# Biometric Recognition
## Technology for Human Identification
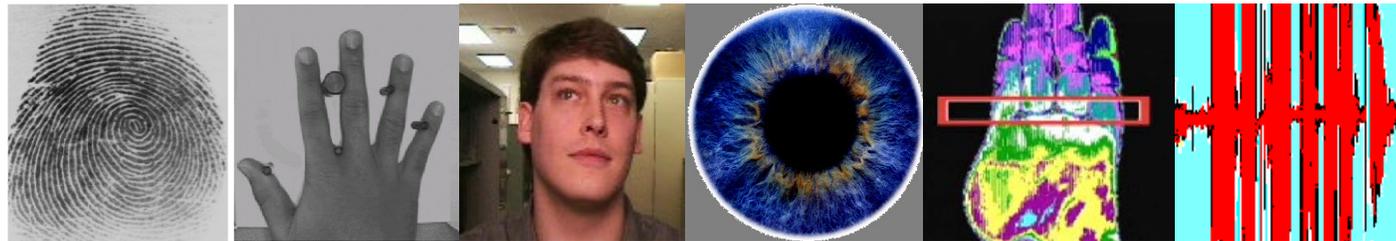
Anil K. Jain

Michigan State University

http://biometrics.cse.msu.edu/

# Biometric Recognition

- Morris (1875): Derived from two Greek words

  *Bios: life; Metron: a measure*

- Pollack (1981): What makes each person unique?

  *Use of biometrics for access control*

- ISO/IEC JTC1 2382-37:2012

  *Automated recognition of individuals based on their behavioral and biological characteristics*



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

# Habitual Criminal Act (1869)

"What is wanted is a means of classifying the records of habitual criminal, such that as soon as the particulars of the personality of any prisoner (**whether description, measurements, marks, or photographs**) are received, **it may be possible to ascertain readily, and with certainty, whether his case is in the register, and if so, who he is**."
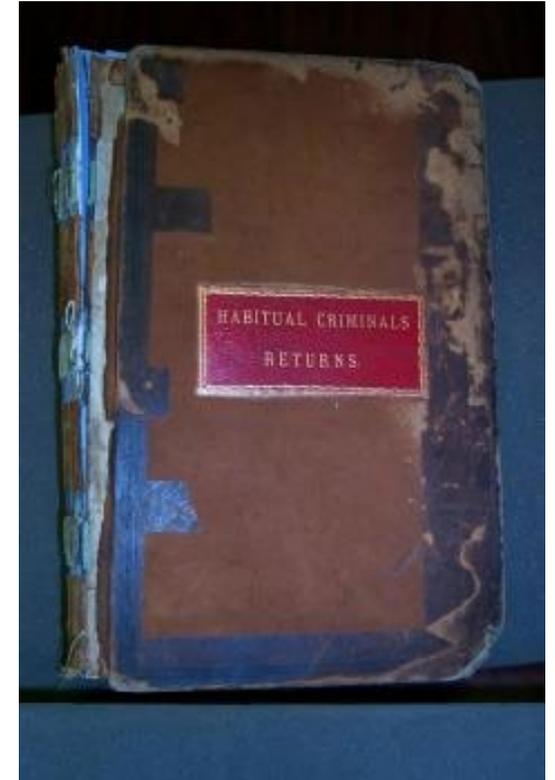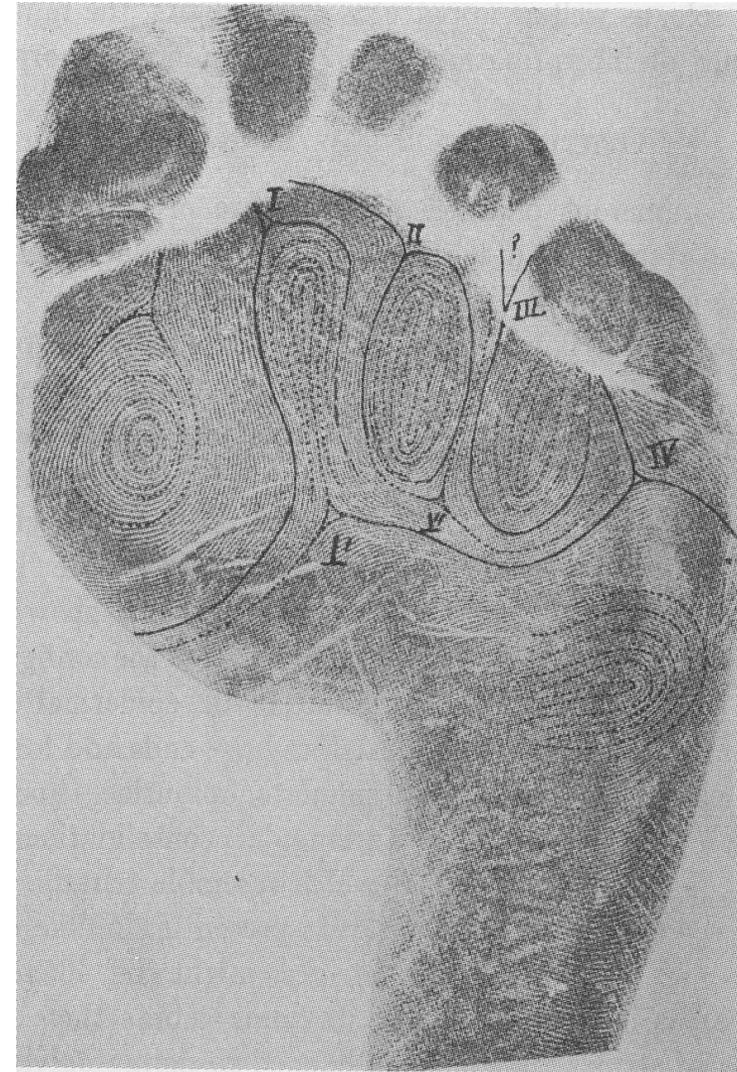


