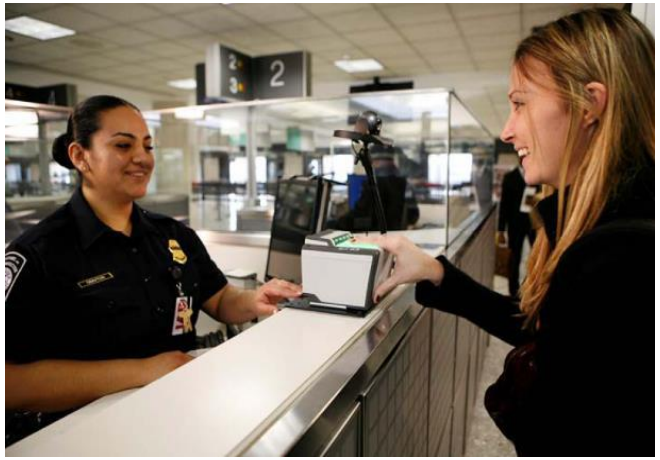
- **Uniqueness** (distinctive across users)
- **Permanence** (does not change over time)
- **Universality** (every user has it)
- **Collectability** (ease of capture)
- **Performance** (error rate, throughput)
- **User experience** (acceptable to the users)
- **Circumvention** (resistant to spoofing)
- **Integration** (easy to embed in an application)

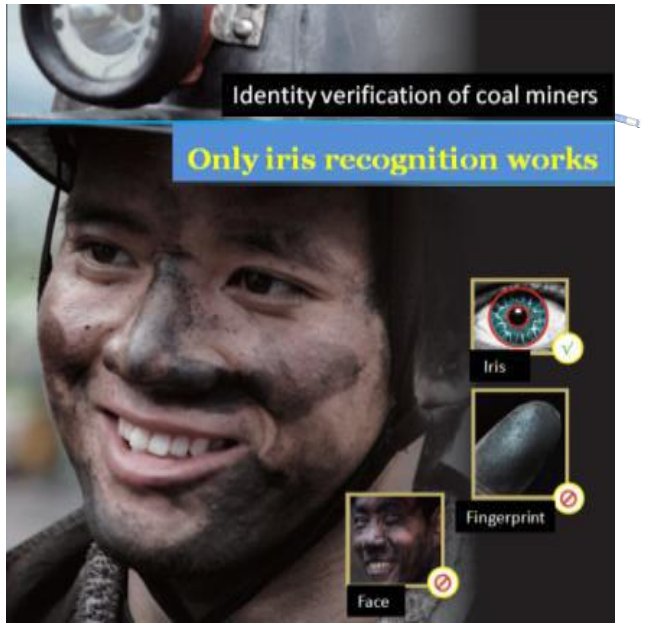
Most Frequently Used Biometric Traits

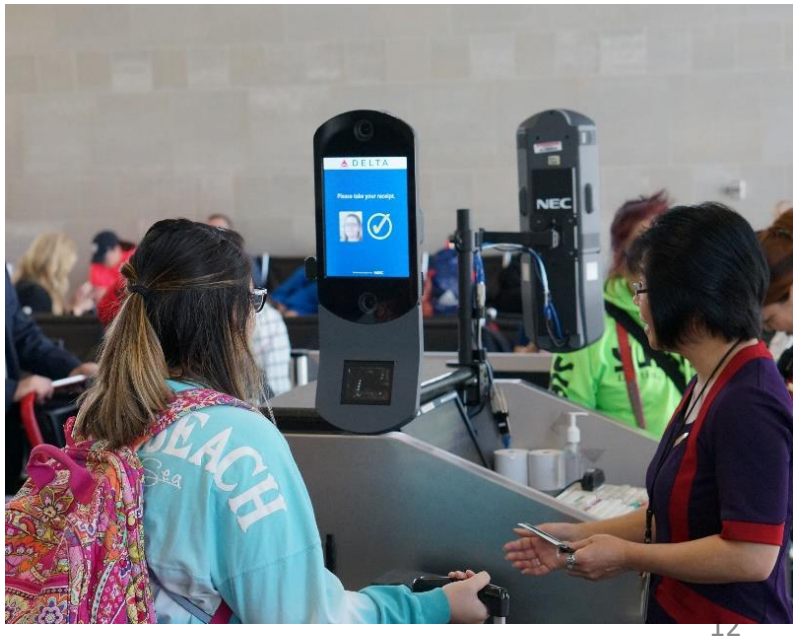


- **Legacy databases**
- **Capability for 1:N search for large N**
- **Uniqueness (capacity) and stability**
- **High accuracy in NIST evaluations**

Biometrics Applications







Applications in Israel

ID card with Face and two index fingerprints

https://www.gov.il/en/service/biometric_smart_id_request

Speed Gate: West Bank Check posts

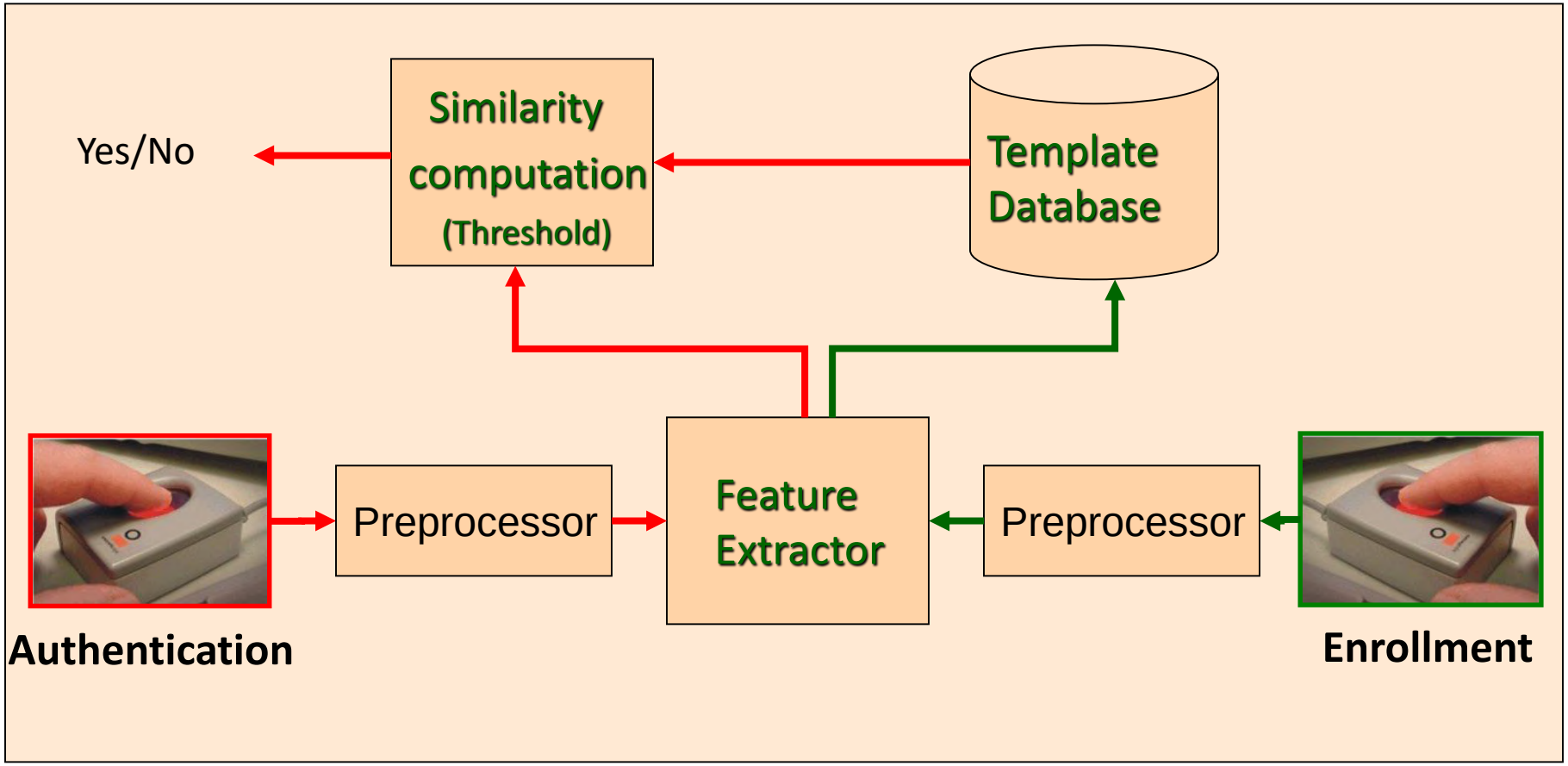
https://www.npr.org/2019/08/22/752765606/face-recognition-lets-palestinians-cross-israeli-checkposts-fast-but-raises-conc

Application Requirements

Walt Disney Theme Park (2005)

- Throughput
- Embedded
- Ease of use
- Low cost
- Spoof detection

Biometrics Recognition System



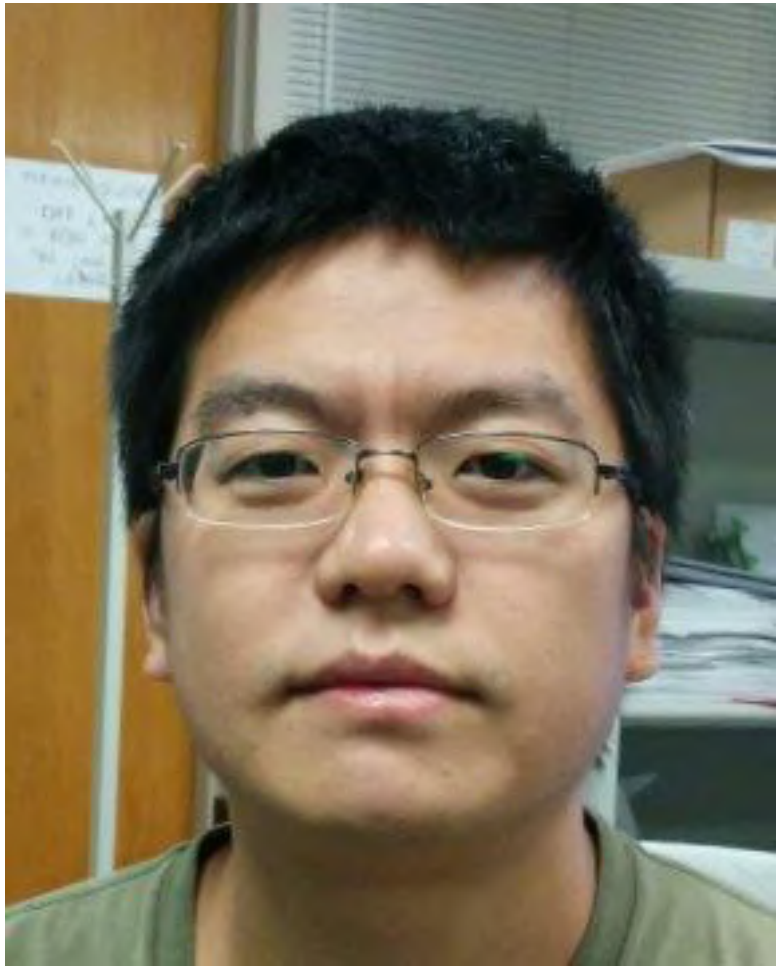
- **Enrollment; Template**
- **Authentication (claim an identity); Search**

