

From the Edge of Biometrics: What's Next?#

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Michigan State University

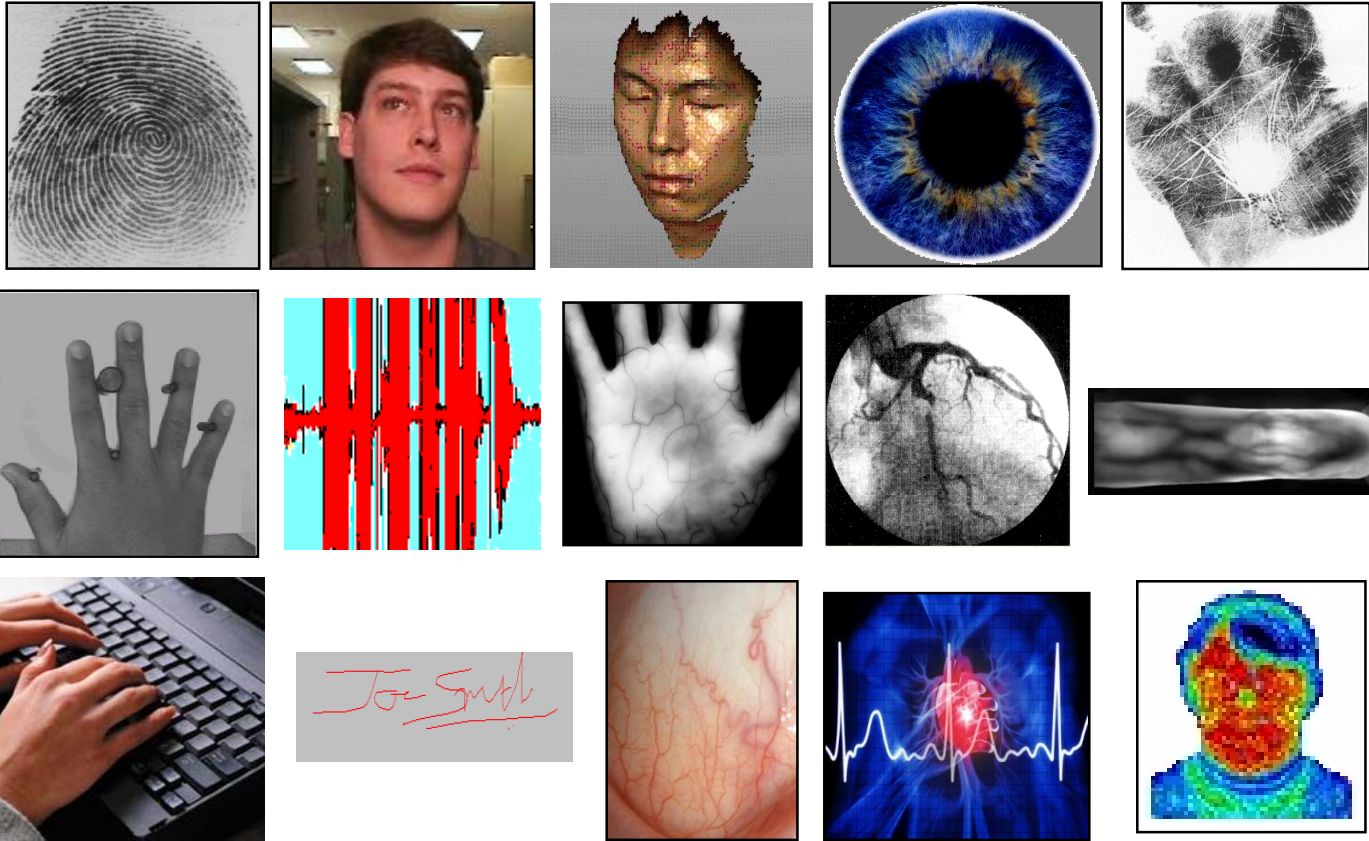
<http://biometrics.cse.msu.edu>

Sichuan University

August 16, 2018

**#Looking at the future where biometrics will be
omnipresent”**

Biometrics



Automatic Person Recognition by Body Traits

Person of Interest

Title clip, Person Of Interest, CBS (2011-16); An ex-assassin and a wealthy programmer save lives via a surveillance AI that sends them the identities of civilians involved in impending crimes

Surveillance Cameras



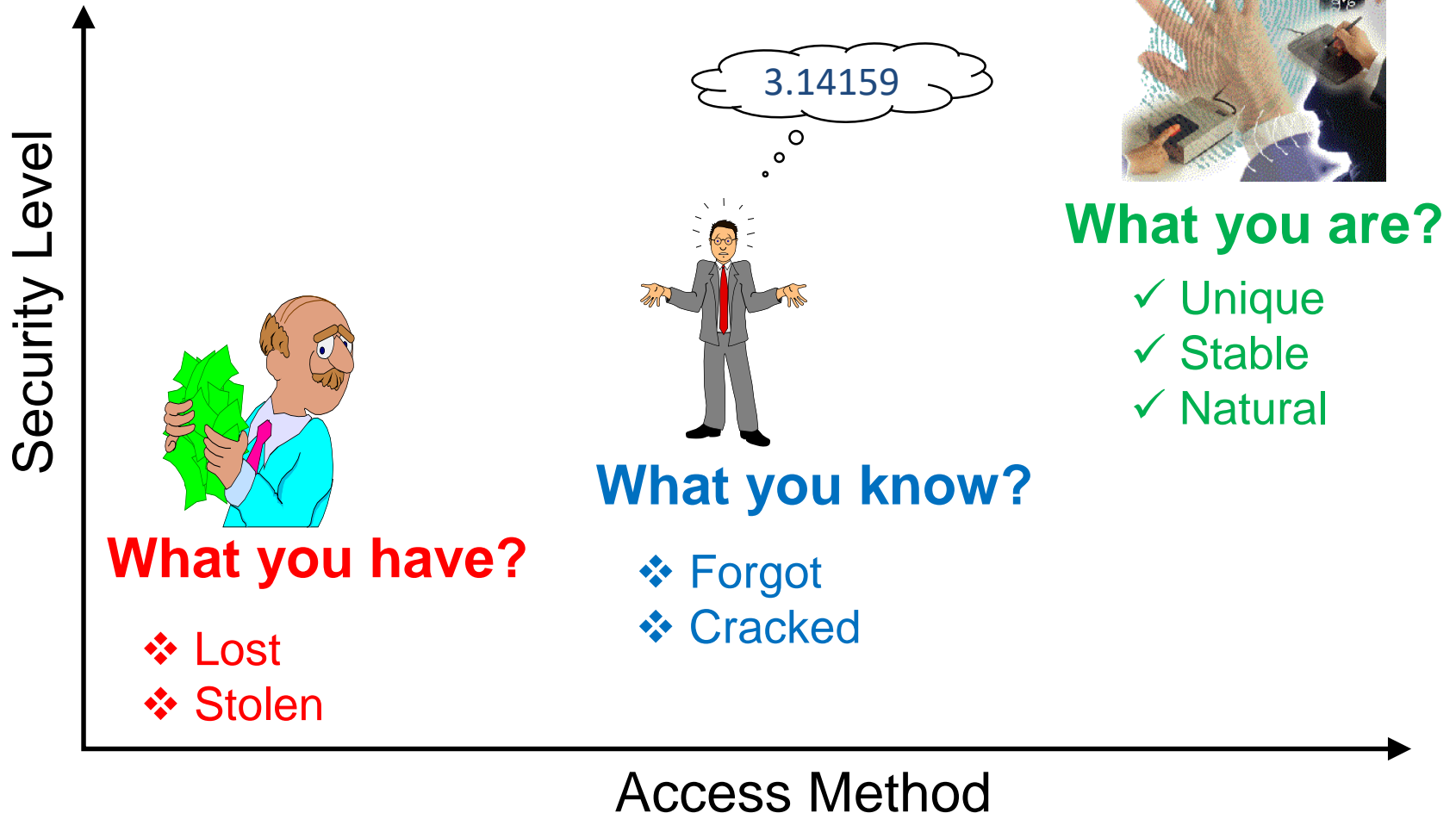
**China is expected to have over 600 million surveillance cameras by 2020
(NYT, July 9, 2018)**

Face Recognition: No Jaywalking!



Xiangyang crosswalk is monitored by cameras linked to face recognition technology, NYT, July 16, 2018

Why Biometrics?



Biometric Technology: Applications



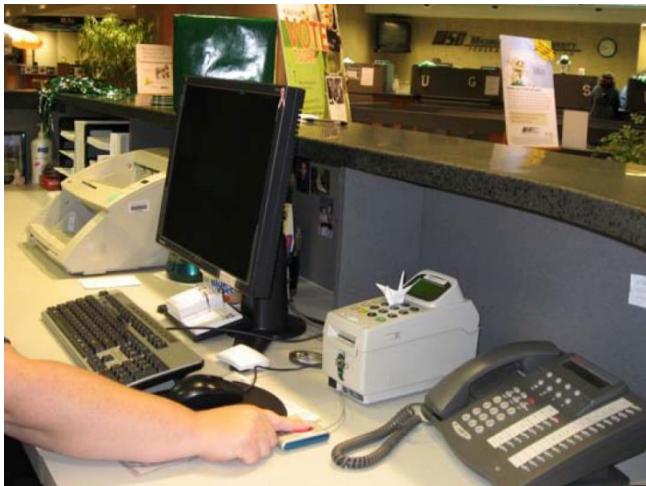
Meijer supermarket, Okemos



Time & Attendance



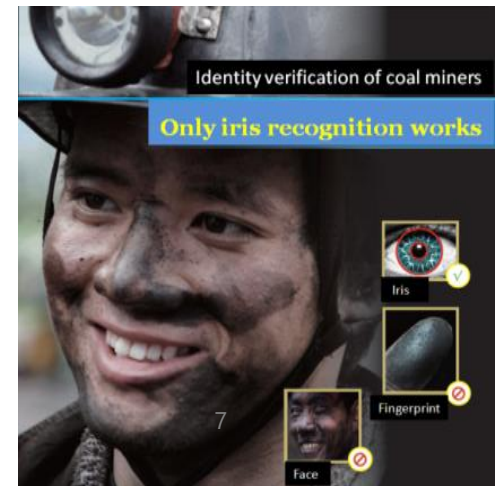
Cashless payment for lunch



MSU Federal Credit Union

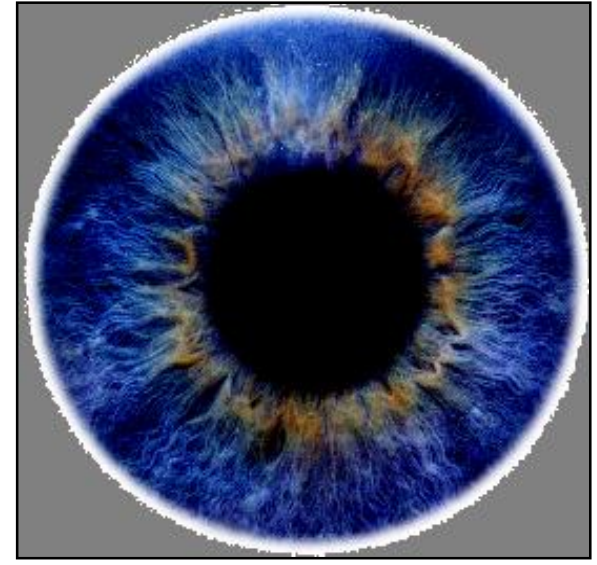


Palm vein ATM



Coal mines in China

Three Most Popular Biometric Traits



- Legacy database available
- Capability for 1:N search
- **Uniqueness** and **Persistence** (?)
- High accuracy on large datasets