Habitual Criminals Returns Book

*G. Pavlich, "The Emergence of Habitual Criminals in 19th Century Britain: Implications for Criminology", Journal of Theoretical and Philosophical Criminology, 2(1), pp. 1–59, 2010*

# The Bertillon System that Cataloged Criminals by their Physical Measurements (1879)



Photographing a suspect in the courtyard of a Police Prefecture in Paris
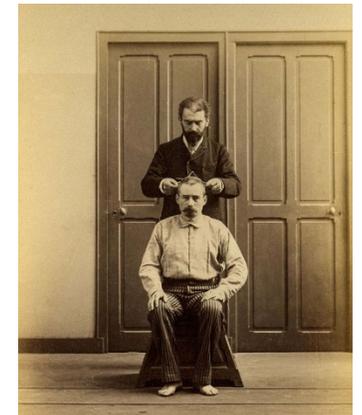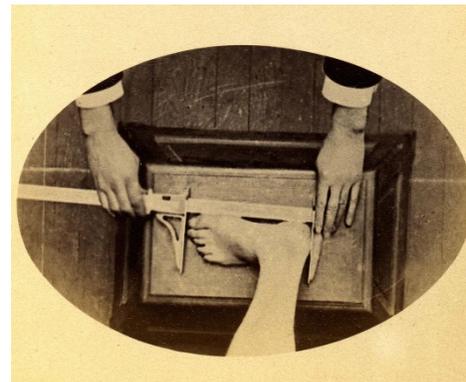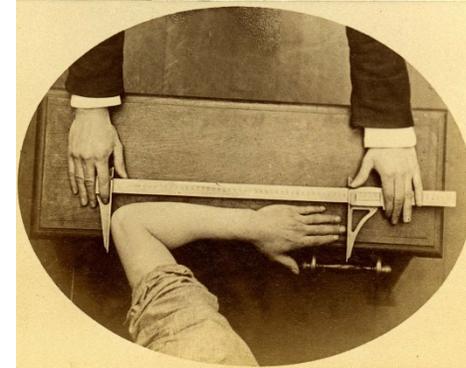
Measurement of *unique features* of suspects; each coded as "small", "medium", "large"

# Friction Ridge Patterns



Fingerprint Pioneers: Galton (1822-1911), Henry (1850-1931), Herschel (1933-1917), Faulds (1843-1936)

# Fingerprint Matching


FBI booking card (1924)


Manual search (1960)


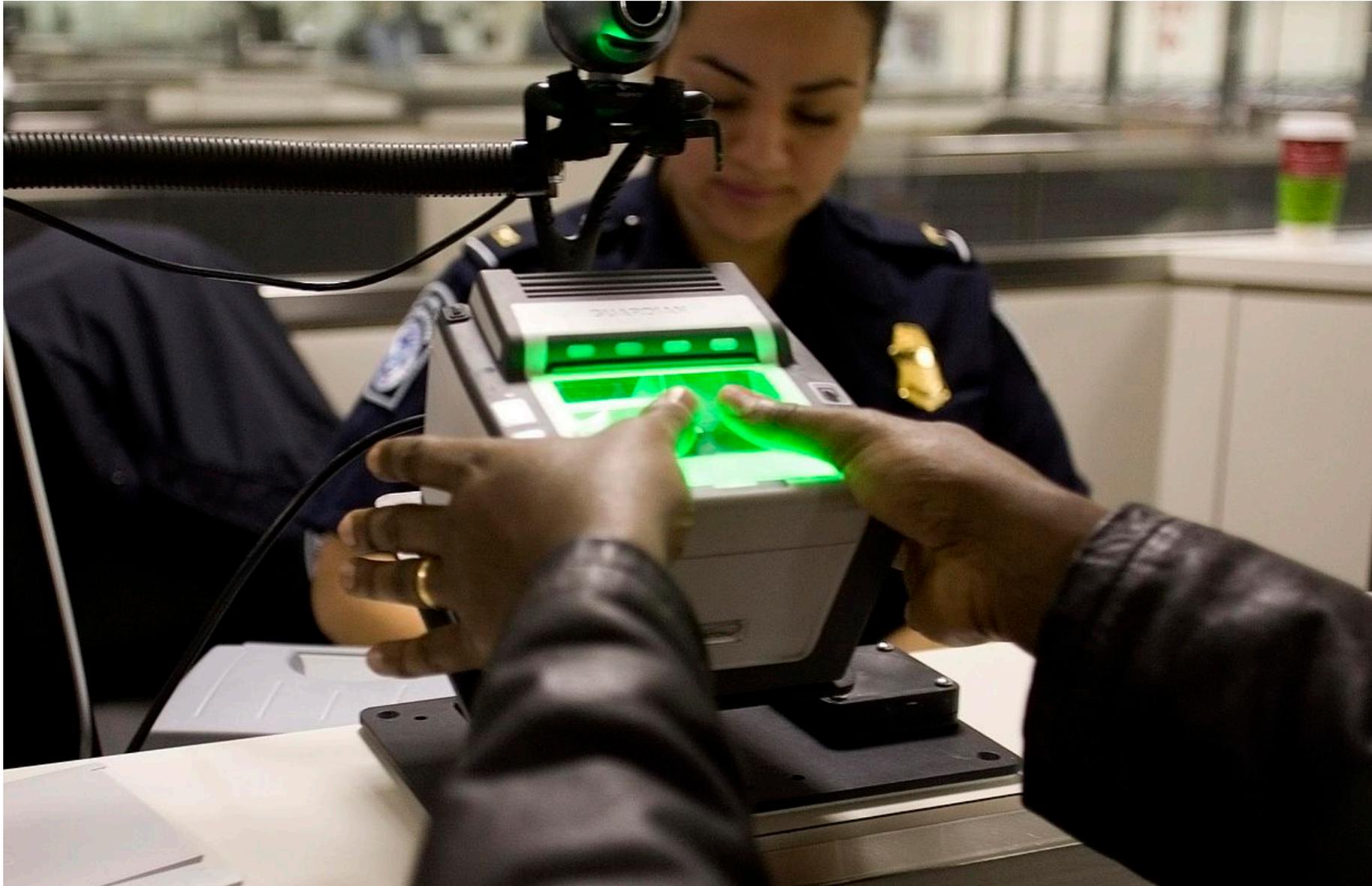AFIS (1988); 15K comparisons/sec.