Biometric Template

Face Authentication

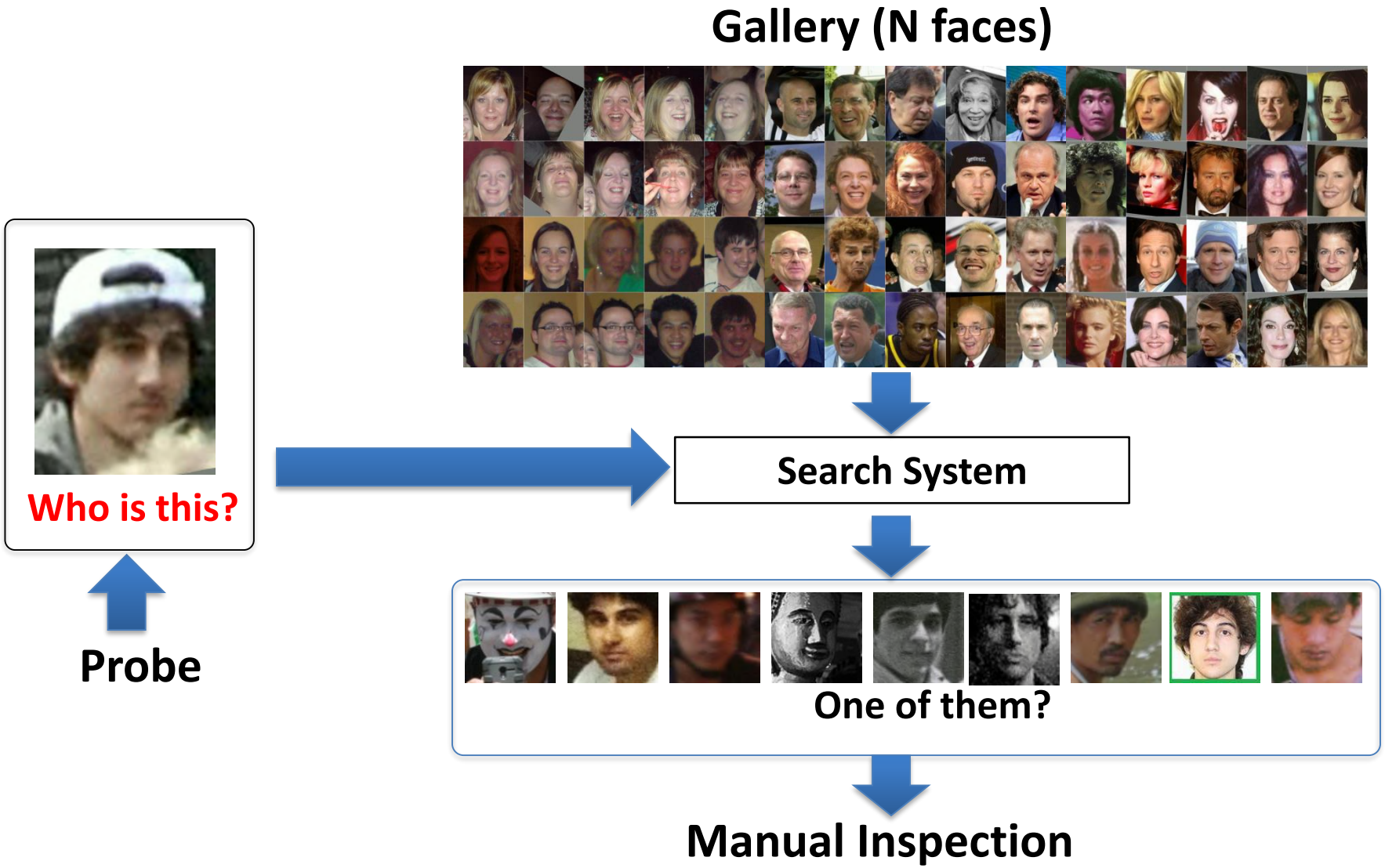
Probe

Same Person?
Similarity > T



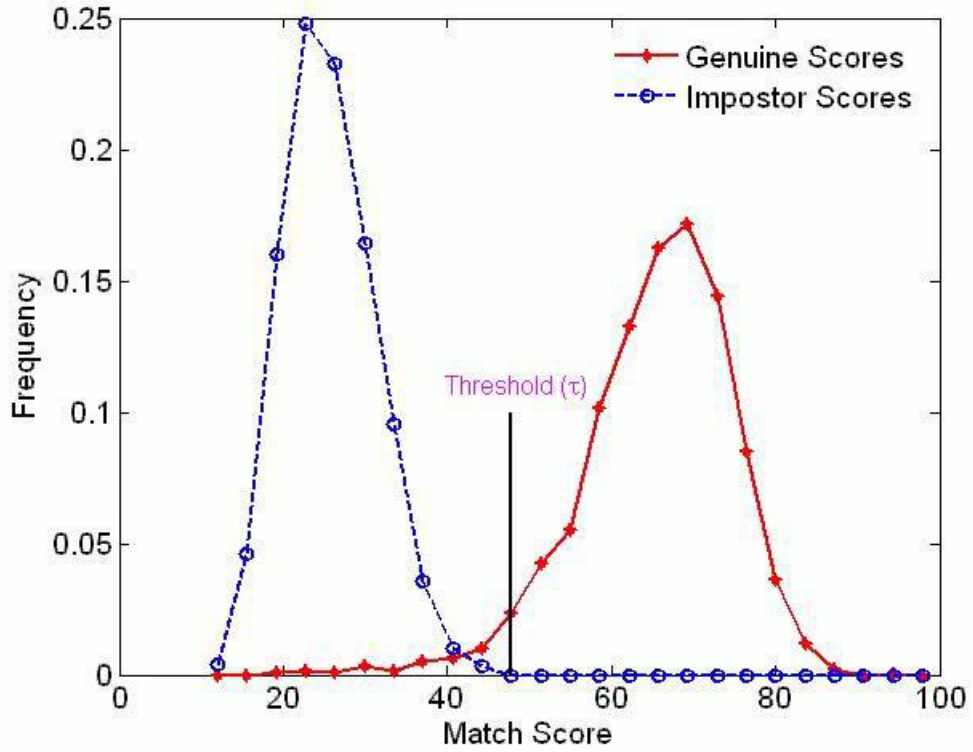
Gallery

Search

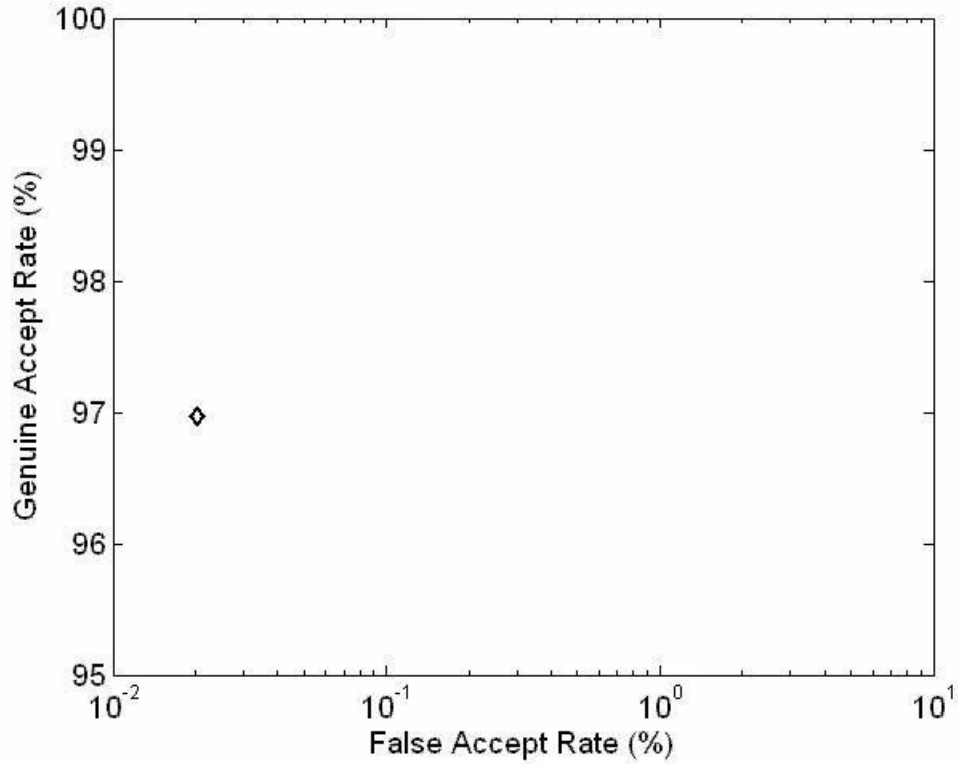


Wang, Otto, Jain, “Face Search at Scale: 80 Million Gallery“, arXiv:1507.07242v2 [cs.CV]