Growing Popularity of Face



Identity: John Doe

Age: ~ 40

Gender: Male

Ethnicity: White

Hair: Short, Brown

Moustache: Yes

Beard: Yes

Mole: Yes

Scar: Yes

Expression: None

Biometrics: A Search Problem

Probe



Gallery



Challenges: Representation, similarity, scalability

Enablers of Biometrics

**Advances in processors,
memory, sensors; cost;
usability, algorithms**



**Martin Cooper: Inventor of cell
phone
Motorola DynaTAC (1973)**



Three billion smartphone users by 2020

<https://www.statista.com/statistics/274774/forecast-of-mobile-phone-users-worldwide/>

Face Recognition Milestones



1964
W. Bledsoe
First paper on
Face recog.



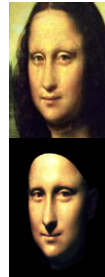
1973
Takeo
Kanade
1st FR thesis



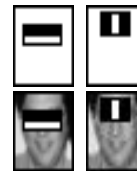
1991
Turk &
Pentland
Eigenface



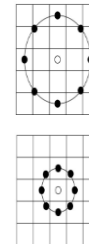
1997
Belhumeur
et al.
Fisherface



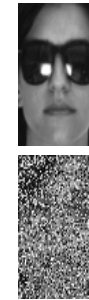
1999
Blanz &
Vetter
Morph face



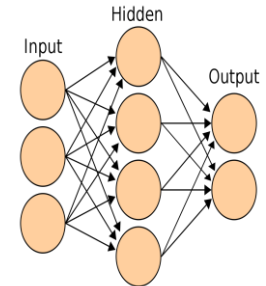
2001
Viola &
Jones
Face det.



2006
Ahonen
et al.
LBP



2009
Wright et al.
Sparse rep.



2014
Jia et al.
Deep Network Library
Caffe



1915
35mm still
camera



1991
Kodak
Digital
camera
1024p



1990s
Surveillance
camera
480p @ 30fps



2000
Sharp
First camera
phone
320p



2010-2013
Wearable
camera
480P @ 30fps
Google Glass
720p @30fps



Nov. 2011
Samsung
Galaxy
Nexus
Face Unlock



2015
Google & Intel
Smartphone
RGB-D Camera



2015+
Body Camera



Face Recognition: State of the Art

NIST FRGC v2.0 (2006)



NIST MBGC (2010)



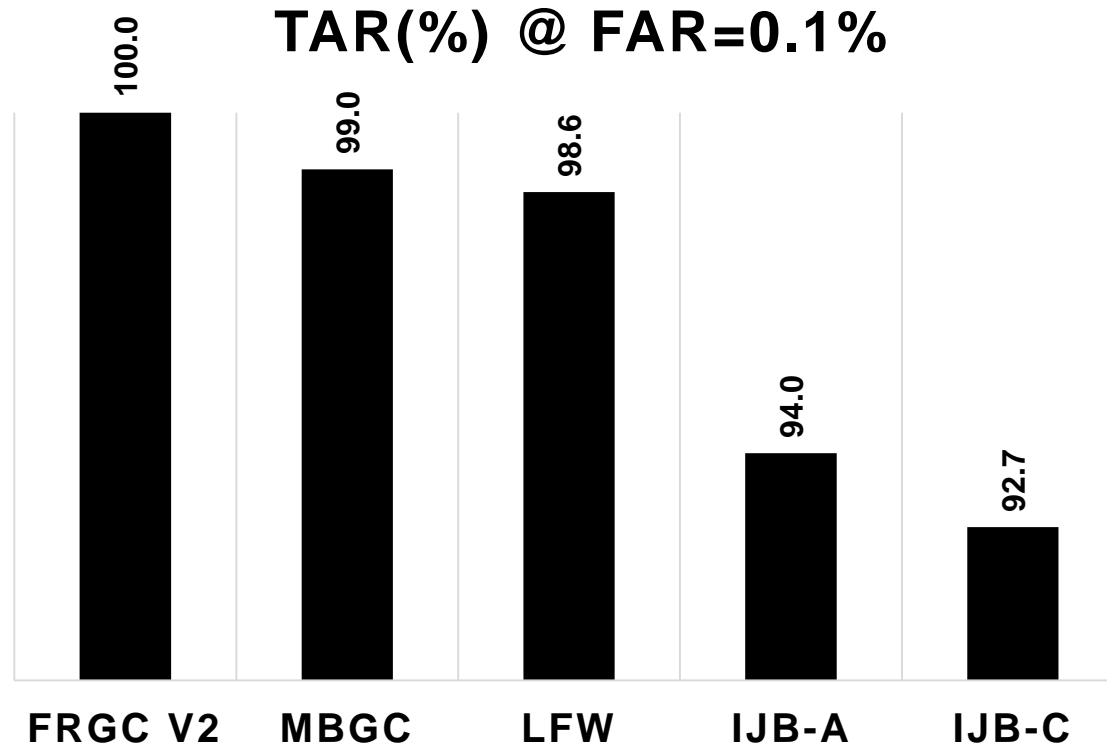
LFW (2007)



NIST IJB-A (2015)

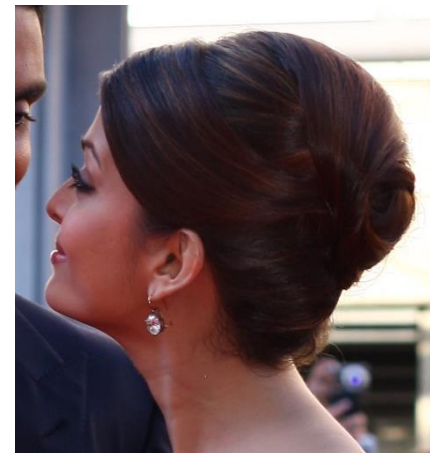
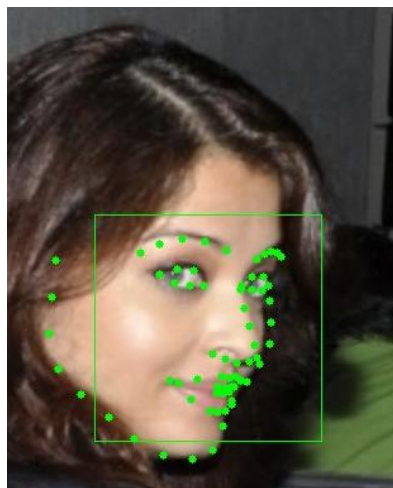
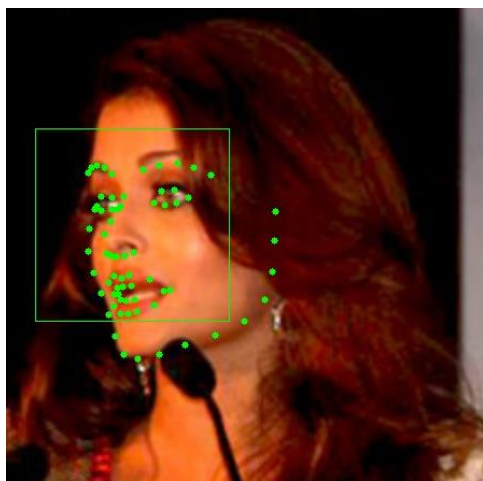
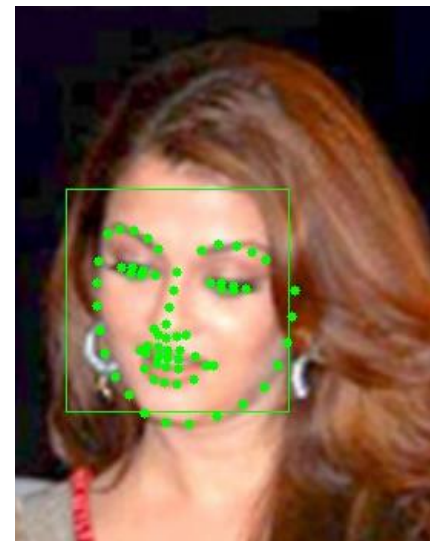
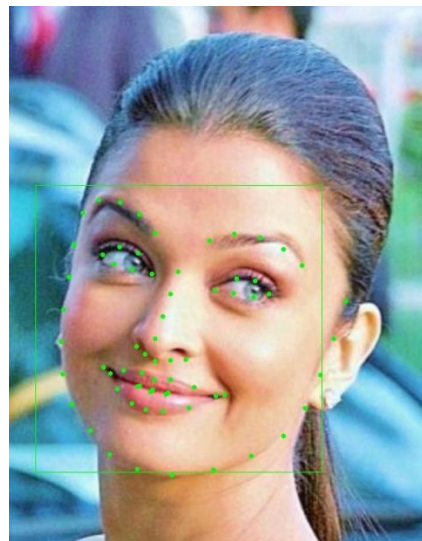
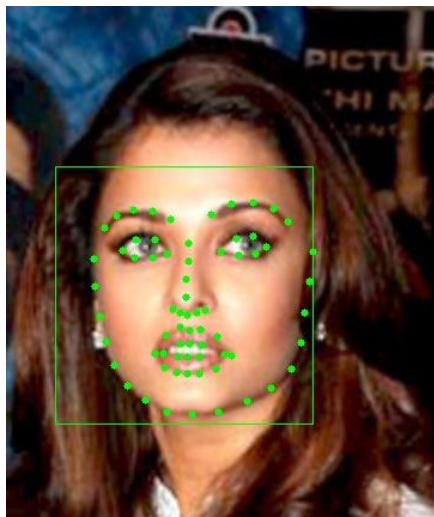
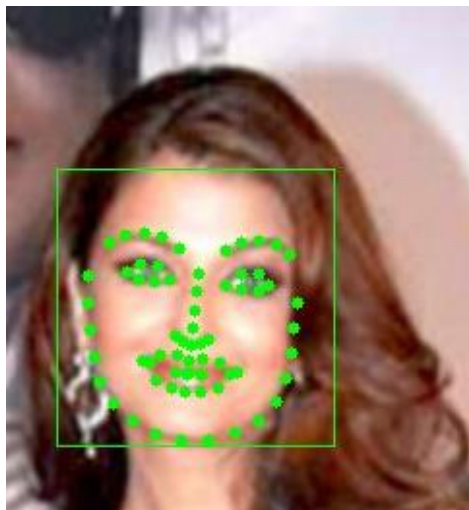