# September 11 Attacks (2001)



- **19 al Qaeda terrorists hijacked four airplanes and carried out suicide attacks in the US**

- **USA PATRIOT Act (2001); Enhanced Border Security and Visa Entry Reform Act (2001)**

*https://www.history.com/topics/21st-century/9-11-attacks*
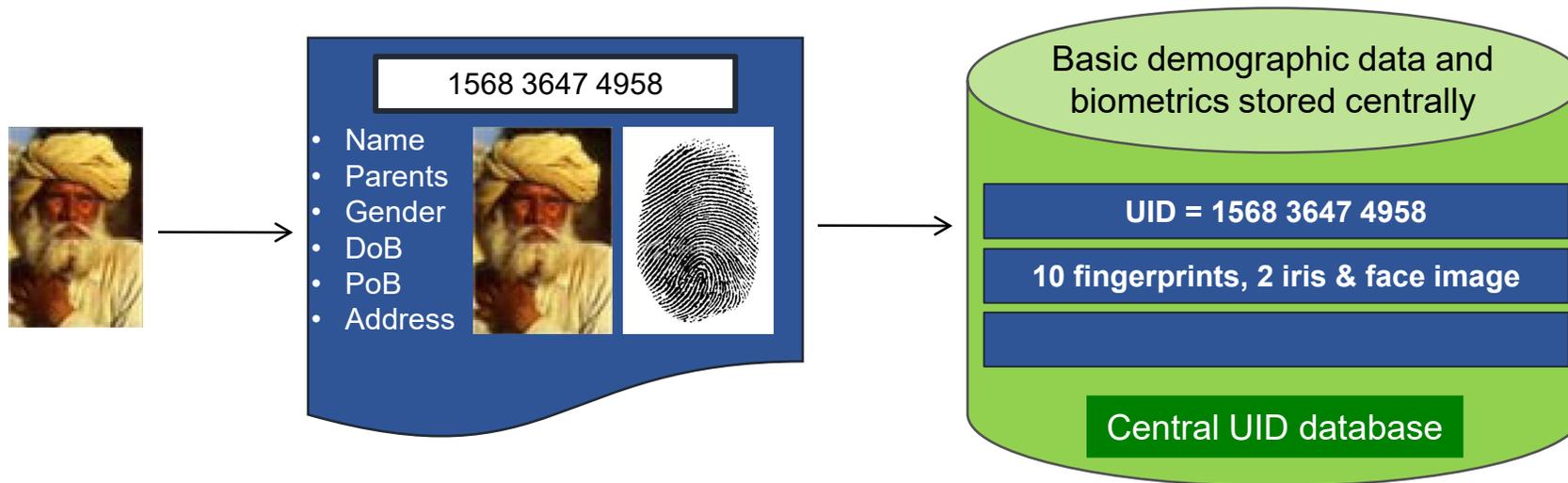
# US-VISIT (2003)

# Walt Disney Theme Parks (2005)



**Fingerprint recognition introduced to prevent ticket sharing**

# Aadhaar (2009)

"Issue a unique identification number (UID) to Indian residents that can be used to eliminate duplicate and fake identities."
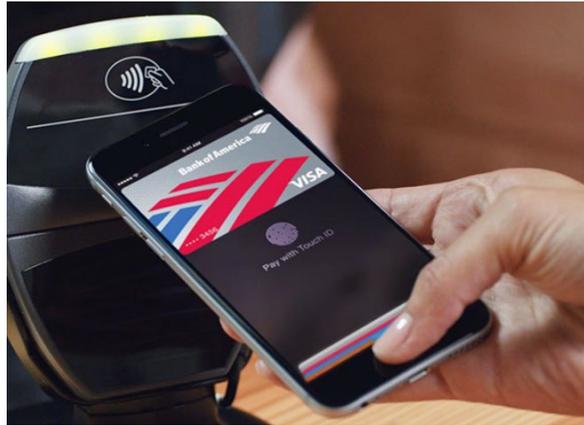


**Enrollment, de-duplication, authentication**

https://uidai.gov.in/

# Mobile Unlock & Payment (2013-2018)



Touch ID (2013)

Apple Pay (2014)

Face ID (2017)