Authentication Performance



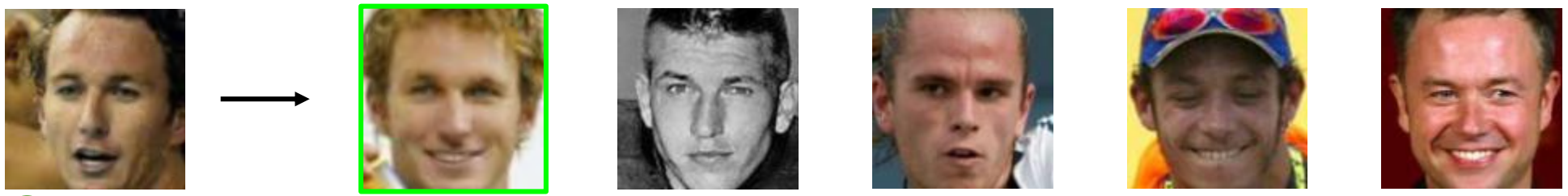
Similarity Score Distribution



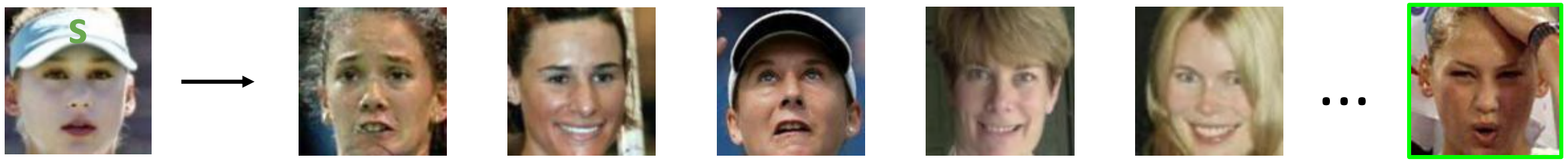
ROC Curve

Closed-set Identification

Probe Image **Top-5 Retrievals**



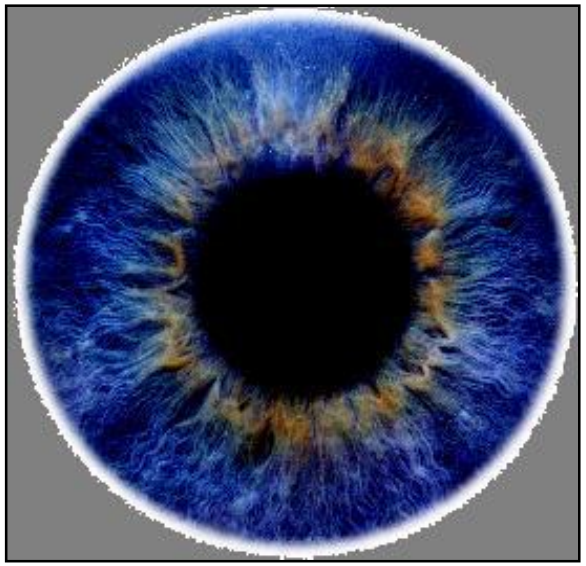
Succes



Failure

- All the probes are guaranteed a mate (green) in the gallery
- Search is a success if the mate is in the top-K retrievals
- **Rank-K retrieval rate** is the percentage of successful searches

State of the Art: Authentication



Fingerprint: TAR = 99.964% @ FAR =0.01% (FVC-ongoing)

Iris: TAR = 99.82% @ FAR = 0.01% (NIST IREX II)

Face: TAR = 99.7% @ FAR = 0.1% (NIST FRVT 2010)

State of the Art: Unconstrained FR Performance

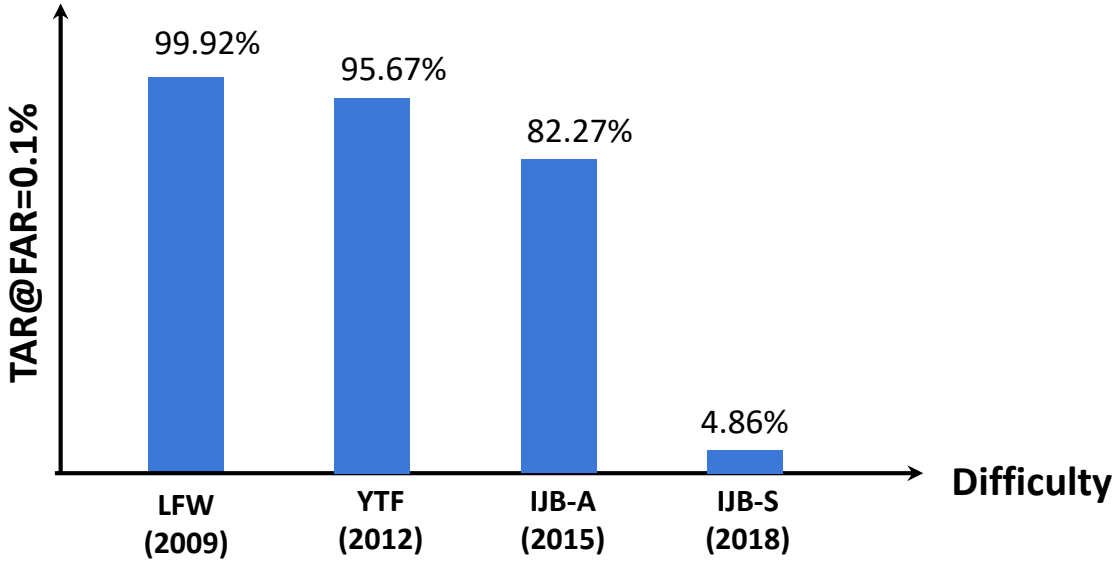
LFW (2009)

YTF (2012)

NIST IJB-A (2015)

NIST IJB-S (2018)

Frame-to-Frame Verification



Template Identification

	Gallery Size	Rank1	Rank5
IJB-A	112	97.5	98.4
IJB-S (S2B)	202	62.0	67.1

S2B: Surveillance to Booking protocol

World's Largest Biometric System

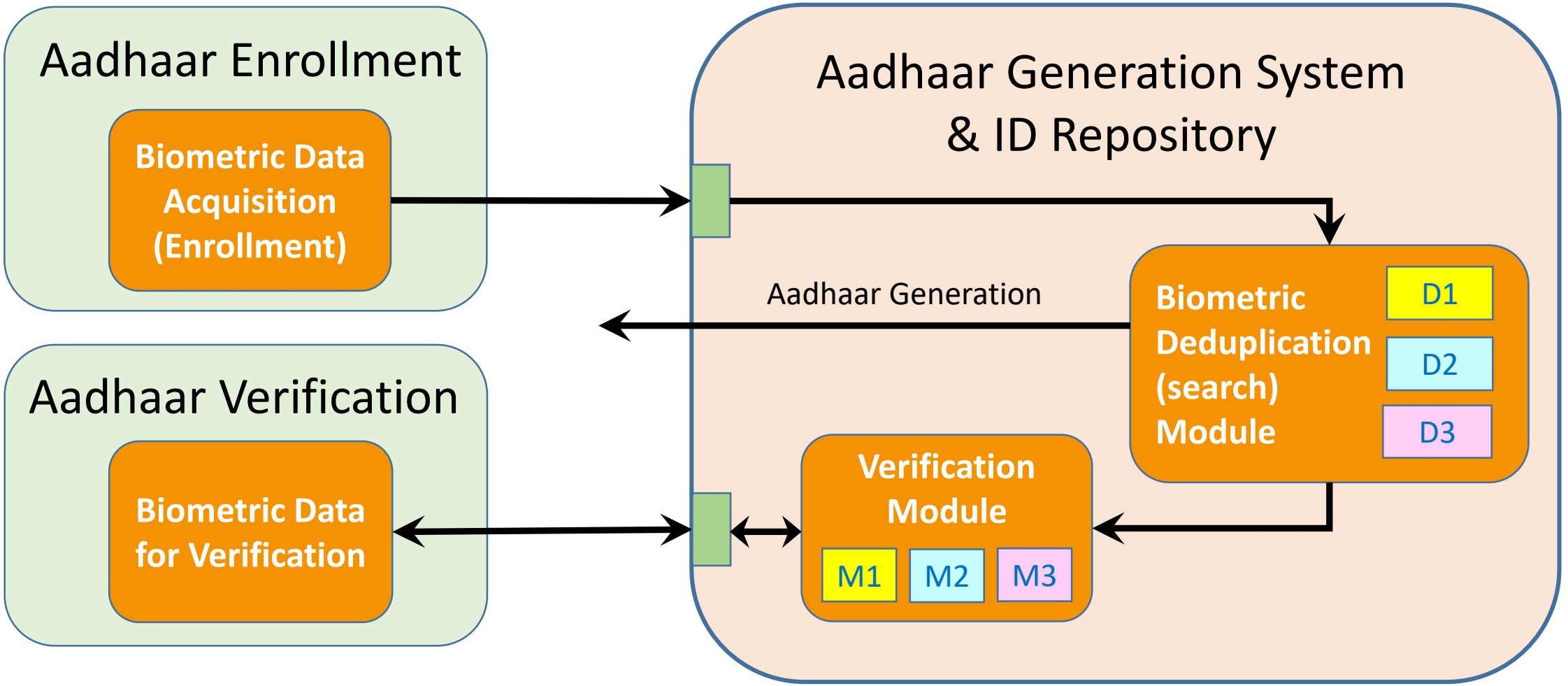
- Established in 2009
- Enrolment of ~1.3 billion residents

"To empower residents of India with a unique identity and a digital platform to authenticate anytime, anywhere."

Aadhaar (*Foundation*)

A 12-digit randomly generated Identifier, linked to your biometrics

Aadhaar Biometric Modules

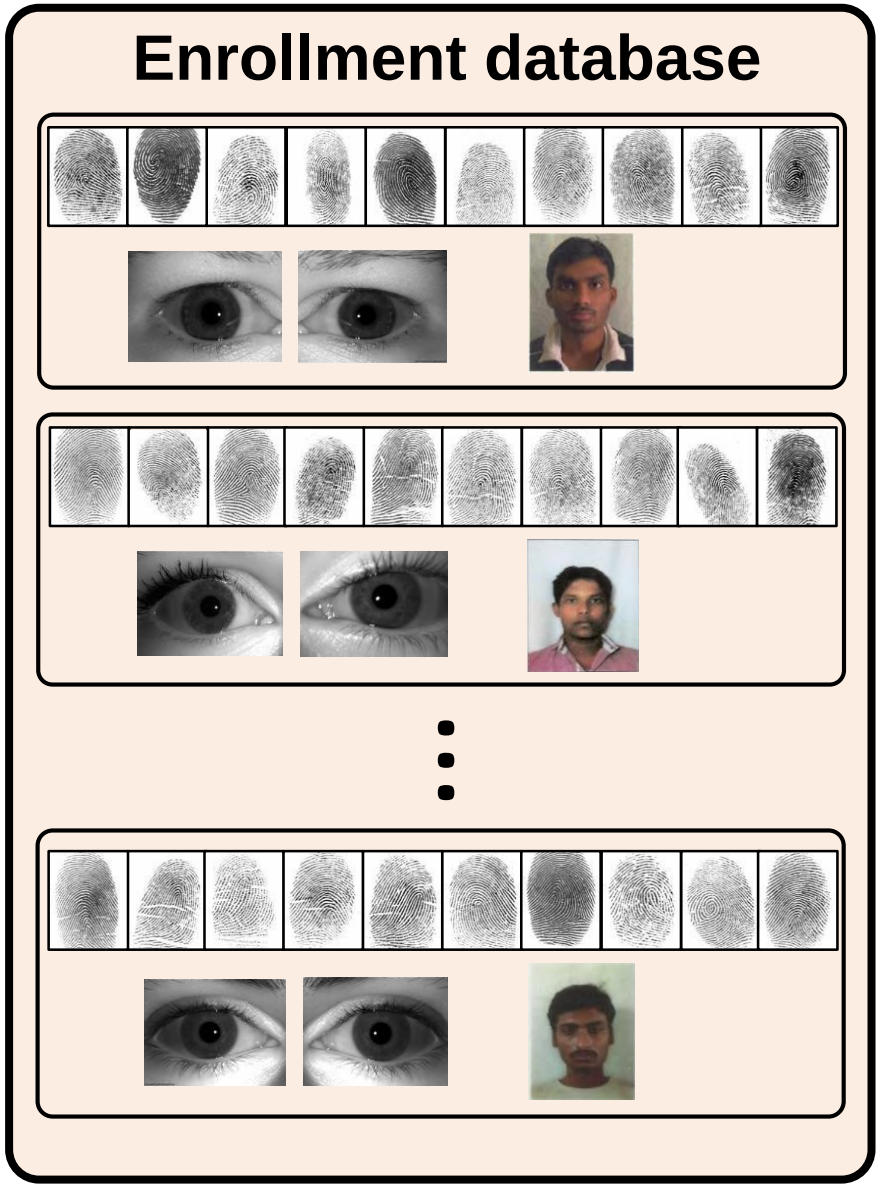


Enrollment

Minimal documentation for enrollment

De-duplication (Find duplicates)