NIST IJB-C (2017)



Wu, He, Sun, Tan. "A light CNN for deep face representation with noisy labels." IEEE Trans. On TFIS, 2018.
Ranjan, Castillo, Chellappa. "L2-constrained softmax loss for discriminative face verification." *arXiv:1703.09507*
Cao, Qiong, et al. "Vggface2: A dataset for recognising faces across pose and age." *FG 2018*

Challenge: Intra-Face Variability



Challenge: Inter-Face Similarity

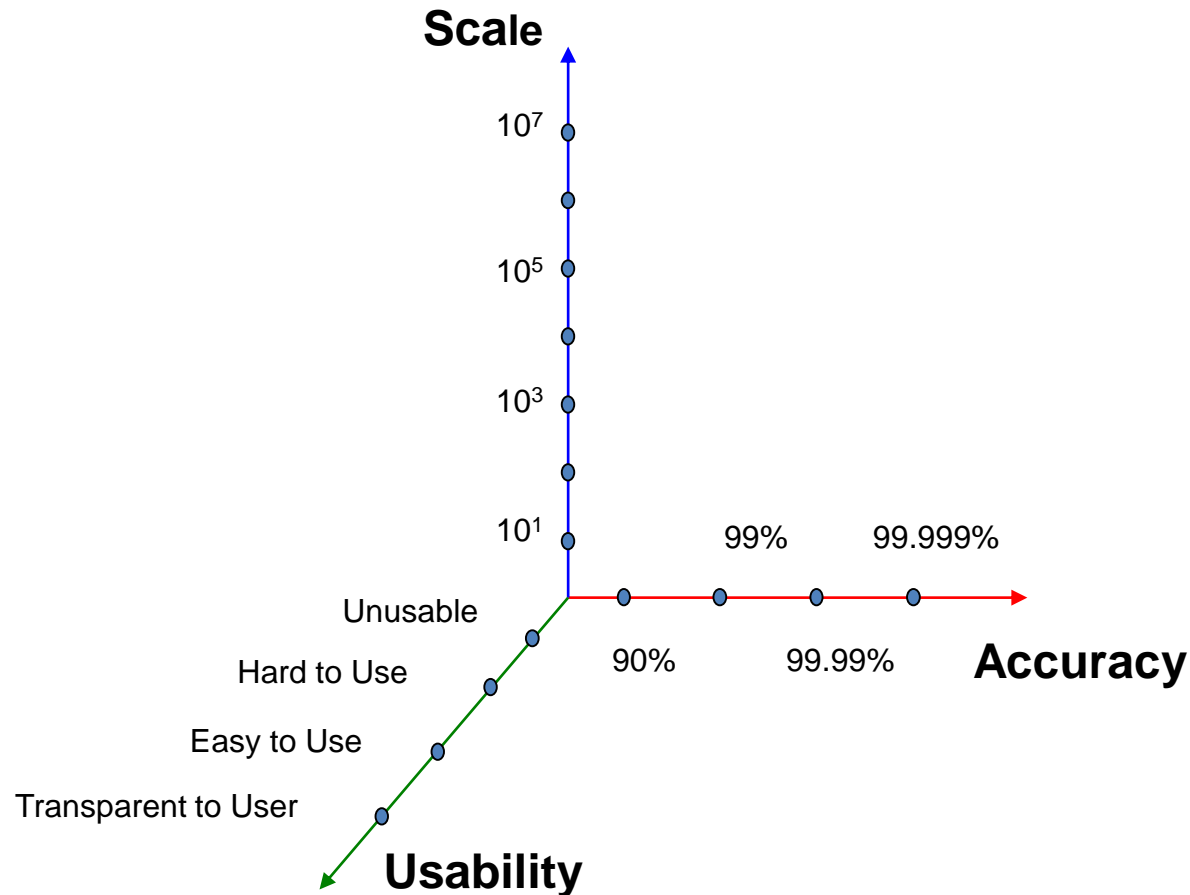


www.cbsnews.com/8301-503543_162-57508537-503543/chinese-mom-shaves-numbers-on-quadruplets-heads

What's Next?

- Understand capabilities & limitations
- Fundamental premise
- Design and build end-to-end systems
- Fusion of biometrics & user behavior data
- Presentation attack (spoof) detection
- Template invertibility

Biometrics: Capabilities & Limitations



Need systems operating at the **edge** of this 3-D space

Fundamental Premise of Biometrics

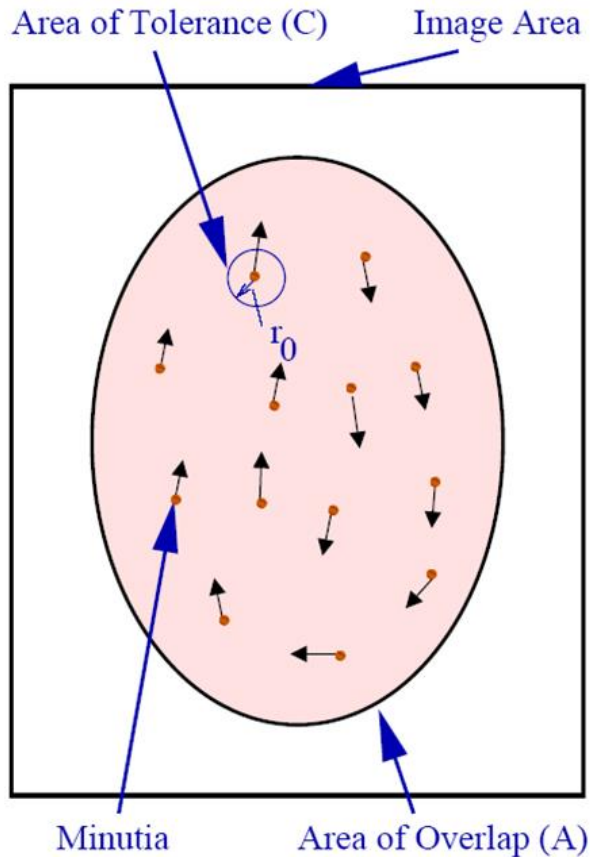
- Uniqueness: Do different individuals have different biometric features?

6-digit code: 10^6 unique PINs; what about biometrics?

- Permanence: How does recognition accuracy change over time?

PINs do not become “stale”; they are easy to guess

Fingerprint Uniqueness



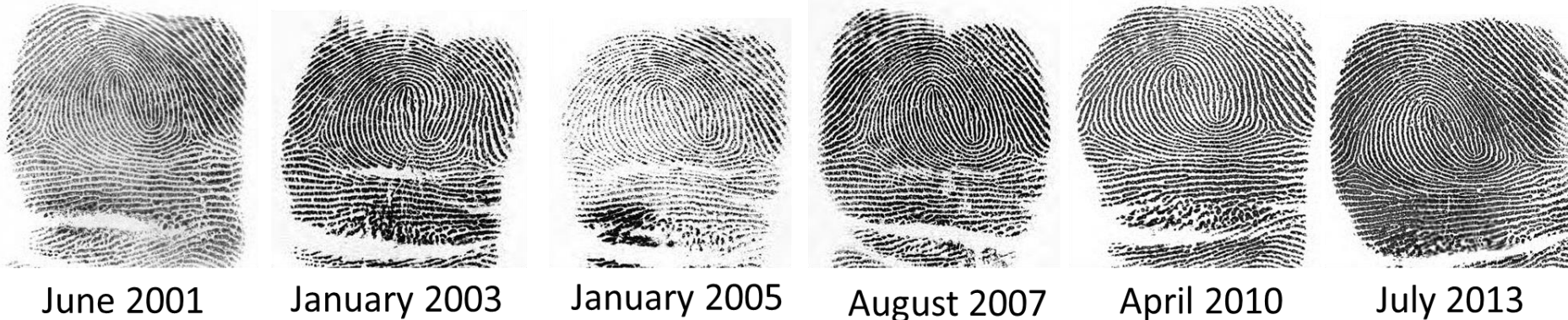
- "Two Like Fingerprints Would be Found Only Once Every 10^{48} Years" (Scientific American, 1911)

- PRC = Prob. of two fingerprints with m and n minutiae sharing q points in common

$$m = n = q = 26, \text{ PRC} = 2.40 \times 10^{-30}$$

$$m = n = 26, q = 10, \text{ PRC} = 5.49 \times 10^{-4}$$

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

Persistence of Face Recognition

Jan 1995



Gallery seed

Jul 1998



Score=0.99

Nov 1999



Score=0.62

Nov 2003



Score=0.41

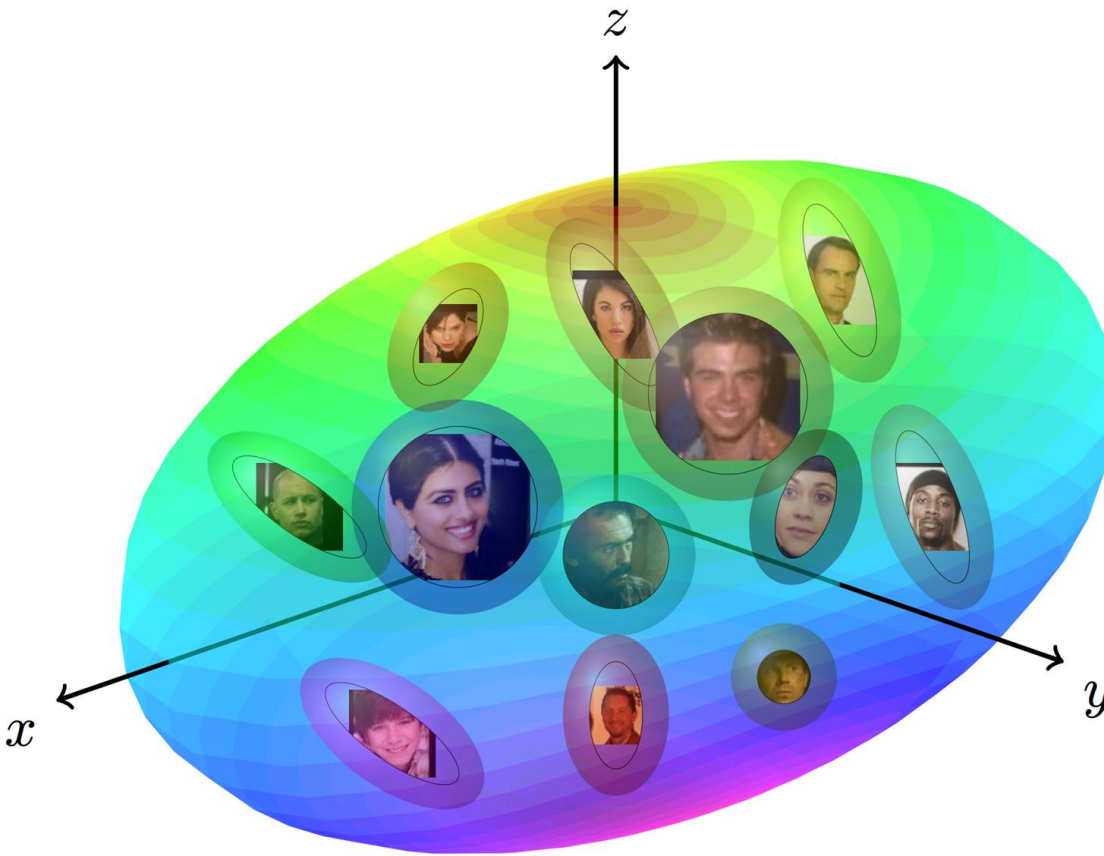
Feb 2005



Score=0.26

- **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**

Capacity of Face Recognition



- How many distinct identities can be embedded in face space @FAR = 0.01%?
- How do we find the most effective subspace?