In-display sensor (2018)
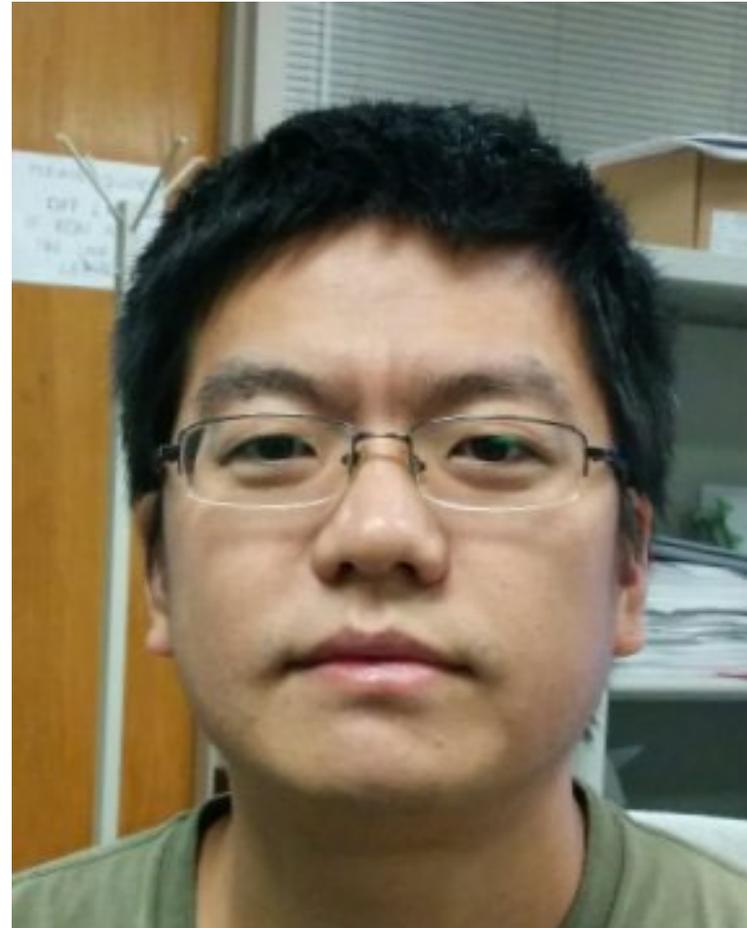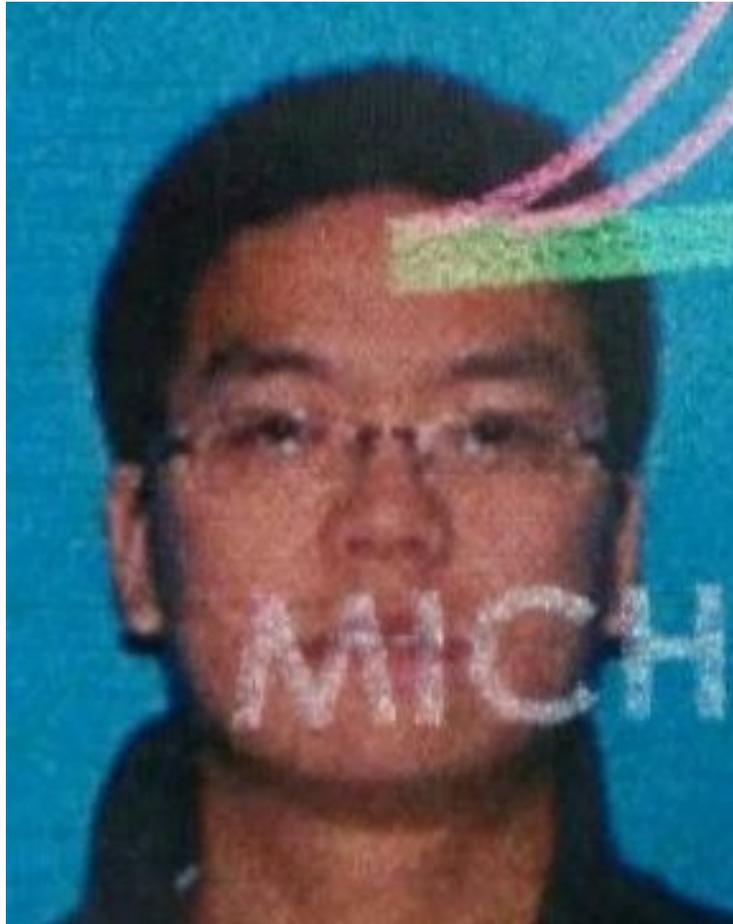
# Emerging Applications
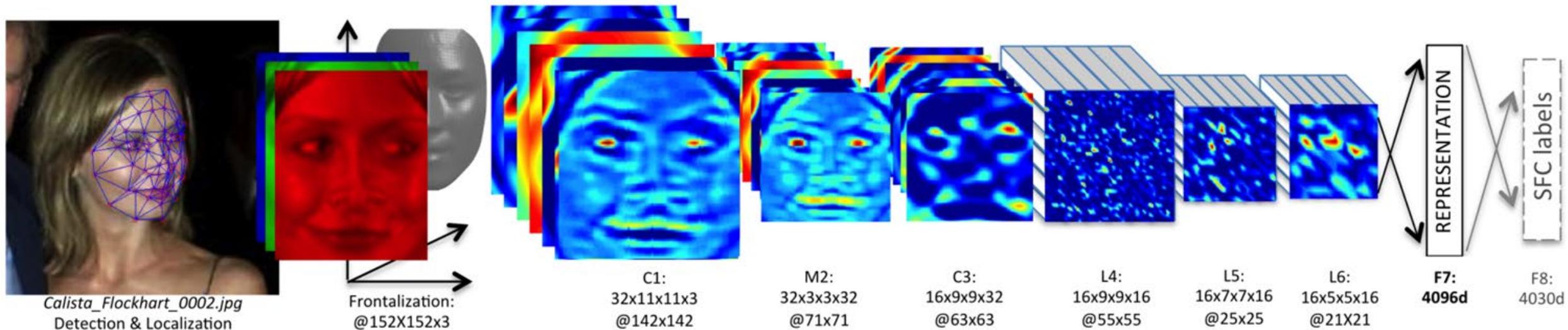