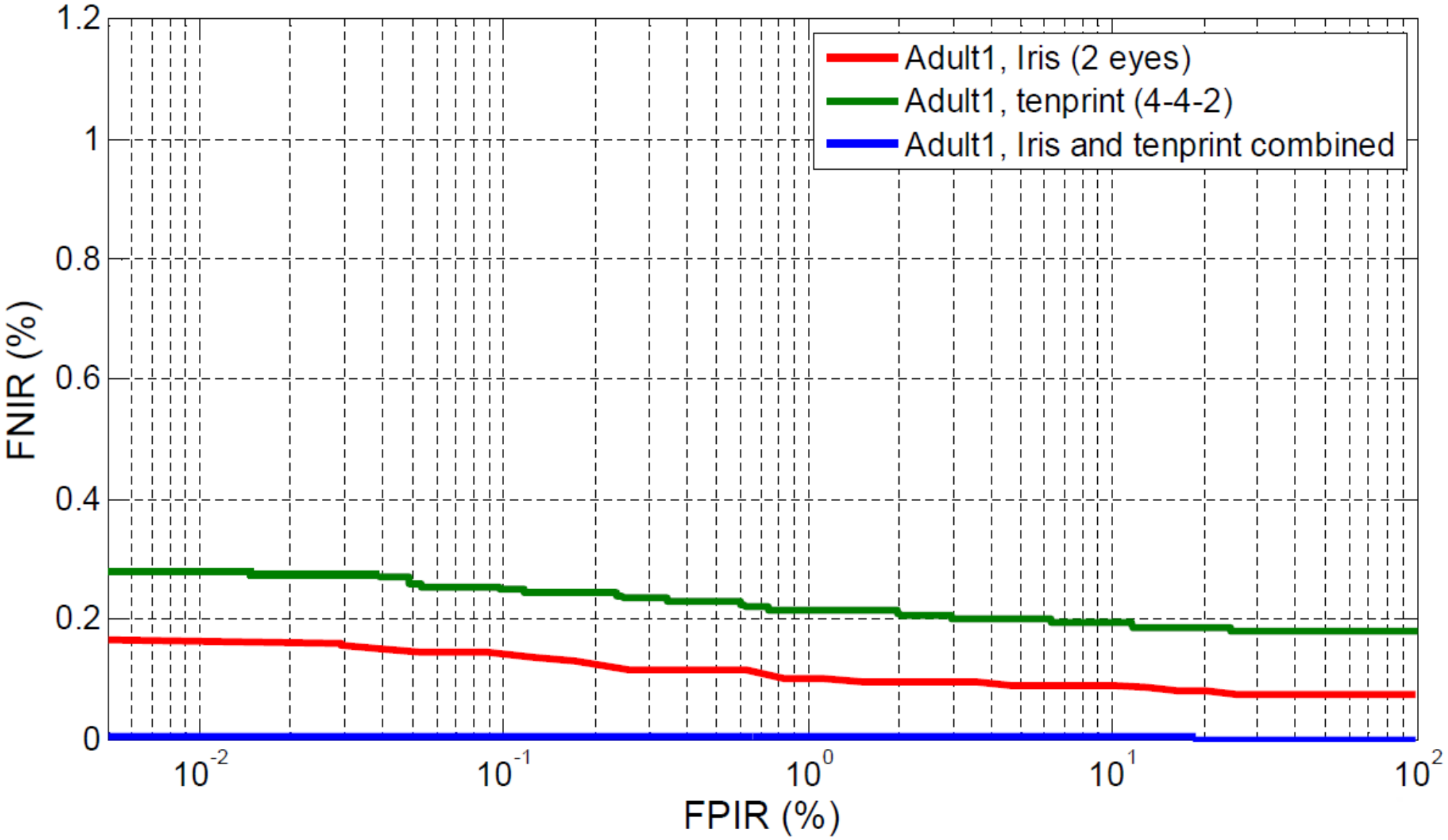
New Applicant



Already Exists in the Database?

Fusion of face, fingerprint and iris improves de-duplication

Biometric Fusion for De-duplication

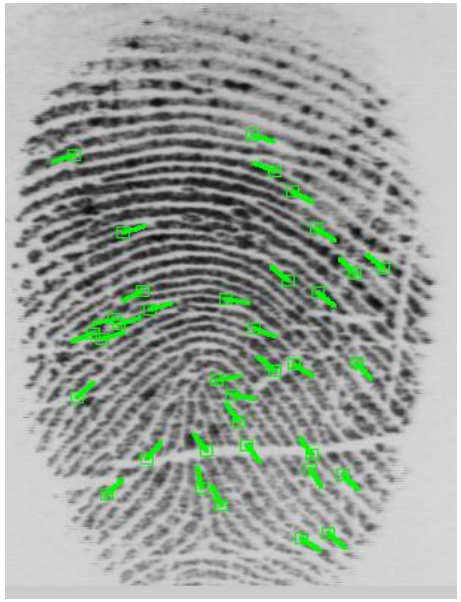


Authentication

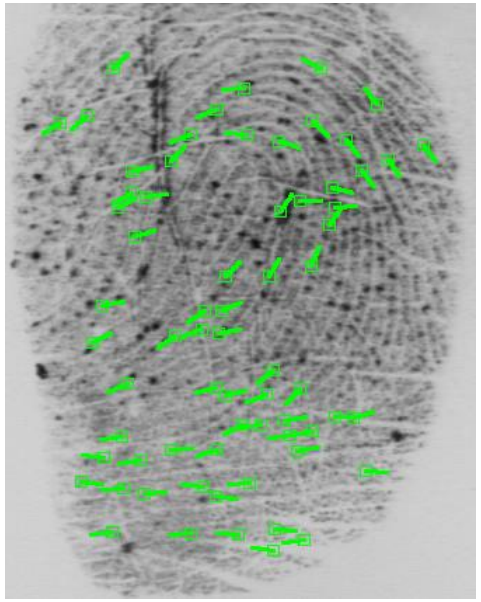
Over 30 million biometric authentication transactions/day

Fingerprint Quality Challenges

No. of false minutiae = 0

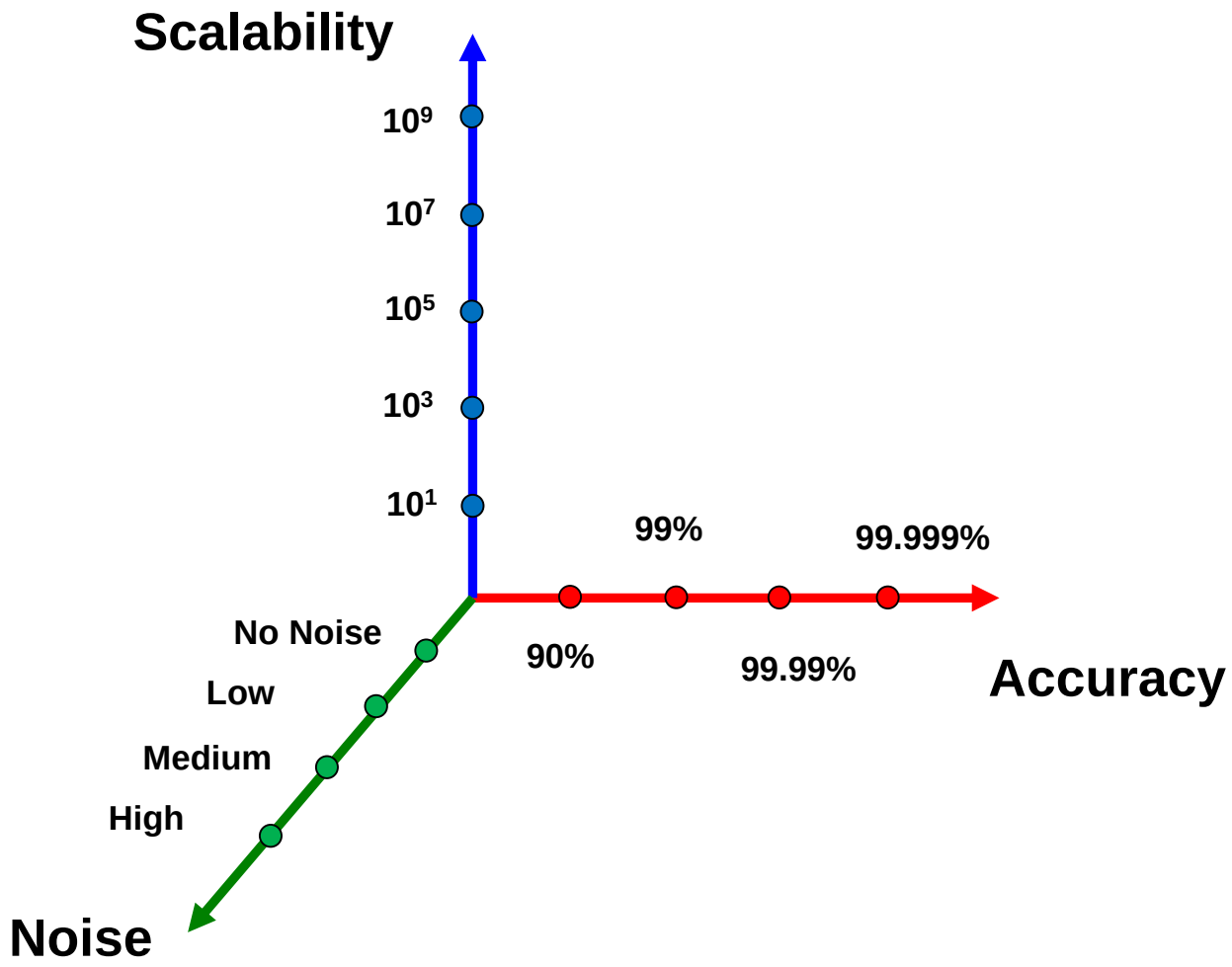


No. of false minutiae = 7



No. of false minutiae = 27

2020 Vision



Systems operating at the edge while maintaining privacy, cost,….