NIST IJB-S: Challenging Face Benchmark



N. Kalka, B. Maze, J. Duncan, K. O'Connor, S. Elliott, K. Hebert, J. Bryan, A. K. Jain, "IJB--S: IARPA Janus Surveillance Video Benchmark", to appear in BTAS, 2018.

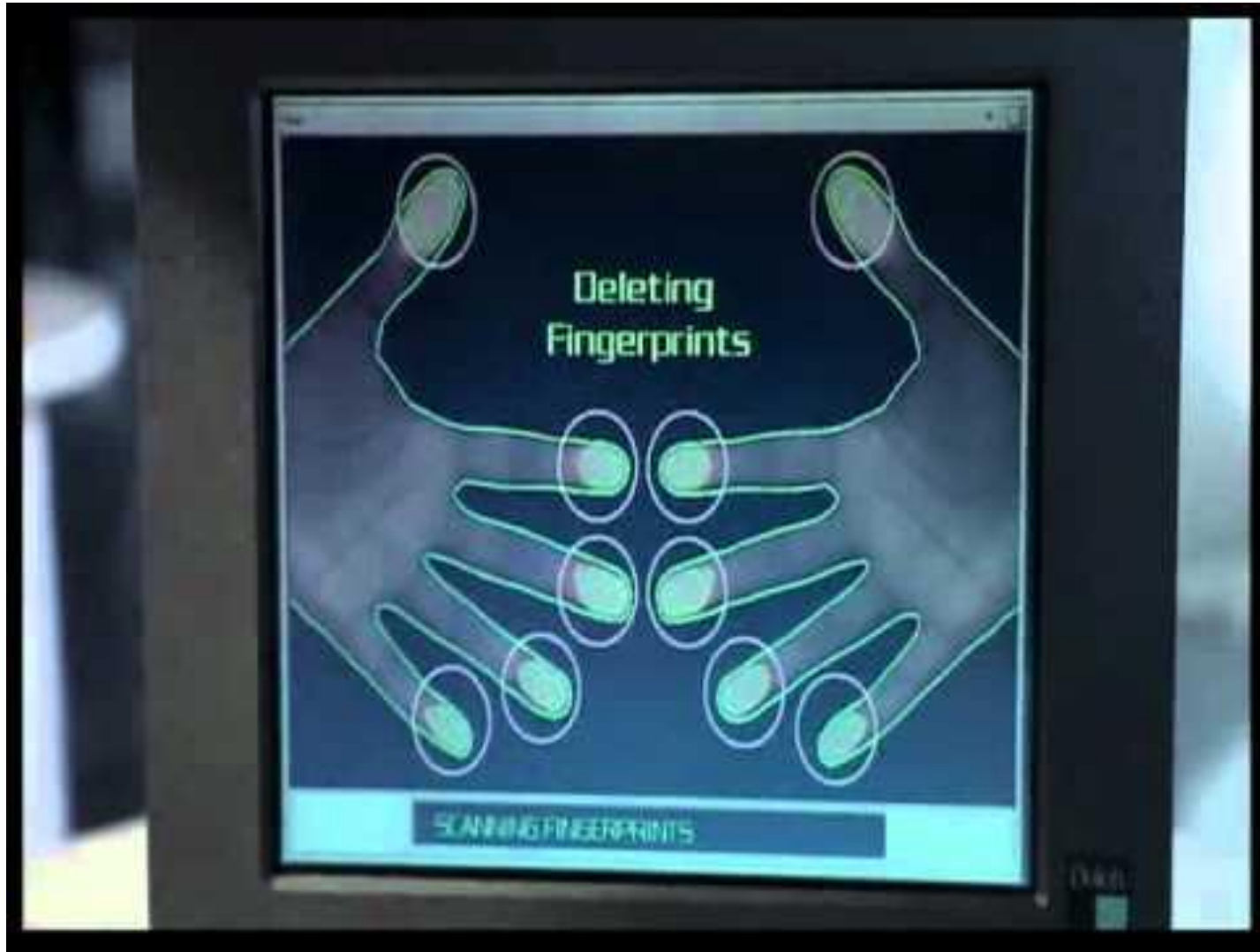
End-to-End Systems: Requirements



- Real-time
- Embedded
- Ease of use
- Low cost
- Robust

Walt Disney Theme Park (2005)

Men in Black (1997)



No fingerprint, no recognition

Minority Report (2002)



Personalization: Hello, Mr. Yakamoto! Welcome back to the GAP. How did the tank top work out for you?

Biometric Spoof Attacks



Liquid
Latex Body
Paint



PlayDoh
(Orange)



Monster
Liquid Latex



Wood Glue



Gelatin



Crayola
Model Magic



Au/Ti
Coating



Print Attack



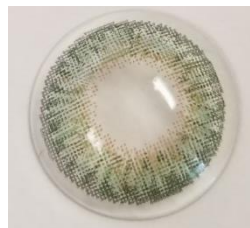
Replay Attack



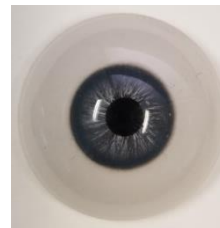
3D mask attack



Print Attack



Cosmetic
Contact



Glass



Prosthetic



Plastic

How to generalize spoof detectors to unforeseen spoof types?