Amazon One (2020)

Personalization (2022)

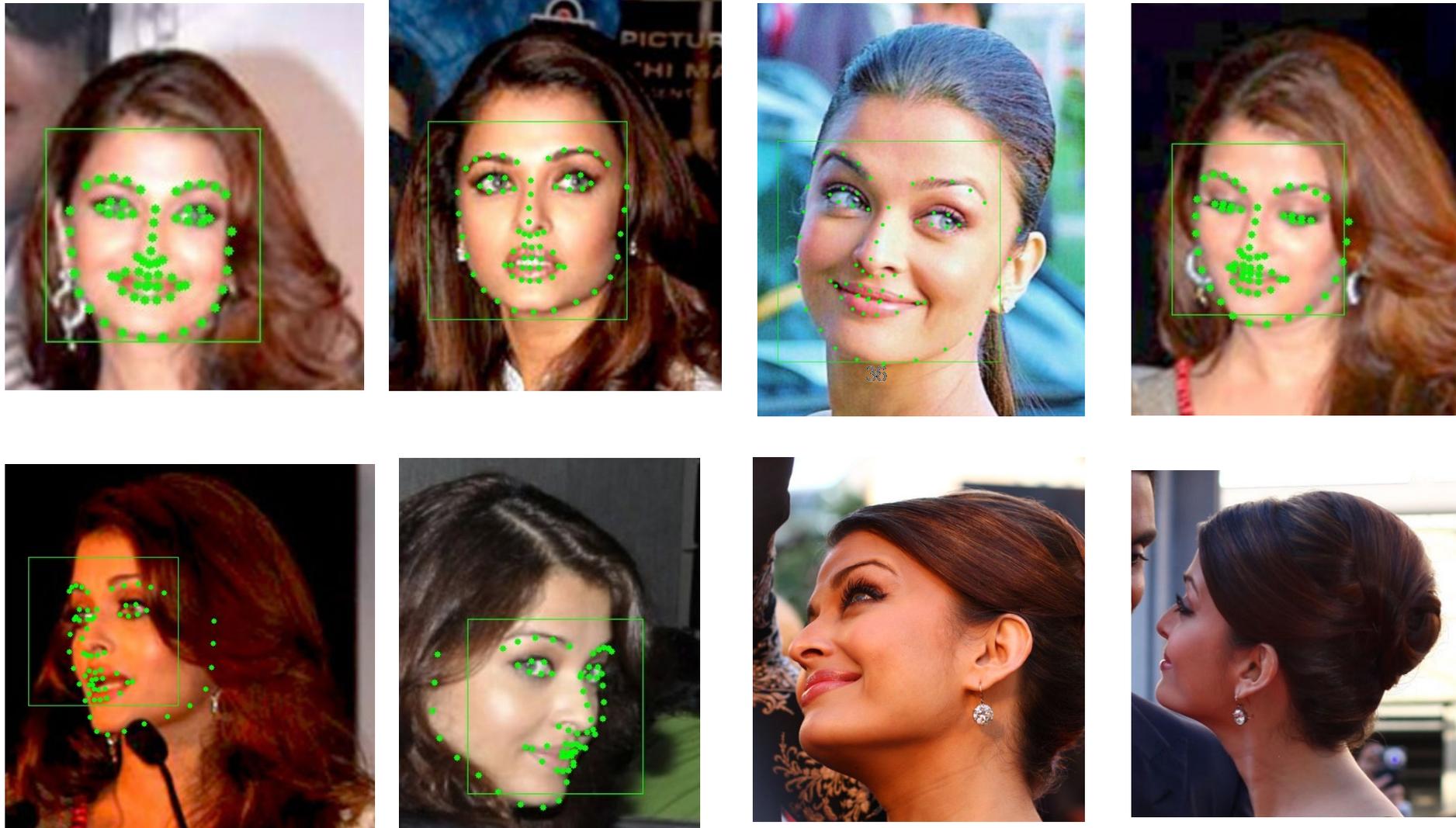Match on card (2022)

# Central Problem: Compute Similarity



Representation (features) and similarity measure

# Deepface (2014)



Calista_Flockhart_0002.jpg
Detection & Localization

Frontalization:
@152X152x3

C1:
32x11x11x3
@142x142

M2:
32x3x3x32
@71x71

C3:
16x9x9x32
@63x63

L4:
16x9x9x16
@55x55

L5:
16x7x7x16
@25x25

L6:
16x5x5x16
@21X21

**F7:**
**4096d**

F8:
4030d

REPRESENTATION

SFC labels

- Multiple layers of "neurons" (nodes) connected via edges to the previous layer
- Fixed-length representation
- Large amounts of data to train the network