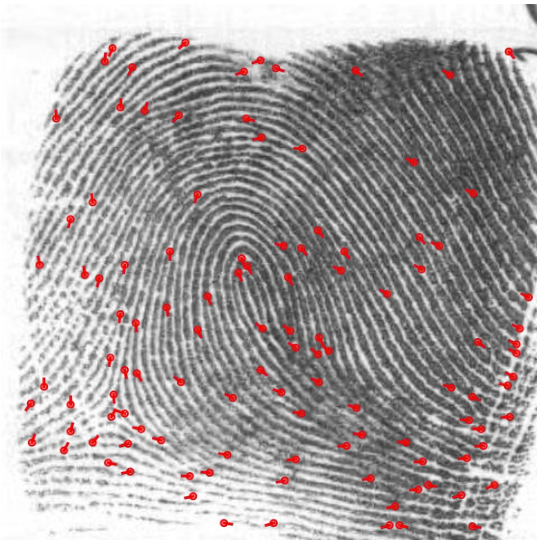
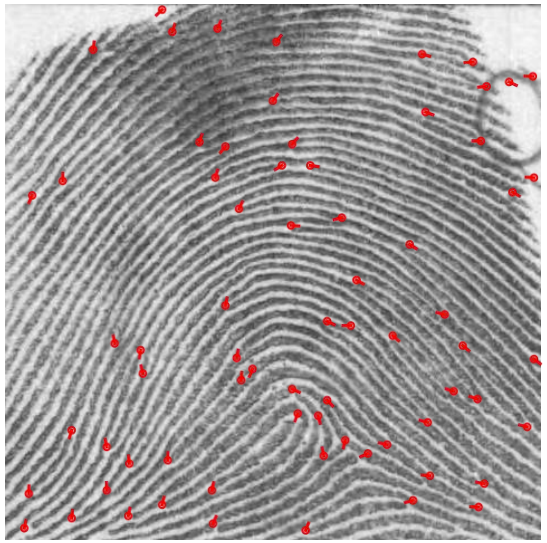
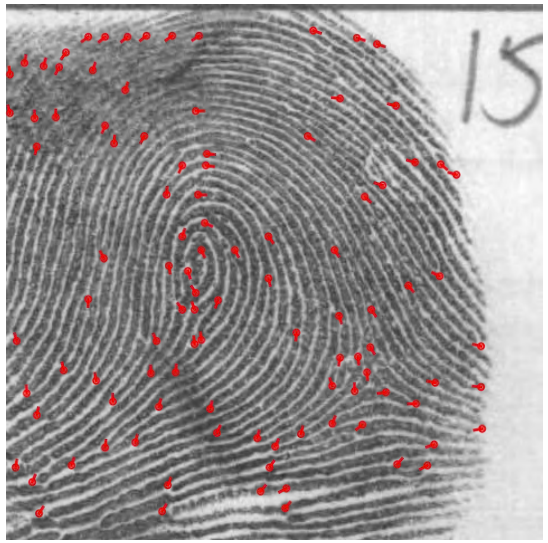
Scalability

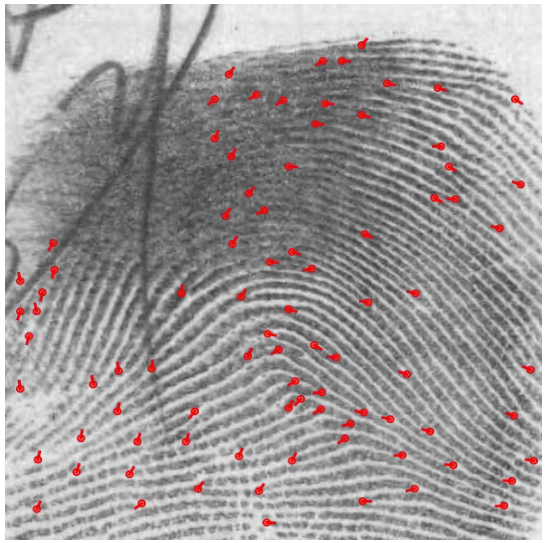
- Population of Israel = 9 m
- #Enrollments in FBI database = 100 m (70 m criminals)
- #Enrollments in Aadhaar = 1.3 bn
- Current World Population = 7.8 bn (11 bn in 2100)
- #New births/year = 130 m/year (250/minute)
- **The United Nations (UN) Member States have adopted Sustainable Development Goal (SDG) Target 16.9: "to provide legal identity for all, including birth registration" by 2030.**
- **That would be 10 times larger than Aadhaar**

How Do We Get Biometric Data?

- Data is necessary for
  - Model training (learning)
  - Evaluation of trained model
- Larger the data sample from population of interest, more robust and generalizable the model
- Data privacy makes it difficult to collect and share data
- *Venmo demands end to harvesting of images by Clearview AI (which has collected 3 bn images), NYT Feb 6, 2020*