Face Spoof Detection



Real Faces misclassified as
spoof



Spoofs misclassified as Real

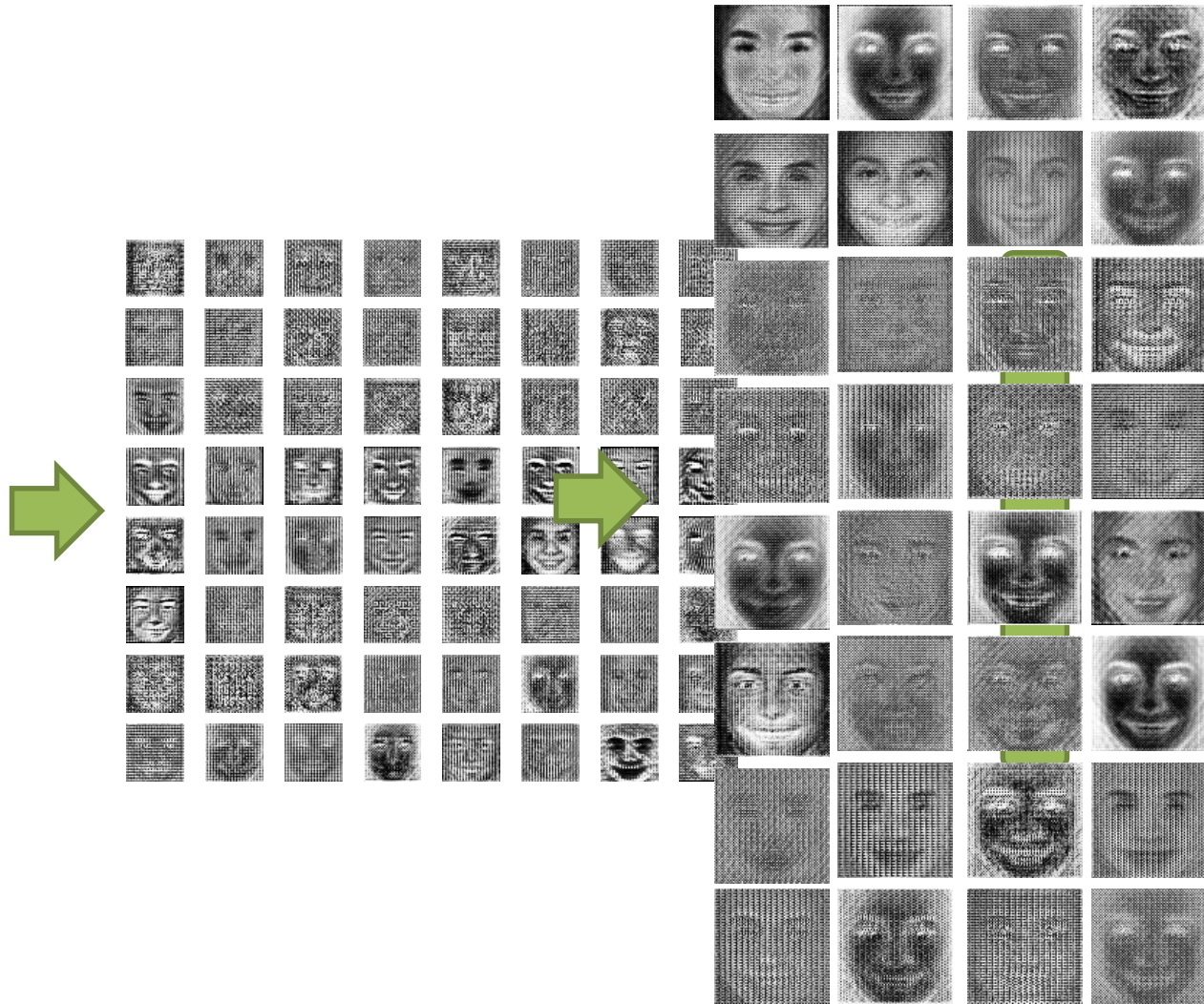
Face Reconstruction from Templates



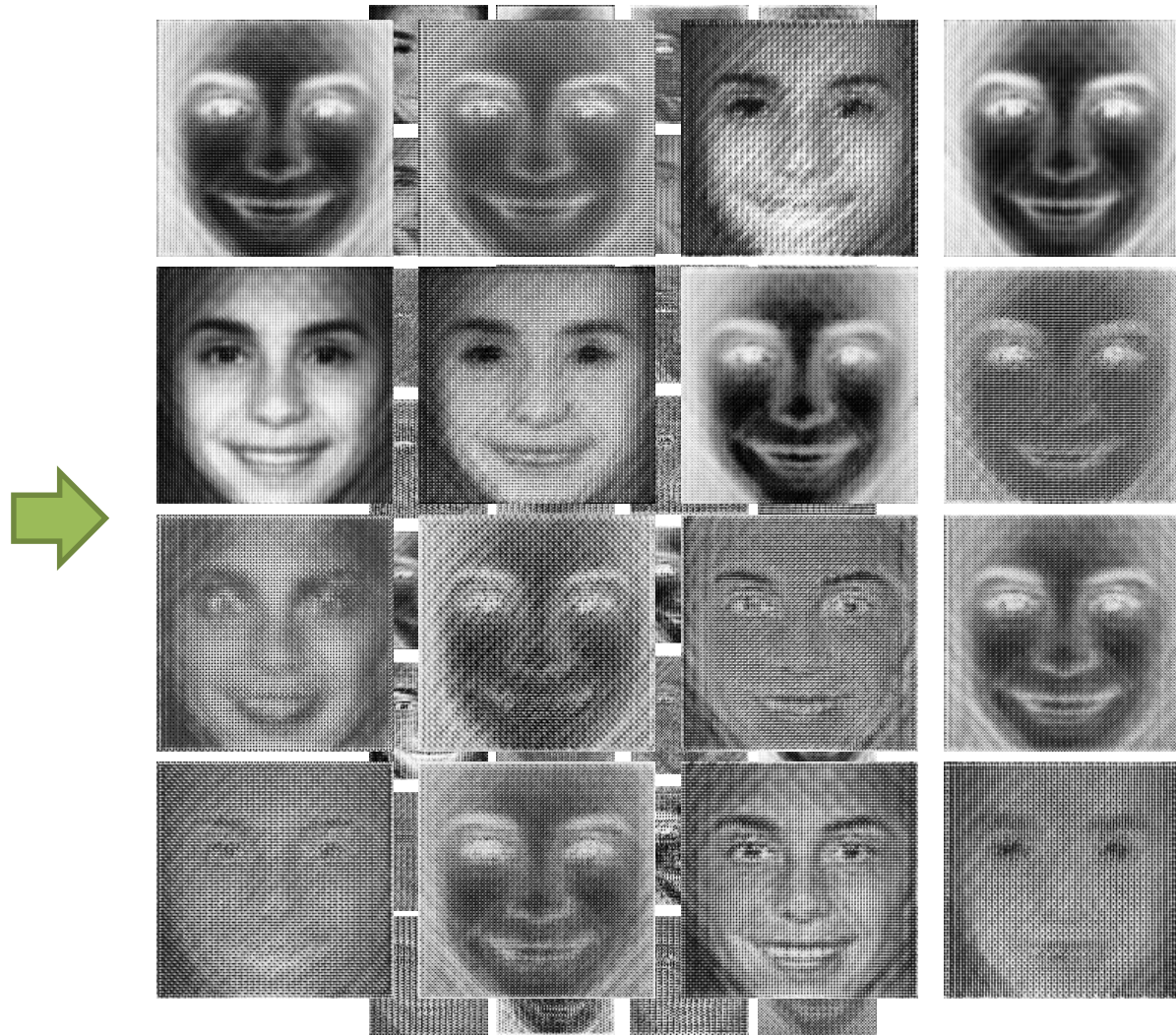
Template
Extractor



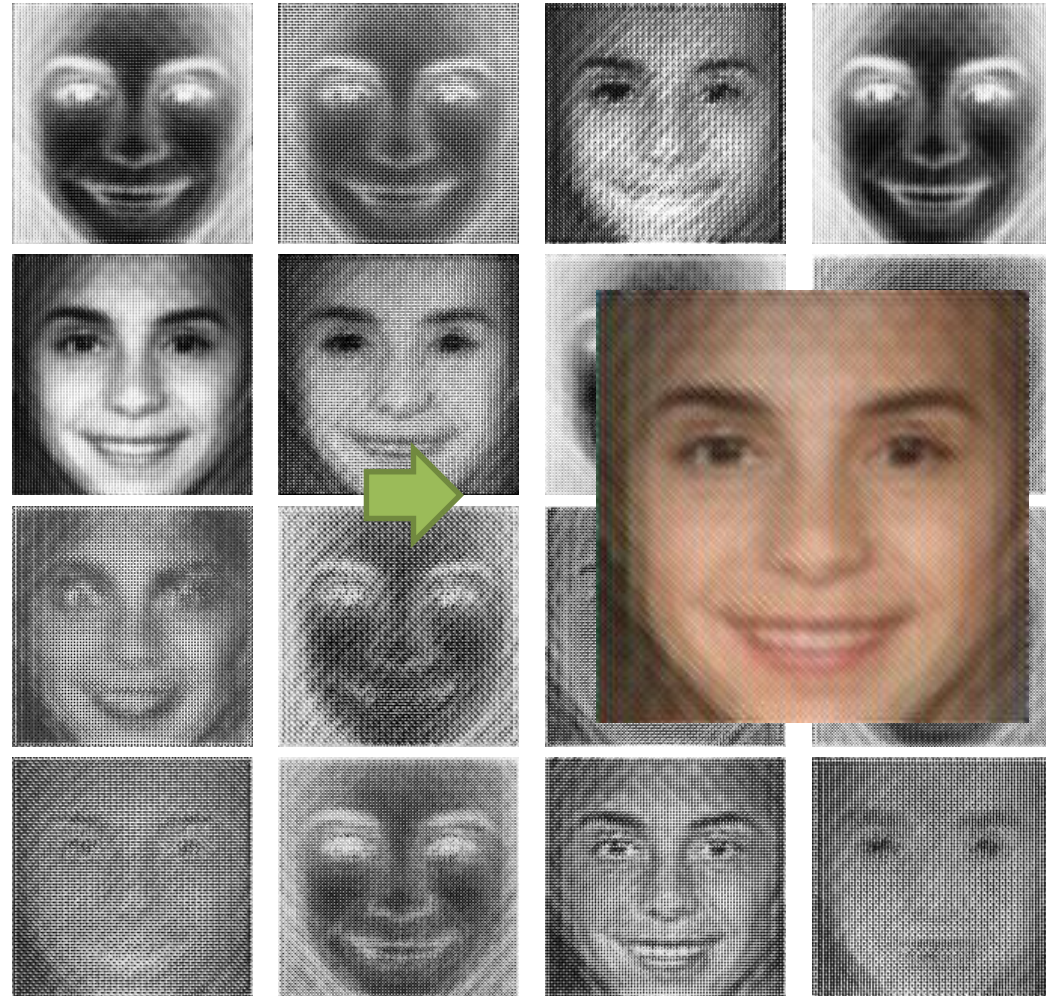
Face Reconstruction from Face Templates



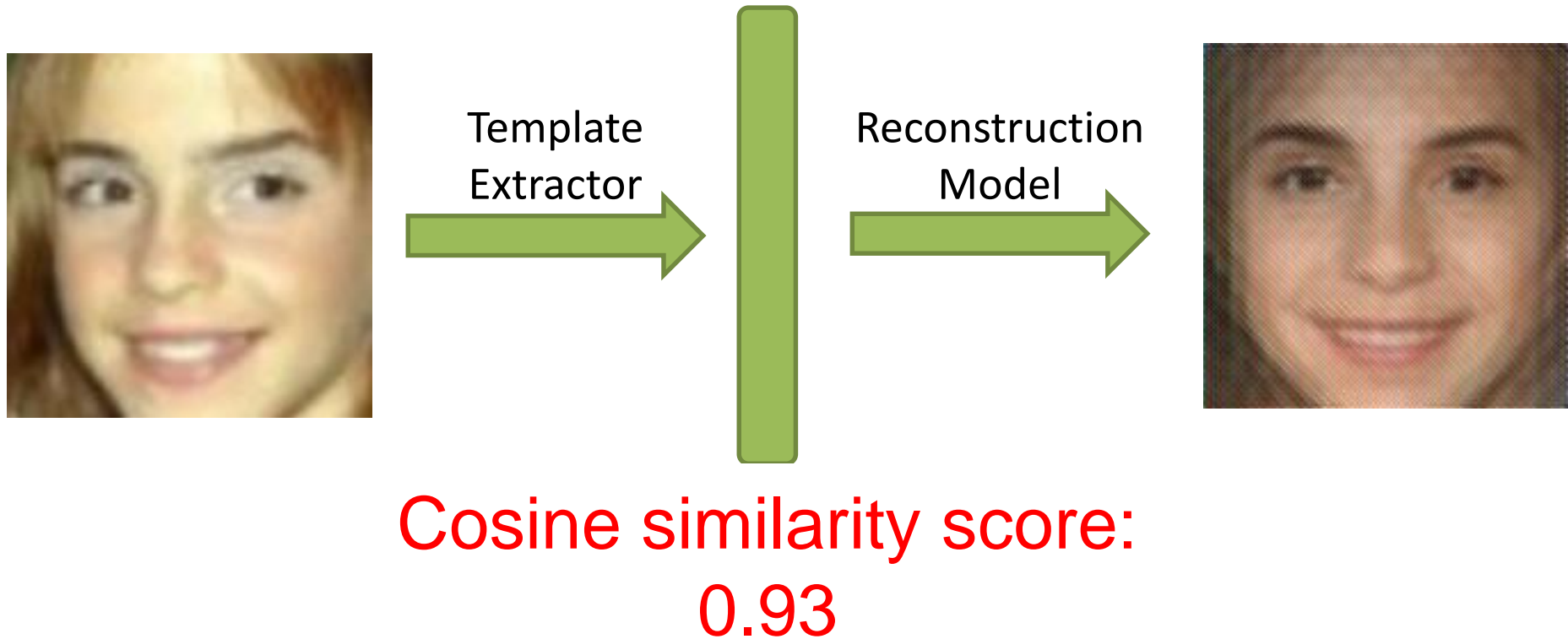
Face Reconstruction from Face Templates



Face Reconstruction From Templates

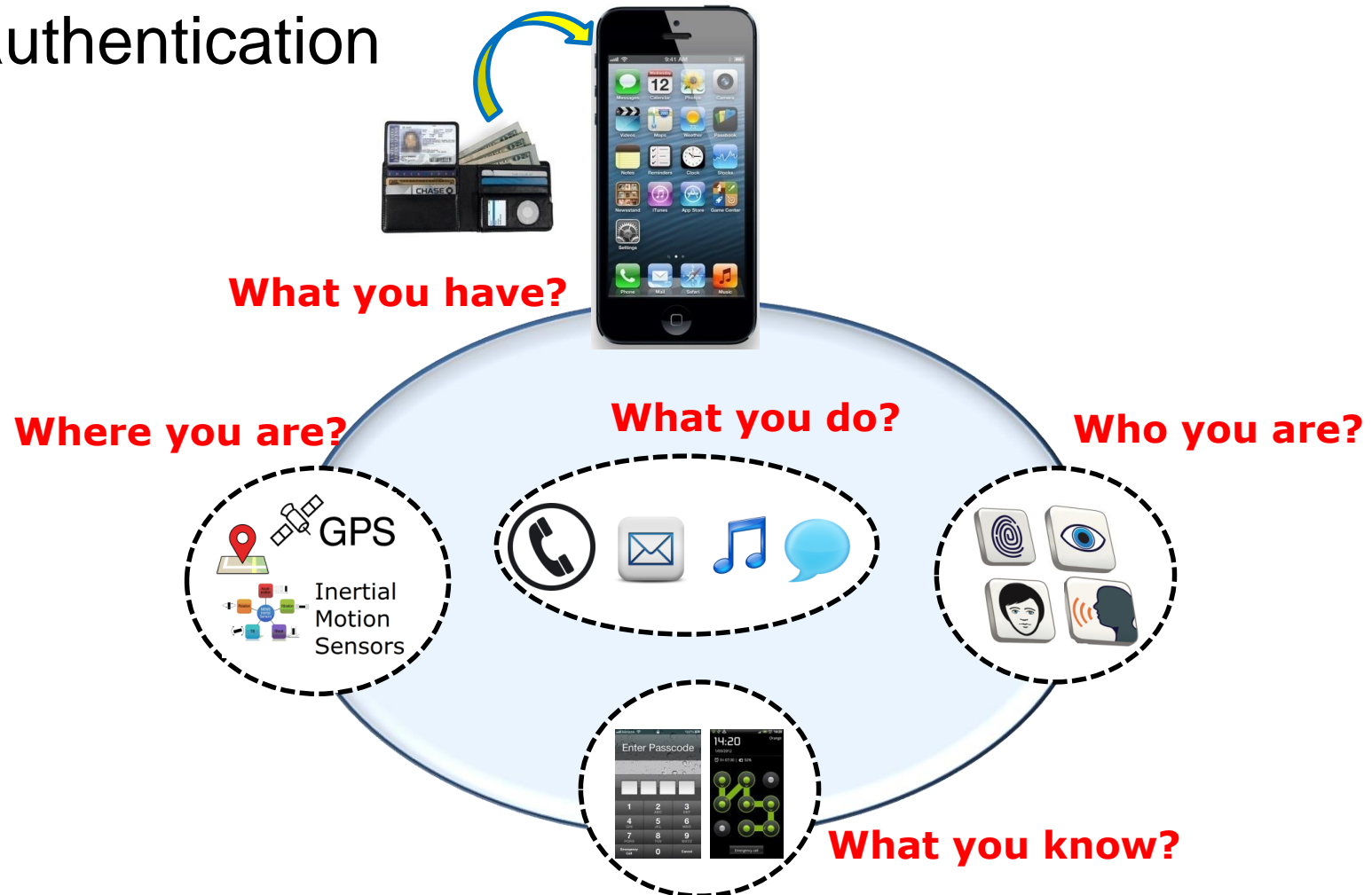


Face Reconstruction From Templates



Passive and Active Authentication

- Combine context (e.g. GPS location) with other soft cues (e.g. most frequented website/app) for authentication



Summary

- Biometric recognition has *permeated our society*
- It is the only way to know if a “*person is who he claims to be*” and “*not who he denies to be*”
- Biometrics must meet application requirements
- Need for *unobtrusive and ubiquitous recognition*
- Performance should be evaluated on benchmarks
- Ensure biometric *data privacy and system*

WITHOUT DEVIATION
FROM THE NORM,
PROGRESS
IS NOT POSSIBLE
—FRANK ZAPPA



Biometrics. 2-Minute Elevator Pitch



To prof. Anil Jain with respect...

Emerging Applications



Seamless Airport Journey

Fan ID (Credentials) v. Face ID (Biometrics)



1.6 million Fan IDs were issued to visitors to enter the FIFA 2018 World Cup stadiums; But, unlike Face ID, Fan IDs can be lost, stolen, or forged