Yaniv Taigman, Ming Yang, Marc'Aurelio Ranzato, and Lior Wolf. "Deepface: Closing the gap to human-level performance in face verification." CVPR, 2014
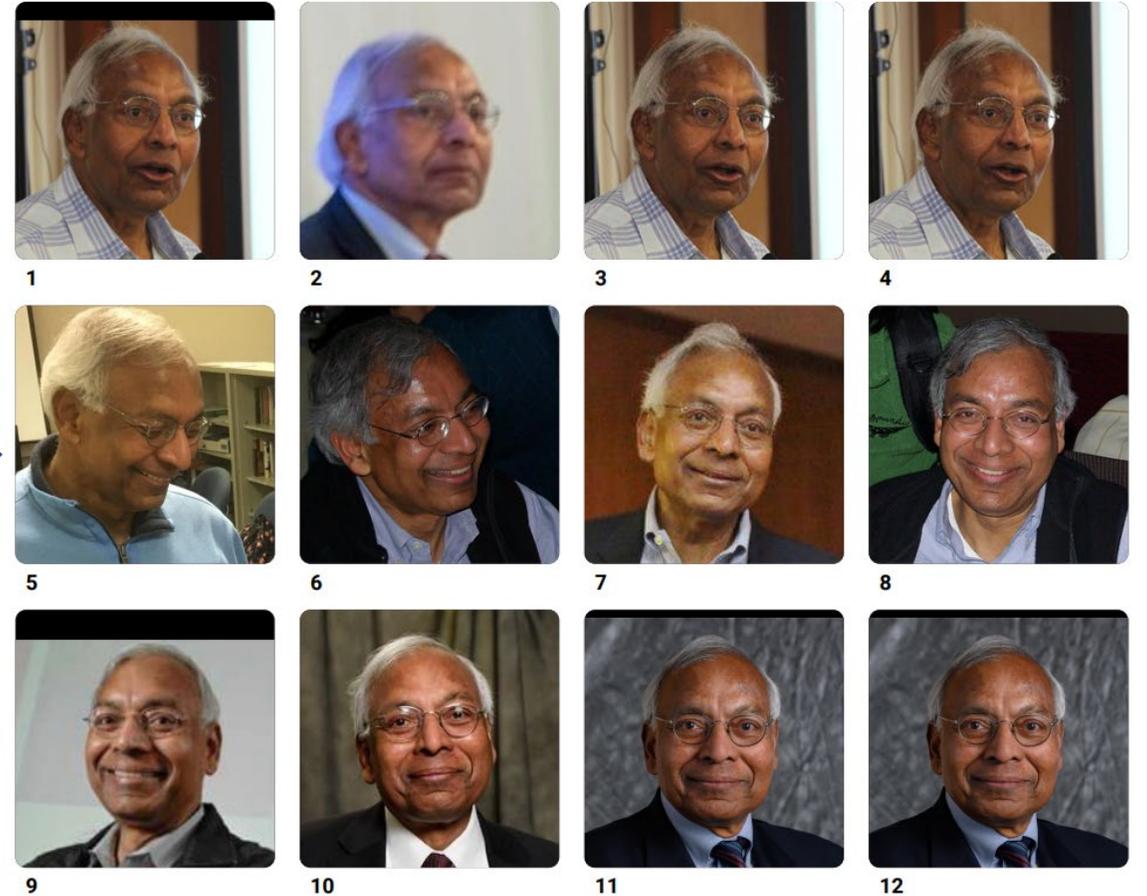
# Training Data for Deep Networks



Large no. of  face images for a  large  number of subjects
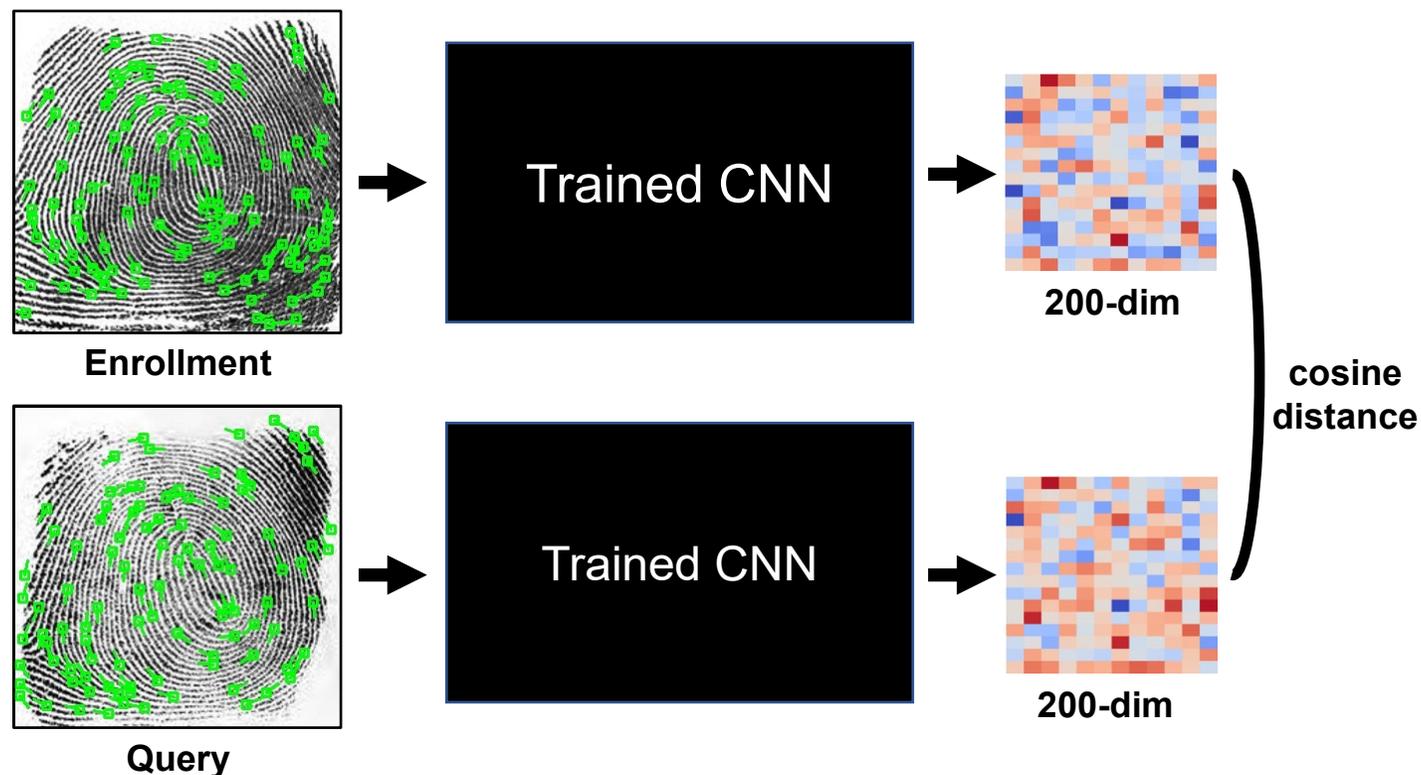
# Unconstrained Face Search