Synthetic Fingerprint Generator

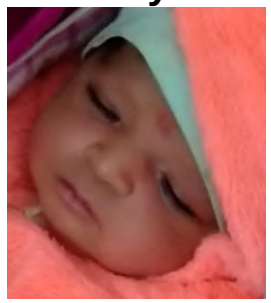








6 days

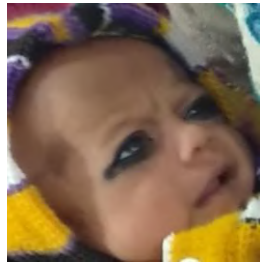
8 days



2 Months, 27 days

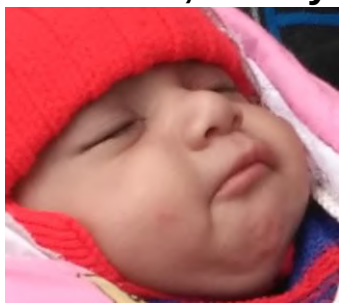
1 Month, 12 days

1 Month, 14 days



4 Months, 5 days

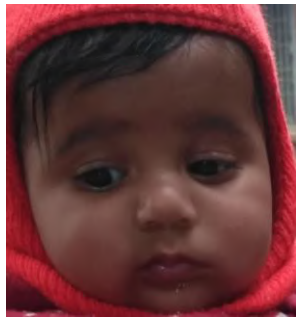
2 Months, 13 days



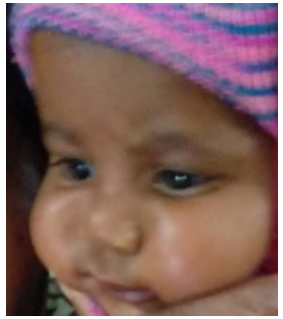
2 Months, 15 days

5 Months, 5 days

3 Months, 13 days



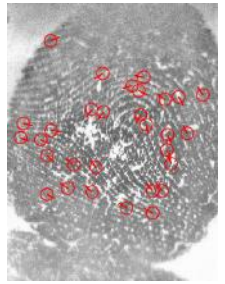
3 Months, 15 days



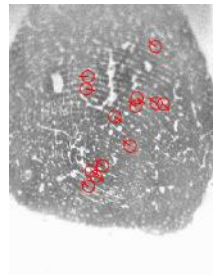
6 Months, 5 days

Longitudinal

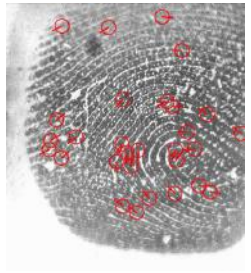
6 days



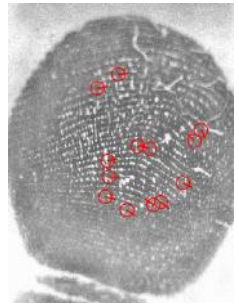
8 days



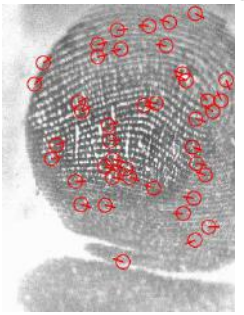
2 Months, 27 days



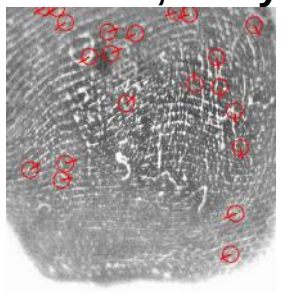
1 Month, 12 days



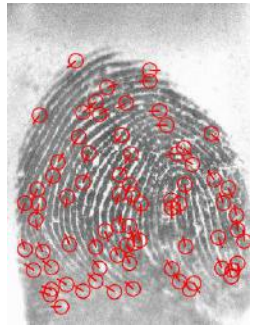
1 Month, 14 days



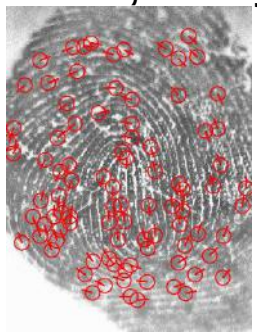
4 Months, 5 days



2 Months, 13 days

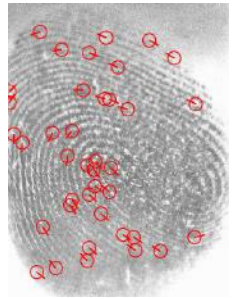


2 Months, 15 days

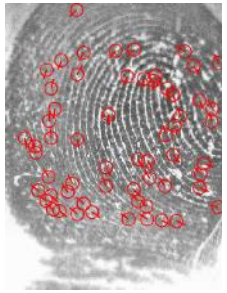


5 Months, 5 days

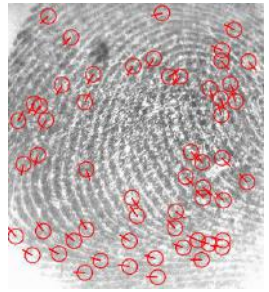
3 Months, 13 days



3 Months, 15 days

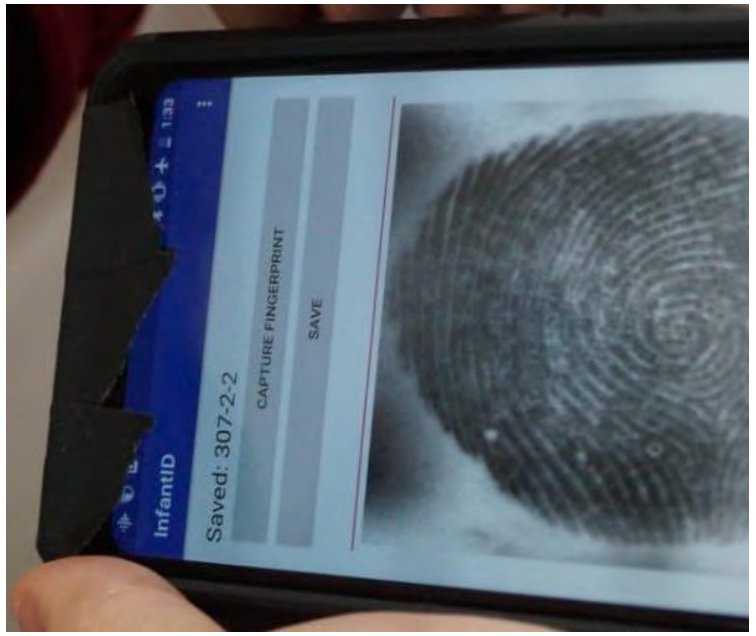


6 Months, 5 days



In-situ Evaluation

Saran Ashram Hospital, Dayalbagh, Agra, India



Enrollment	0-1 Months	1-3 Months	2-3 Months
Left Thumb	59.0% (65.4%)	62.3% (69.6%)	76.5% (82.4%)
Right Thumb	55.8% (58.4%)	60.9% (63.8%)	68.4% (74.5%)
Thumbs Fused	66.7% (78.2%)	75.4% (85.1%)	90.2% (94.1%)

- **TAR @ FAR = 0.1% (1.0%)**
- **Authenticate with 3-months gap**
- **Fusion of three matchers**

Infant ID

- **Is this the infant (0-12 mos.) his parents claim him to be?**
- **Have we seen this infant before?**

Engelsma, Deb, Jain, Sudhish, Bhatnagar, "Infant-Prints: Fingerprints for Reducing Infant Mortality", CVPR Workshop on CV4GC, 2019
Jain, Arora, Cao, Best-Rowden Bhatnagar, "Fingerprint Recognition of Young Children", IEEE TIFS, 2016

Why Infant Identity?

Birth registry
Vaccination
Nutrition
Baby swapping

Vaccination Clinic

Food distribution

In many Sub-Saharan African countries rural birth registration for children under 5 is less than 50 percent

https://bit.ly/1oIVAOf

Which Biometric for Infants?

Palmprint

Face

Iris

Fingerprint

Footprint or Ballprint

Requirements: permanence, uniqueness, ergonomic, acceptability, low cost, lifelong usability

Fundamental Premise of Biometrics

- **Individuality:** Do different individuals have different biometric features? Does the same person always has the same feature vector?

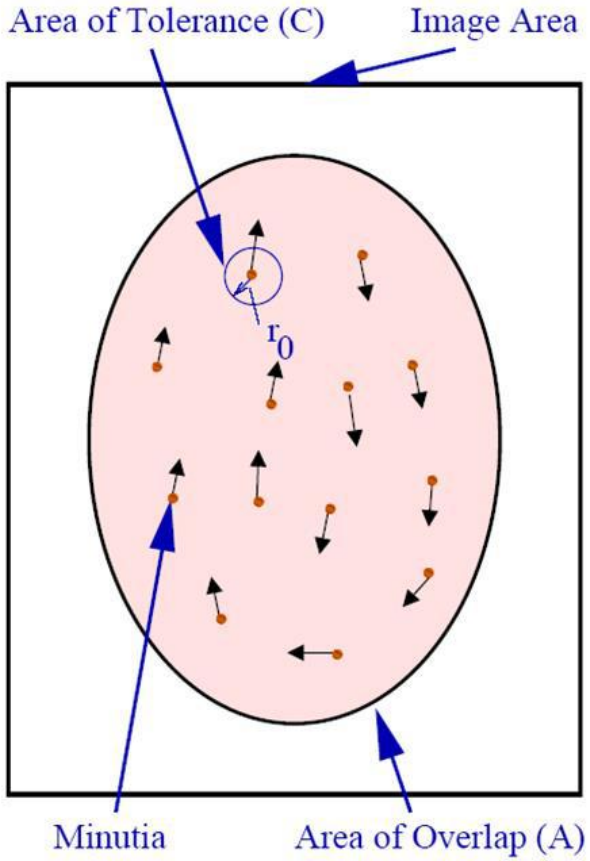
- **Permanence**: How does recognition accuracy change with increasing time gap between enrolled and query biometric?

Large Intra-Person Face Variability

Large Inter-Person Face Similarity

Ilham Anas, a photographer from Java, travels the world cashing in on his uncanny resemblance to the former US president

Fingerprint Individuality



- "Two Like Fingerprints Would be Found Only Once Every 10^{48} Years" (Scientific American, 1911)
- PRC = Prob. of two fingerprints with *m* and *n* minutiae sharing *q* points in common

m = n = q = 26, PRC = 2.40×10^{-30}

m = n=26, q=10, PRC = 5.49×10^{-4}

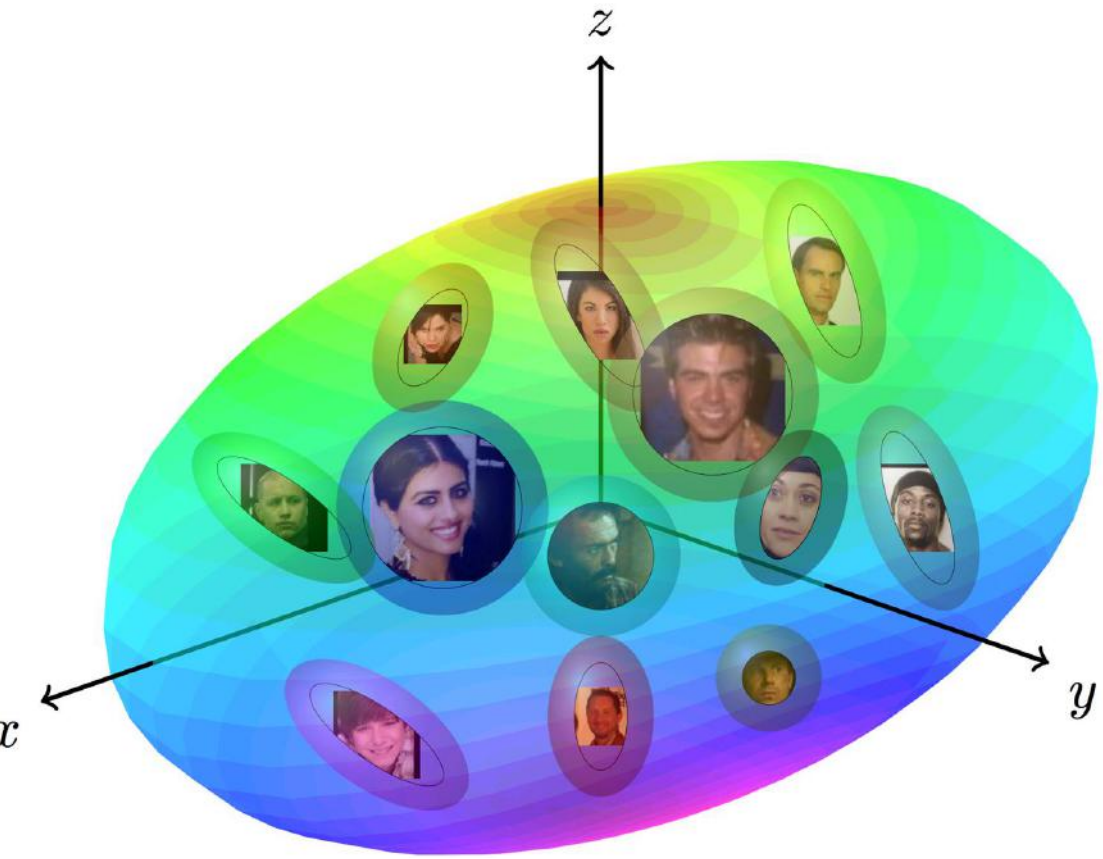
Pankanti, Prabhakar and Jain, On the individuality of fingerprints, PAMI, 2002

Fingerprint Persistence

- Fingerprint records of 16K subjects over 12 years
- Longitudinal model showed: (i) Accuracy is stable over time;
  (ii) Accuracy depends on the fingerprint image quality

Yoon and Jain, "Longitudinal Study of Fingerprint Recognition", PNAS, 2015

Capacity of Face Recognition



- **#Identities resolved at a specified FAR and feature space (FAR of 0.01% and SpehereFace model)**

IJB-A, capacity = 1.1 x 10^4

IJB-C, capacity = 2.0 x 10^2

Gong, Boddeti, Jain, "On the Intrinsic Dimensionality of Face Representation", arXiv:1803.09672, 2018

Persistence of Face

- **Longitudinal face data of 20K subjects**
- **Findings: 99% of the subjects could be recognized @ 0.01% FAR up to 6 years irrespective of age, gender & race**

Best-Rowden and Jain, "Longitudinal Study of Automatic Face Recognition", PAMI, 2017

Soft Biometrics

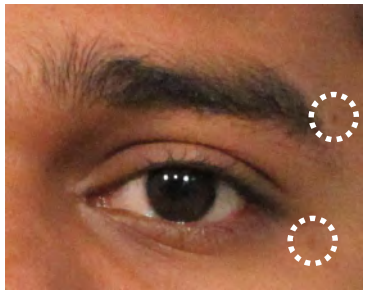
Provide some discriminatory information; can be used alone or in conjunction with primary traits

Ethnicity, Gender, Skin & Hair color
(Sub-Saharan African, Indian, Southern European, and Northwest European)

Height

Eye color

Scars, Marks, and Tattoos (SMT)