Drivers of Biometrics: Applications



ATM, Aadhaar



UAE immigration



Coal mine entry/exit



Time & attendance

Improve security, eliminate fraud, user convenience

Fingerprint Recognition: 1960s



Courtesy: James Blanchard, Michigan State Police

Michigan AFIS (1989)



725K Tenprints; 4.8K searches; no latent search; 15K comparisons/sec.

Michigan AFIS (2018)



4 million tenprints; 650K rolled print and 5.6K latent searches in 2017

Avg. time for rolled search: 5.3 sec; avg time for latent search: 12.2 sec

Touch ID



Tactile Switch

Capacitive Single-Touch Sensor

Stainless Steel Detection Ring

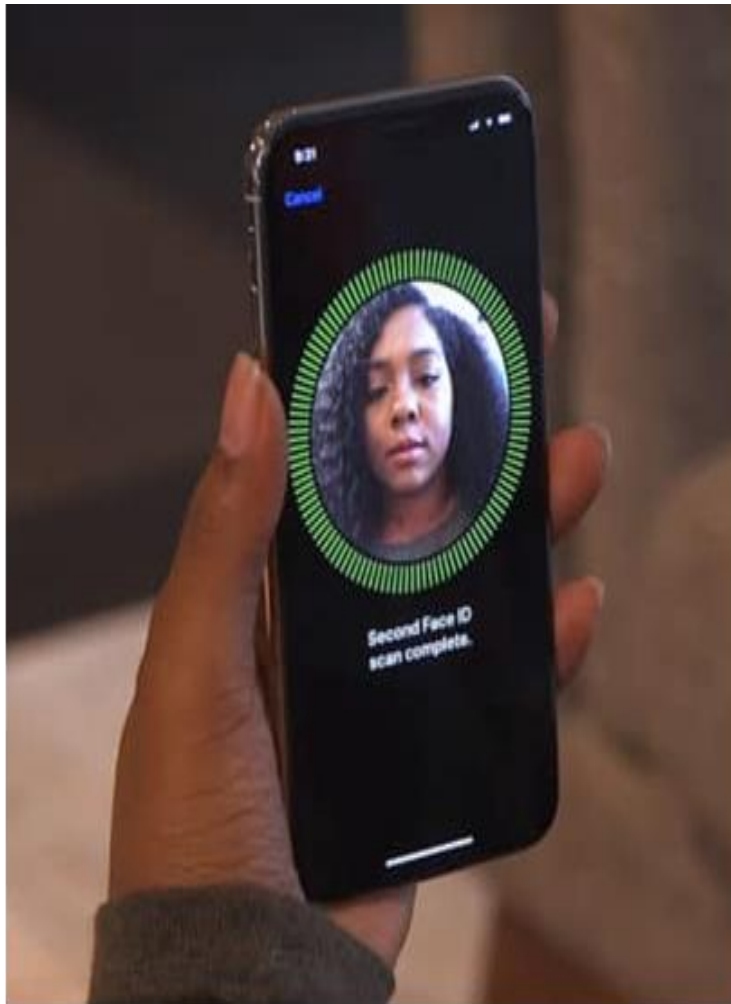
Laser-Cut Sapphire Crystal



iPhone 5 (2013); Apple Pay (2014)

**Cost of sensor & matching algorithm/phone is
under US \$9**

FaceID



iPhone X (2017)

Match on Card



Step 1: Cardholder taps card at a chip-enabled terminal while holding thumb on sensor



Step 2: Cardholder's fingerprint image is compared against stored biometric images within the card.



Step 3: Issuer receives chip data indicating whether biometric authentication was successful or failed.

Match in Box

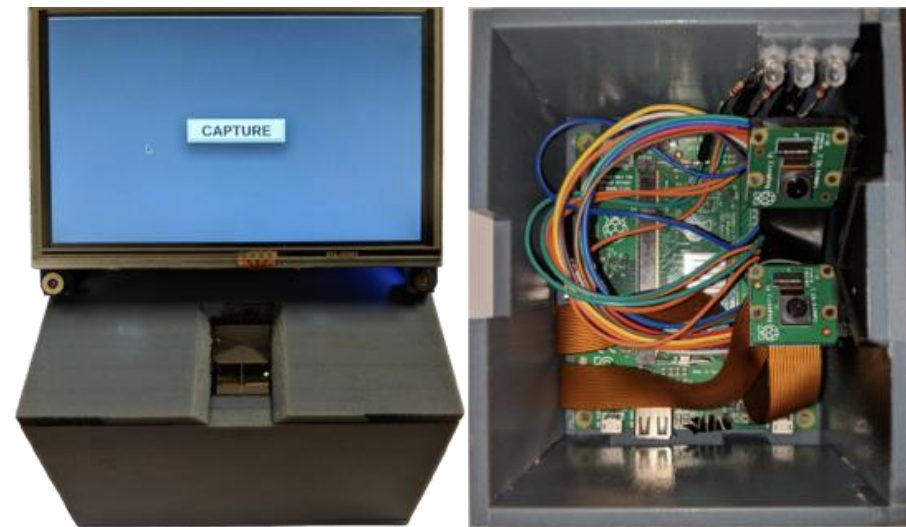


Figure 1. Open source, end-to-end fingerprint recognition system (1900 ppi, dual-camera spoof detector, feature extractor, template storage, 1:N search). Dimensions: 4"x4"x4"