Query

Top 12 retrievals

20 billion face image database (Clearview.AI)

# TinyFace Dataset



- **Low resolution face images (average 20×16 pixels) of ~5K identities.** (https://qmul-tinyface.github.io/)
- Rank-1 accuracy + **75.80%**

# Fixed-Length Fingerprint Representation



**Enrollment** → **Trained CNN** → **200-dim**

**Query** → **Trained CNN** → **200-dim**

cosine distance

200-byte representation allows faster matching and encryption

J. J. Engelsma, K. Cao and A. K. Jain, "Learning a Fixed-Length Fingerprint Representation", in *IEEE PAMI*, 2019
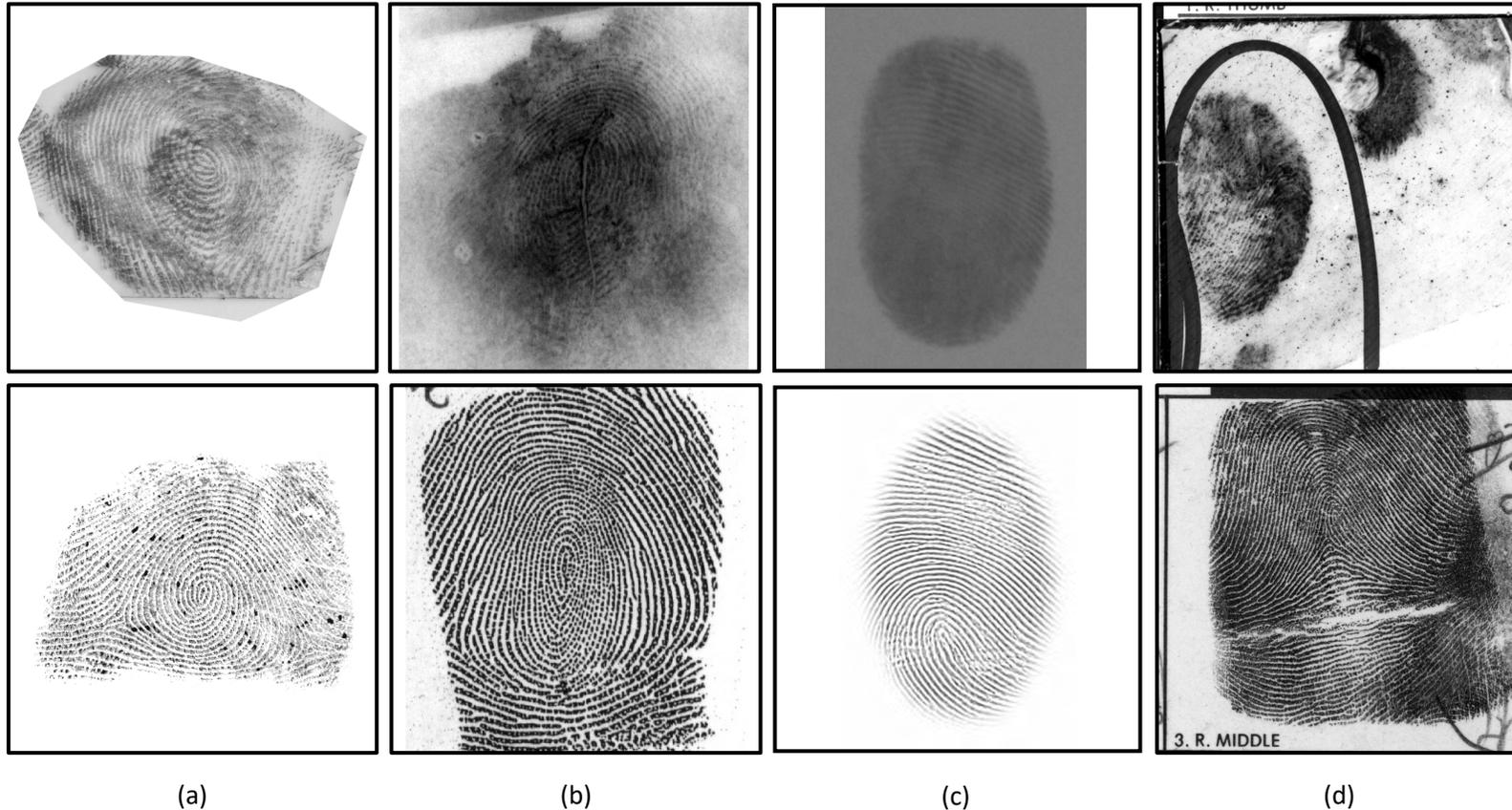
# Synthetic Fingerprint Generator