Periocular

Weight

A Tattoo Reveals True Identity

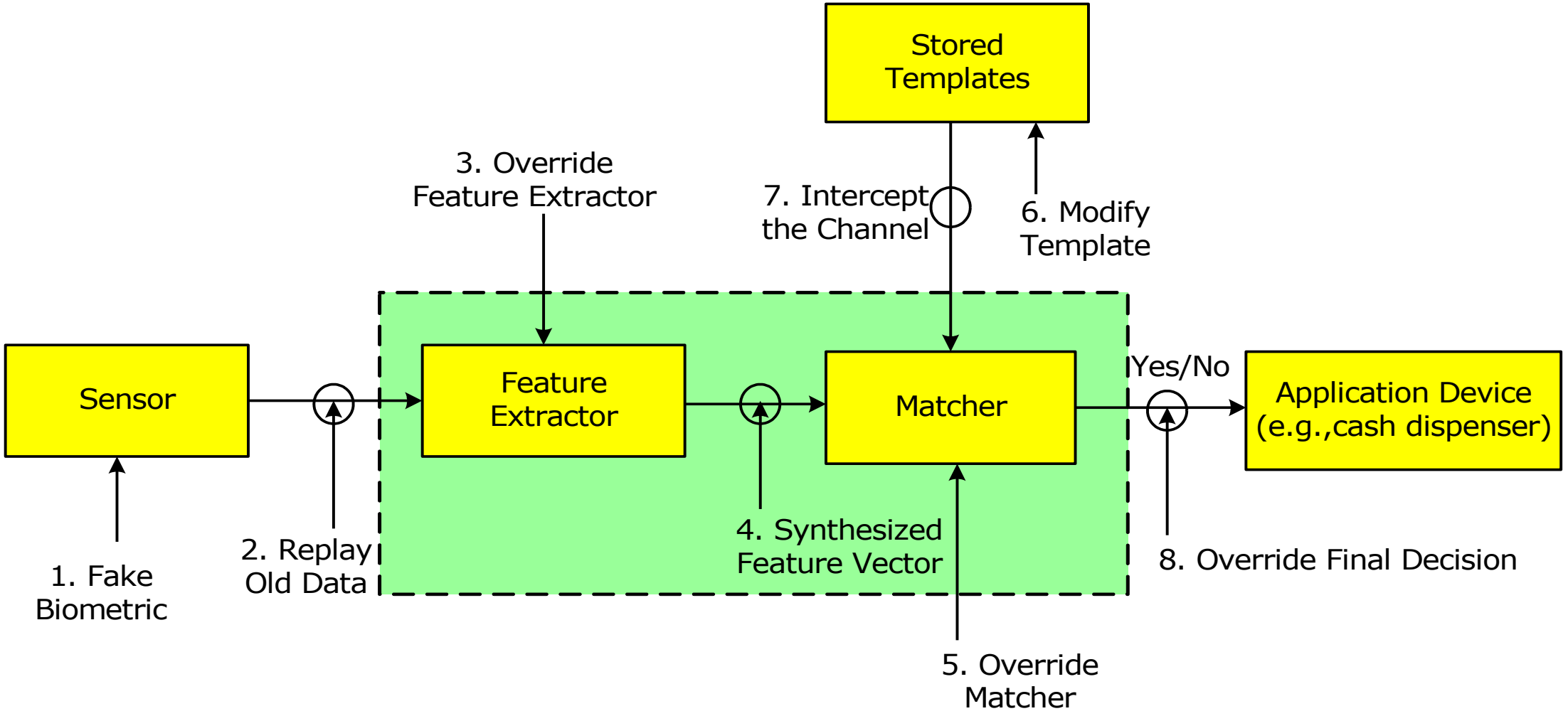
The suspect gave his name as “Darnell Lewis”, but his real name, “Frazier” was tattoed on his neck! He was arrested on four misdemeanor warrants (Dec. 2008, St. Paul)

Tattoo Caught in Surveillance Camera

Detroit police linked at least six armed robberies at an ATM on the city's west side after **matching up a tipster's description of the suspect's distinctive tattoos**

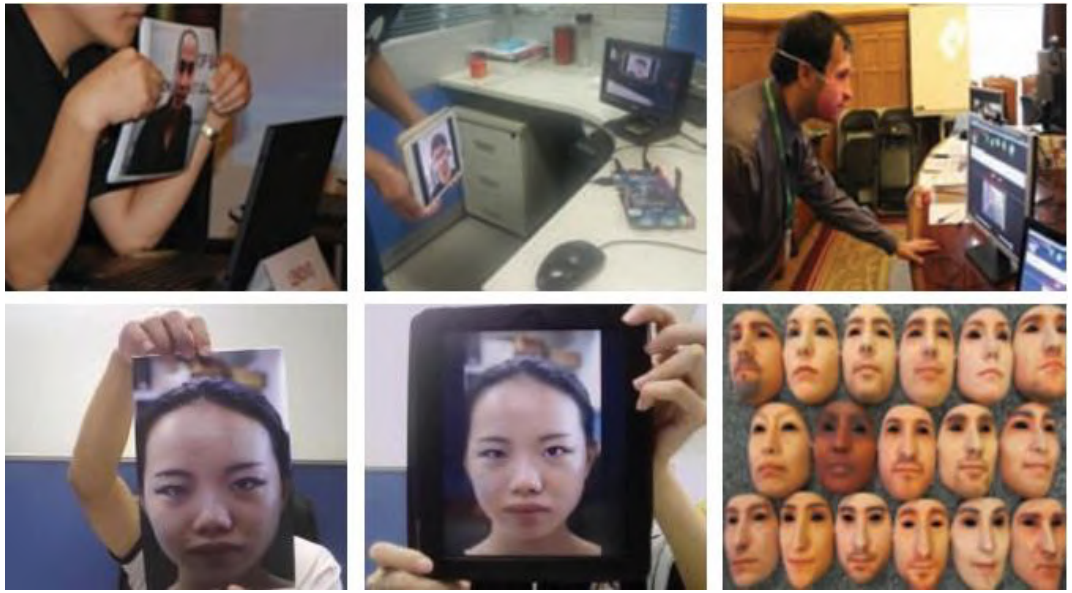
www.DetroitisScrap.com/2009/09/567/

Security of Biometric Systems



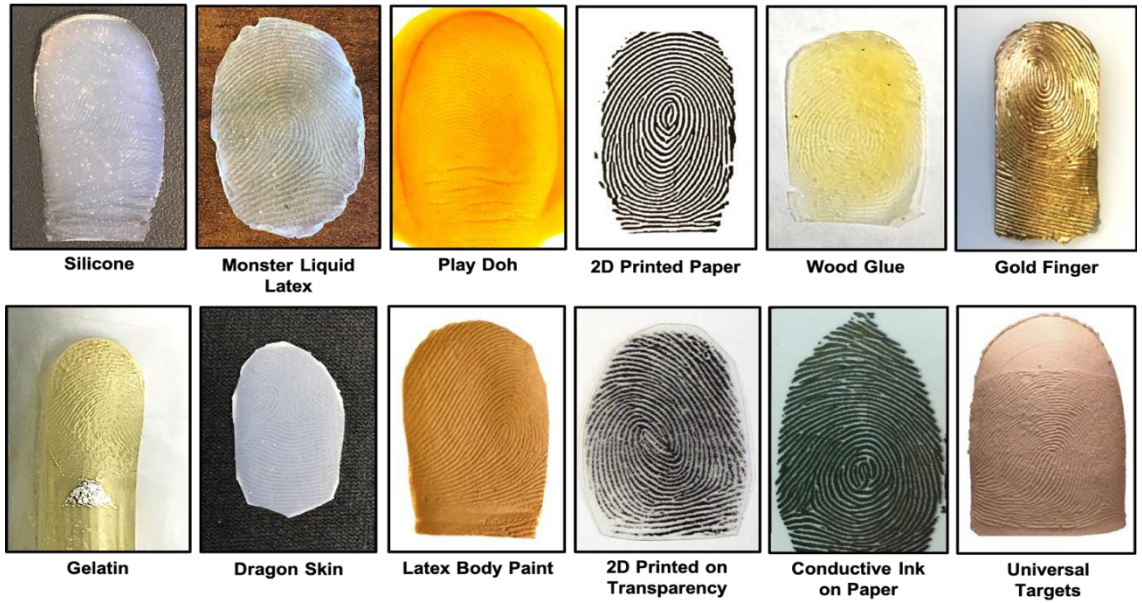
Ratha, Connell, Bolle, "Enhancing security and privacy in biometrics-based authentication systems", IBM Systems Journal, 2001

Biometric Spoofs



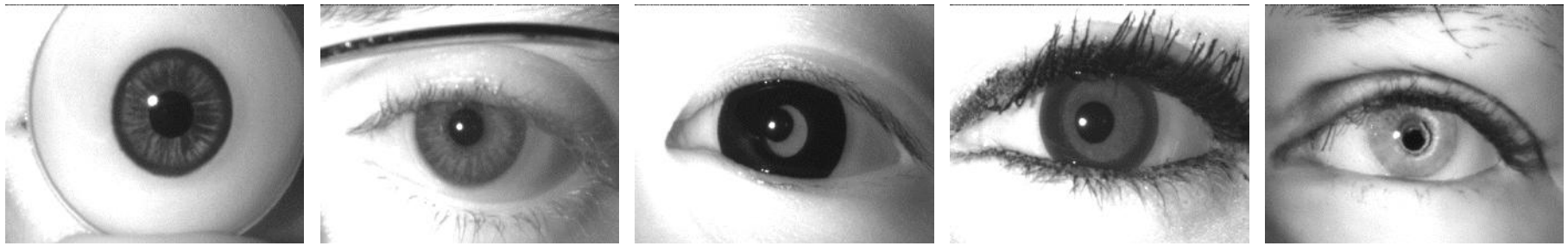
Face Attacks

Printed, Replay, 3D Mask



Fingerprint Attacks

Different materials and fabrication techniques



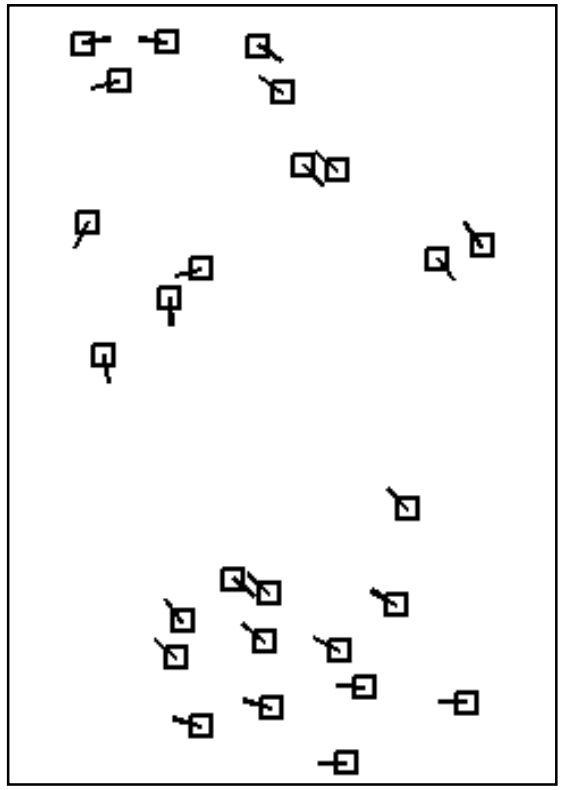
Iris Attacks

Van Dyke, Pattern Contact Lenses, Glass eyes

Digitally Altered Faces

D. Deb, J. Zhang, and A. K. Jain, "AdvFaces: Adversarial Face Synthesis", arXiv:1908.05008, 2019.

Template Protection



Template

Reconstructed Image

Spoof

Minutiae-based ISO/IEC 19794-2:2005 standard template

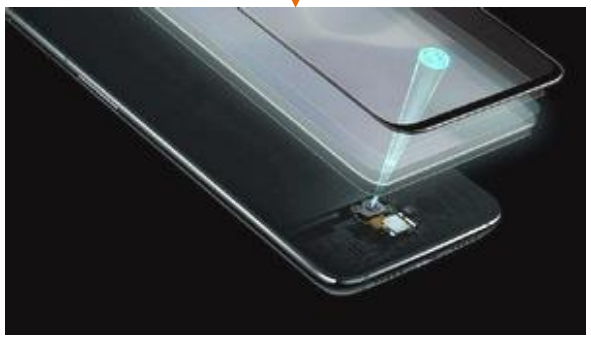
Match on Device

Serial Peripheral Interface (SPI)