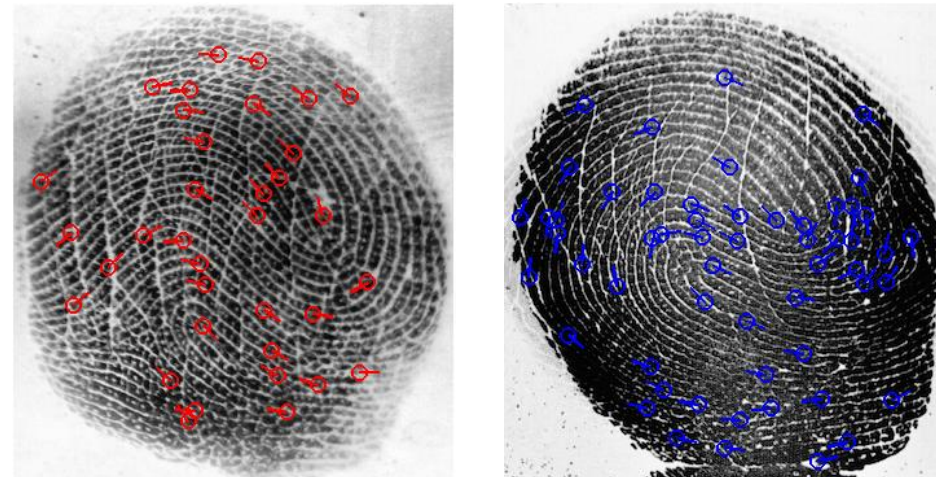


Figure 2. 1900 ppi infant fingerprint images. Right thumb of a 3-month old infant by (a) Match in Box and (b) 1270 ppi NEC infant reader

Biometric Recognition Algorithms



Fingerprint (1963)

- M. Trauring, “On the Automatic Comparison of Finger Ridge Patterns”, *Nature*, vol. 197, pp. 938–940, 1963



Face (1966)

- W. W. Bledsoe, “Man-Machine Facial Recognition”, Tech. Report PRI 22, Panoramic Res., 1966
- T. Kanade, “Picture Processing System by Computer Complex and Recognition of Human Faces”, Doctoral Dissertation, Kyoto University, 1973



Voice (1963)

- S. Pruzansky, “Pattern-Matching Procedure for Automatic Talker Recognition”, *J. Acoustic Society of America*, vol. 35, pp. 354–358, 1963



Hand geometry (1971)

- R.H. Ernst, “Hand ID System”, *US Patent No. 3576537*, 1971



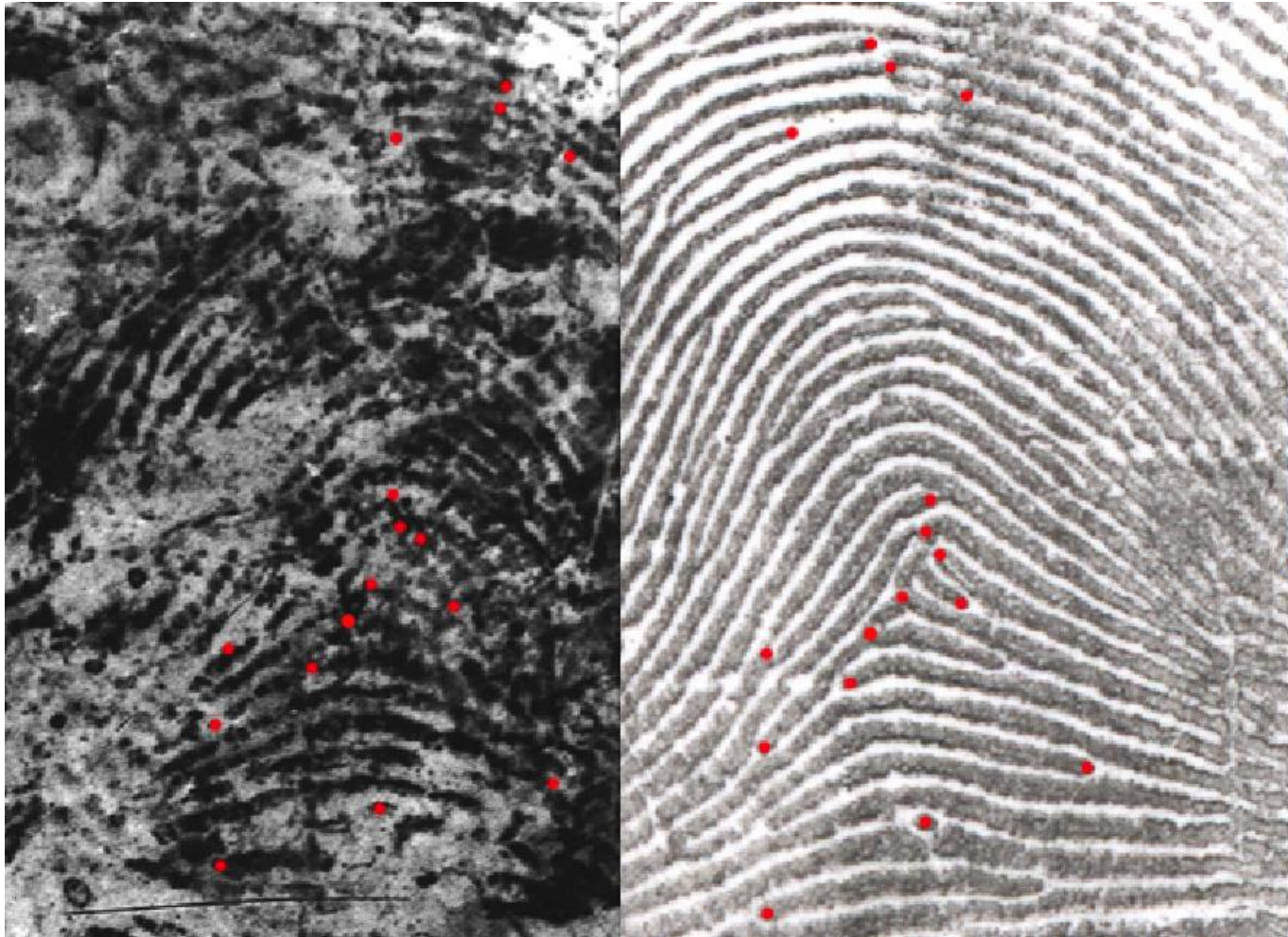
Iris (1987)

- L. Flom and A. Safir, “Iris Recognition System”, *US Patent 4641349 A*, 1987
- J. G. Daugman, “High Confidence Visual Recognition of Persons by a Test of Statistical Independence”, *IEEE Trans. PAMI*, vol. 15, pp. 1148–1160, 1993

Growing Popularity of Face

- Universality
 - Everyone has a face; covert, touchless, remote acquisition; legacy databases
- Applications
 - De-duplication, surveillance, targeted ads, social media, mobile phones
- Fast Search
 - Face matcher: ~1.5 million comparisons/sec/core
- Benchmark databases
 - FERET, FRVT, MBGC, LFW, YTF, IJB-A, IJB-B, IJB-C, IJB-S,...

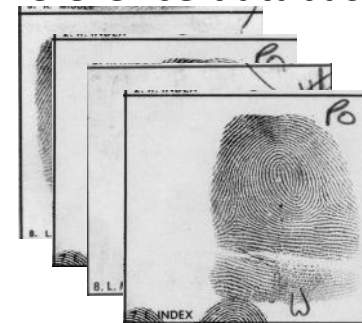
False Match



Brendan Mayfield was wrongly accused of the Madrid train bombing (2004) after his partial fingerprints matched those found at the bombing site

MSU End-to-End Latent Matcher



Reference database

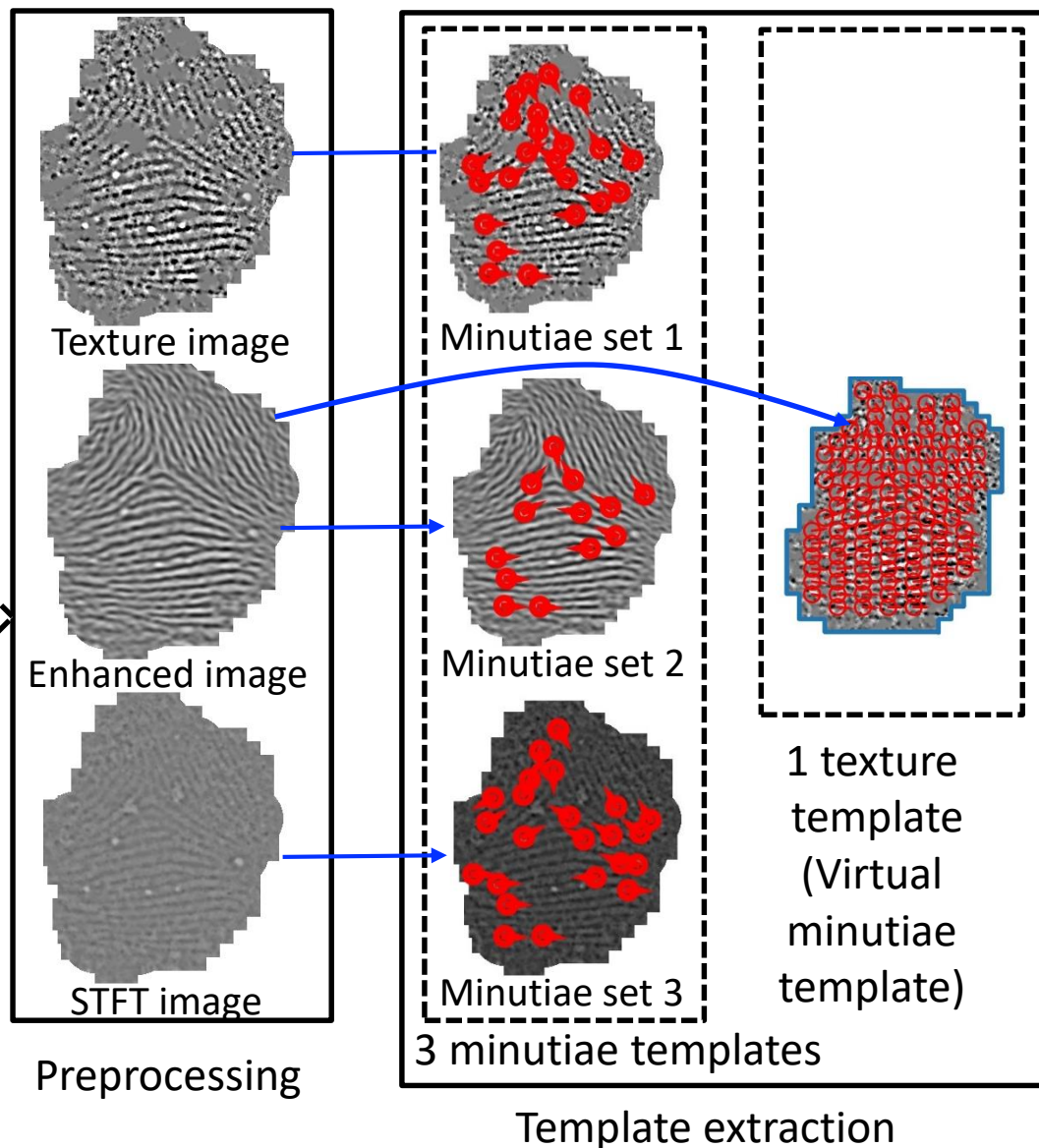


Minutiae
matcher

Texture
matcher

Comparison

Candidate	Rank (score)
	1 (0.83)
...	...
	N (0.04)