J. J. Engelsma, S. A. Grosz and A. K. Jain, "PrintsGAN: Synthetic Fingerprint Generator", IEEE TPAMI, 2022
A. B. V. Wyzykowski and A. K. Jain, "Synthetic Latent Fingerprint Generator", IEEE WACV, 2023

# Synthetic Fingerprint Generator

# Fusion of Local (ViT) and Global (ResNet) Embeddings



(a)     (b)     (c)     (d)

Latents (top row) and corresponding rolled images (bottom row). In each case, true mate for query latent was retrieved at rank-1 against a gallery of 100K rolled prints

# False Biometric Match: Wrongful Apprehension



Face recognition incorrectly matched a poor quality CCTV frame to driver license photo of Robert William

AFIS incorrectly matched partial print at Madrid train bombing site (2004) to Brandon Mayfield's prints in the FBI database
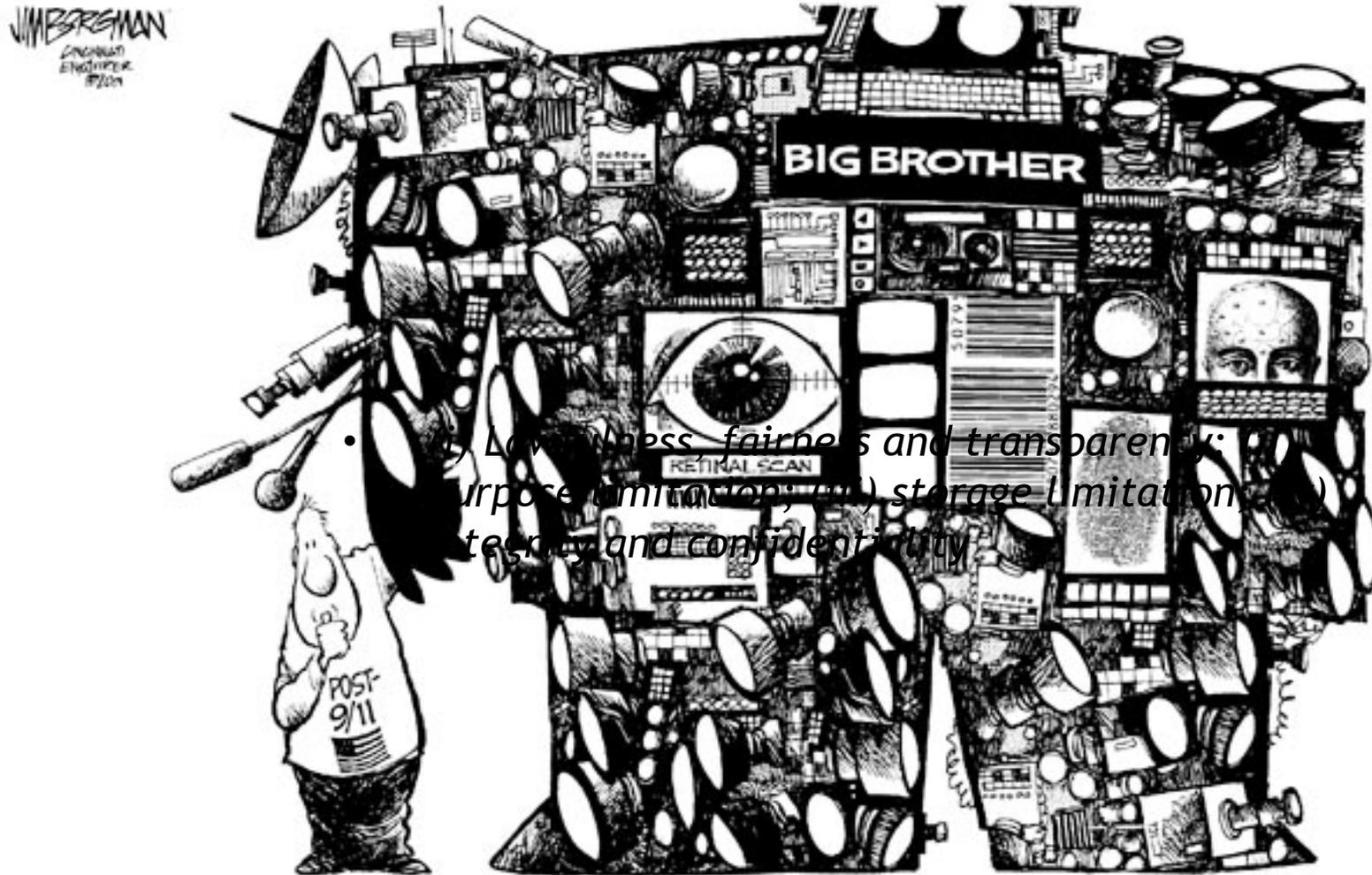
# Legal Identity for All


Vaccination Clinic


Food distribution

U.N. Sustainable Development Goal (16.9): *By 2030, provide legal identity for all, including birth registration.*

https://bit.ly/1oIVAOf

# Data Privacy & Protection



- *i) Lawfulness, fairness and transparency; ii) purpose limitation, iii) storage limitation, iv) integrity and confidentiality*

**GDPR (2018) data protection principles:** Lawfulness, fairness, transparency, purpose limitation, storage limitation and Integrity and confidentiality

# Summary

- Biometric recognition is essential for security, payment, social good,.

- Aadhaar has raised the bar for large-scale de-duplication (1.5 billion enrollment) and authentication (~70M/day)

- What is the capacity of Aadhaar ecosystem? India's population is projected to grow to 1.7 billion by 2050

- How to lower the age of enrollment to below 5? There are 120M children in India under the age of 5 with 25 million born every year

- With improvements in sensing technology, can we obtain sensor-invariant representation?