Encrypt Raw Data

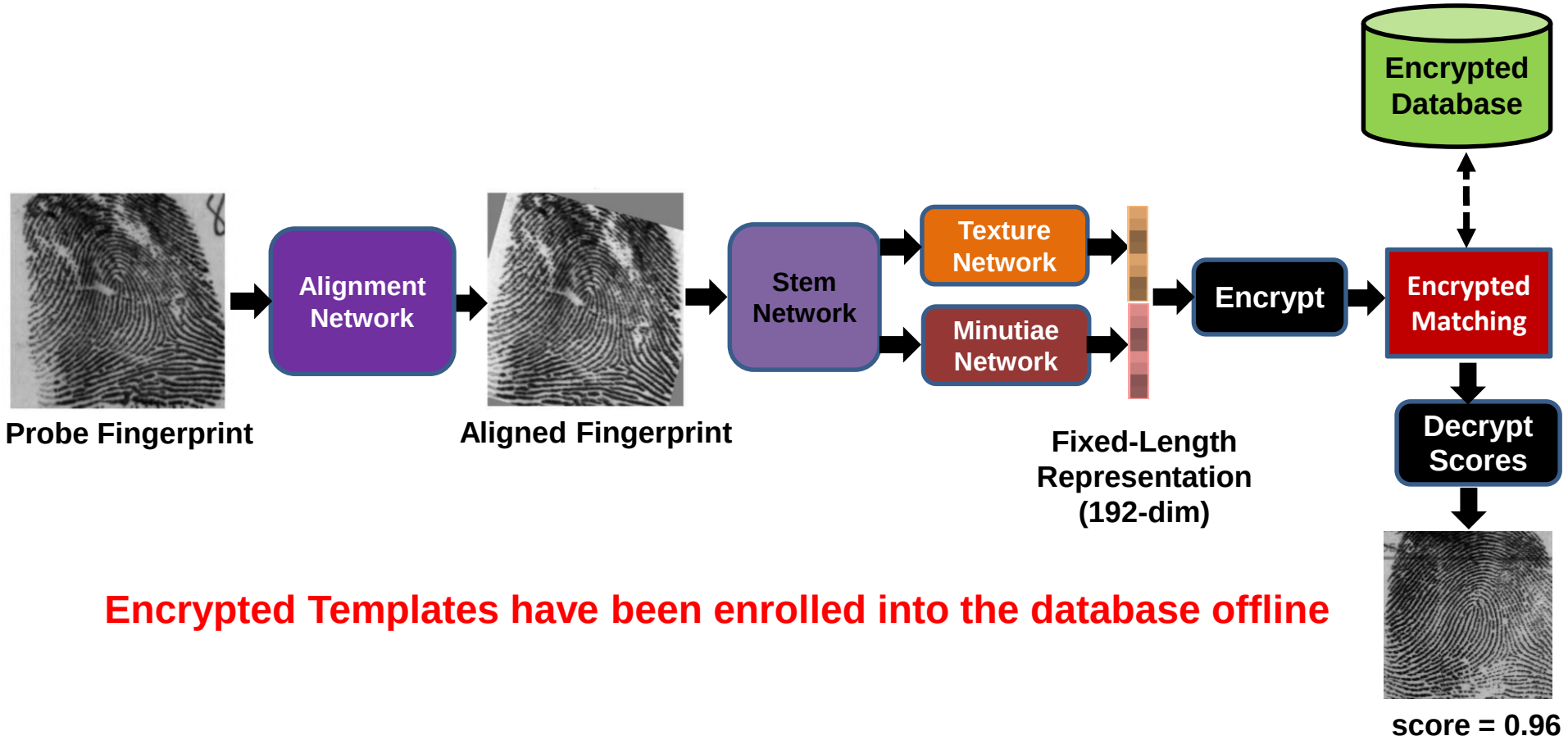
To secure fingerprint, processing is done in **TEE** (Trusted Execution Environment)**:**

- Image pre-processing
- Feature extraction
- Alignment and recognition



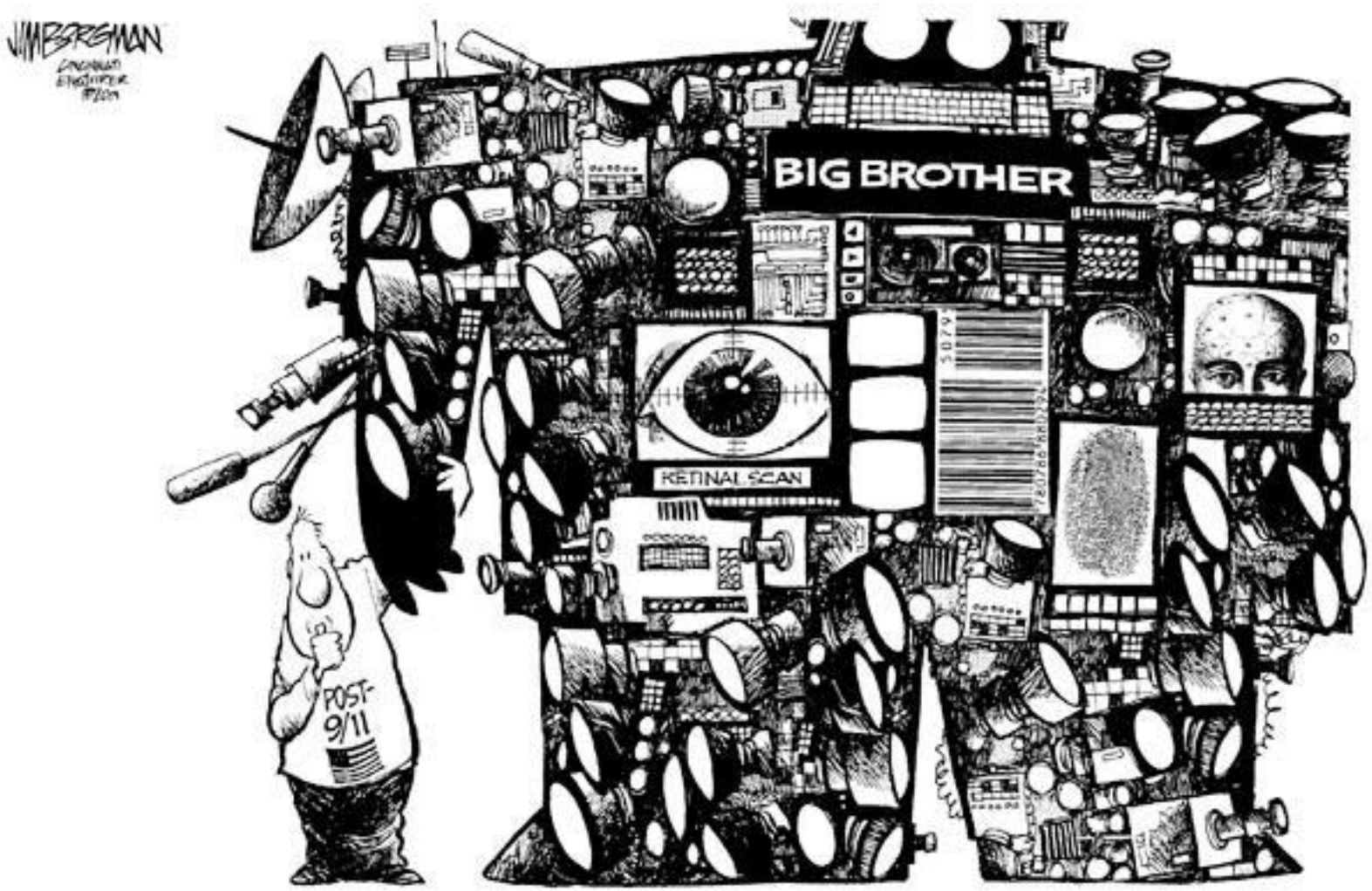
GOODIX IN-DISPLAY FINGERPRINT SENSOR™

Matching in the Encrypted Domain



Encrypted Templates have been enrolled into the database offline

Biometrics: Privacy Concerns



User consent, data security, retention policy, linking to other databases

Chongqing: World's Most Heavily Surveilled

2.58m cameras covering 15.35 million people – equal to one camera for every six residents

https://www.theguardian.com/cities/2019/dec/02/big-brother-is-watching-chinese-city-with-26m-cameras-is-worlds-most-heavily-surveilled

Facial Recognition Gains Entry Into Schools

A camera, connected to the Aegis system (Clearview AI), in the ceiling of a hallway at the Lockport Board of Education building. Libby March, **NYT, Feb 6, 2020**

- **PRO:** A crime-fighting tool, to help prevent mass shootings and stop sexual predators.
- **CON:** False matches "can lead to very dangerous and completely avoidable situations," said Jayde McDonald, a former Lockport student.

Security v. Privacy

- Citizens right to protest and independent judiciary
- What recourse do you have if you are incorrectly recognized?

Social Good v. Privacy

"*Aadhaar gives dignity to the marginalized. Dignity to the marginalized outweighs privacy*" - Justice Sikri, Indian Supreme Court (Sept 2018)

Kenya's High Court Delays Biometrics ID Program

A Kenyan being photographed for a national ID, NY Times, Jan 29, 2020)

….until the government enacts laws to protect the security of the data and prevent discrimination against minorities (marginalization)

Summary

- Reliable and automated person identification is becoming a necessity; No substitute to biometrics for effective person identification
- It can enhance security, eliminate fraud and offer convenience to the users
- Biometric sensors are inexpensive-fingerprint, face and voice sensors are embedded in laptops & mobile phones; system performance is not meeting the expectations
- Deployed systems should not infringe on civil liberties, ……