Preprocessing

3 minutiae templates

Template extraction

Texture image

Enhanced image

STFT image

Minutiae set 1

Minutiae set 2

Minutiae set 3

1 texture
template
(Virtual
minutiae
template)

Query latent

Automated
cropping

Face Recognition Milestones



1964
W. Bledsoe
First paper on
Face recog.



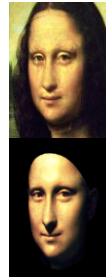
1973
Takeo
Kanade
1st FR thesis



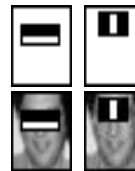
1991
Turk &
Pentland
Eigenface



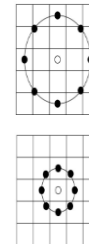
1997
Belhumeur
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Fisherface



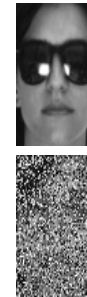
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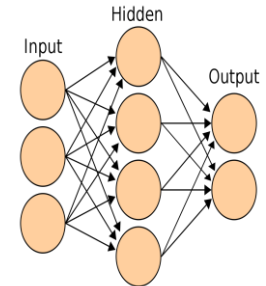
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Deep Network Library
Caffe



1915
35mm still
camera



1991
Kodak
Digital
camera
1024p



1990s
Surveillance
camera
480p @ 30fps



2000
Sharp
First camera
phone
320p



2010-2013
Wearable
camera
480P @ 30fps
Google Glass
720p @30fps



Nov. 2011
Samsung
Galaxy
Nexus
Face Unlock



2015
Google & Intel
Smartphone
RGB-D Camera

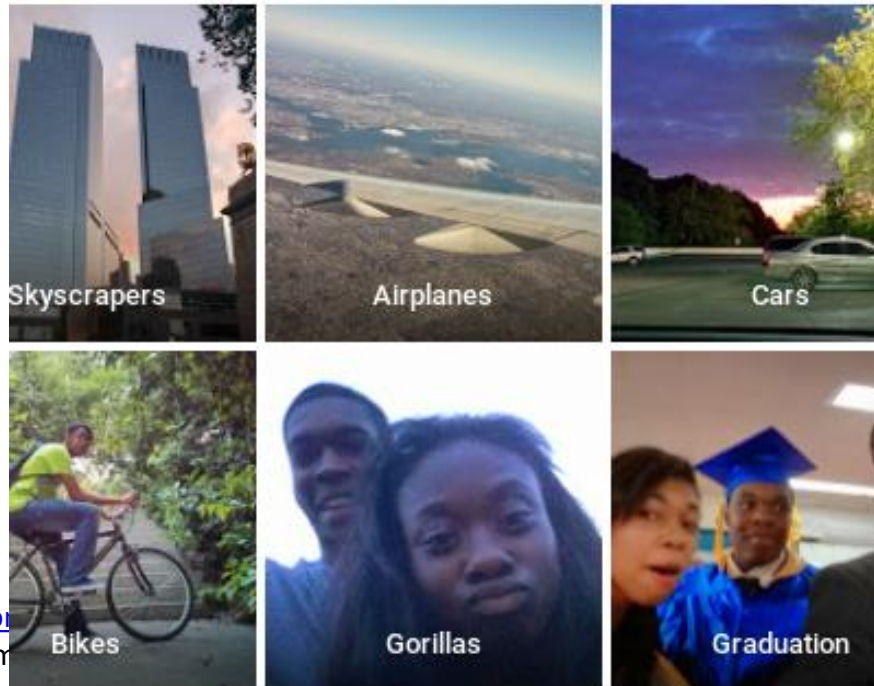


2015+
Body Camera
Used by NYPD &
Chicago PD

i phone X

Training Bias: Need Representative Samples

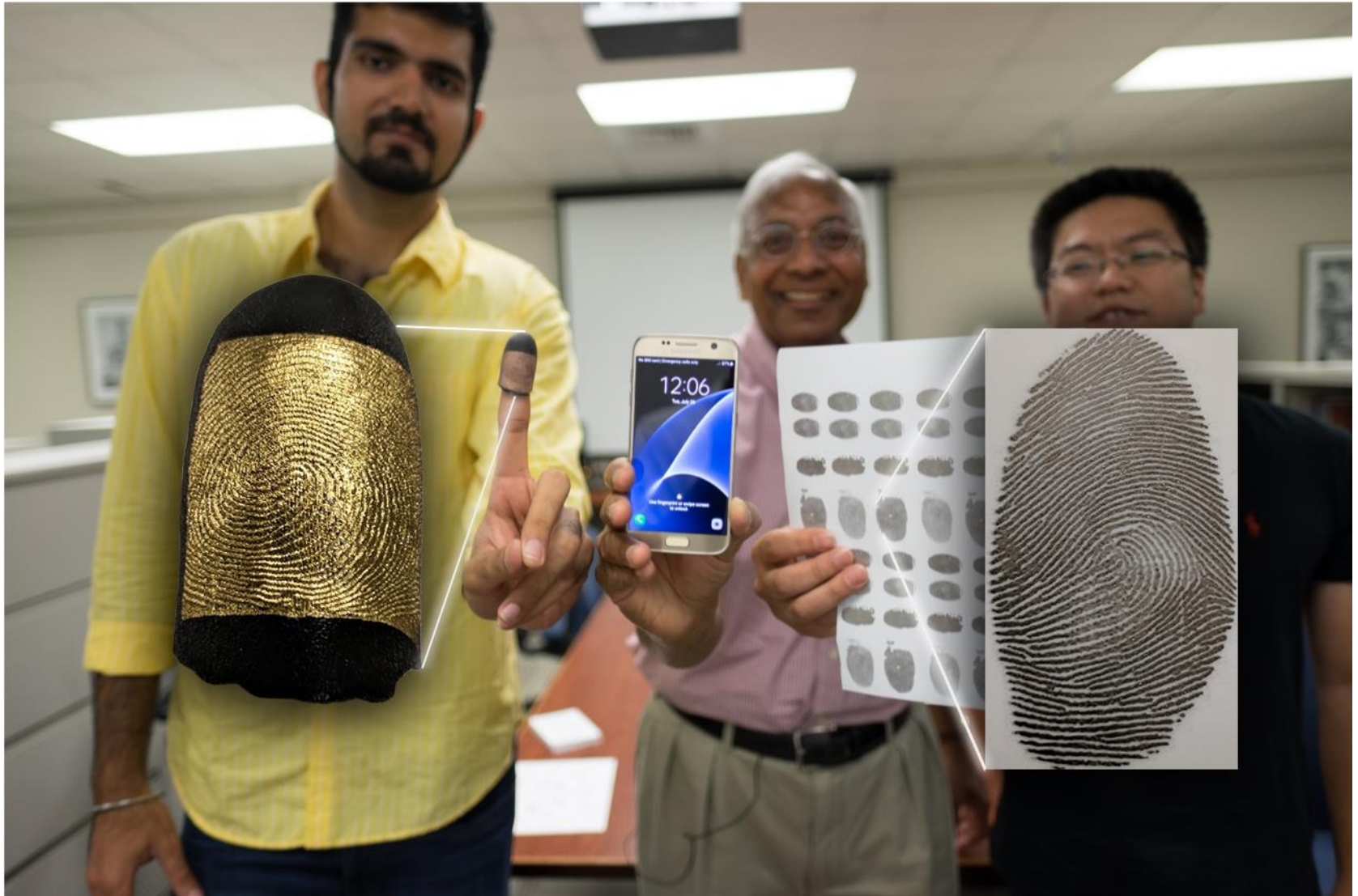
- Gender and skin-type bias in face recognition systems
www.media.mit.edu/articles/study-finds-gender-and-skin-type-bias-in-commercial-artificial-intelligence-systems/
- Datasets for training and evaluating FR systems marketed in the U.S. are mostly white and male



<https://www.theverge.com/2018/12/18/face-recognition-bias/>
www.wired.com/story/ai-bias/

<https://www.theverge.com/2018/12/18/face-recognition-bias/>

Unlocking of Galaxy S6 of Dead Person



Using dead man's fingerprints in the police database, Jain and his team built spoofs to unlock the phone
<https://msutoday.msu.edu/news/2016/accessing-a-murder-victims-smartphone-to-help-solve-a-crime/>

Fingerprint Spoof Buster



Chugh, Kai and Jain, "Fingerprint Spoof Buster: Use of Minutiae-centered Patches",
IEEE TIFS, 2018

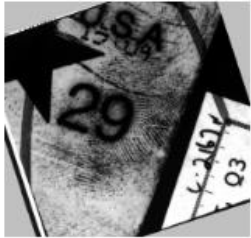
MSU End-to-End Latent Matcher

File Edit View Window Help

MSU Latent AFIS

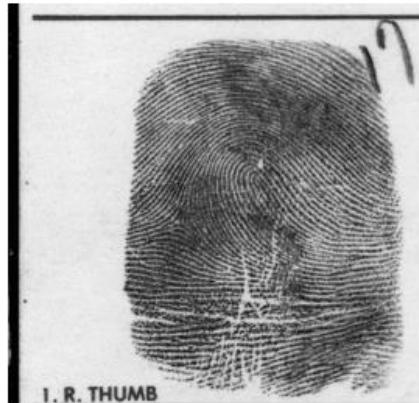
Latent Query

Candidate List



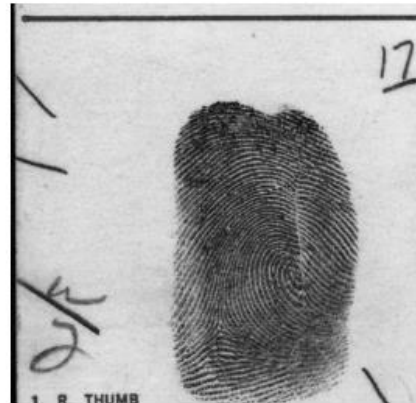
Rank: 1

Score: 175.91



Rank: 2

Score: 6.19



Rank: 3

Score: 4.14



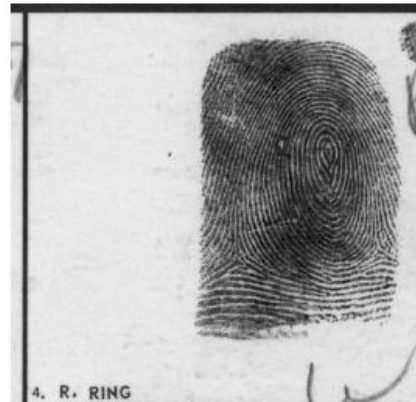
Rank: 4

Score: 3.27



Rank: 5

Score: 2.77

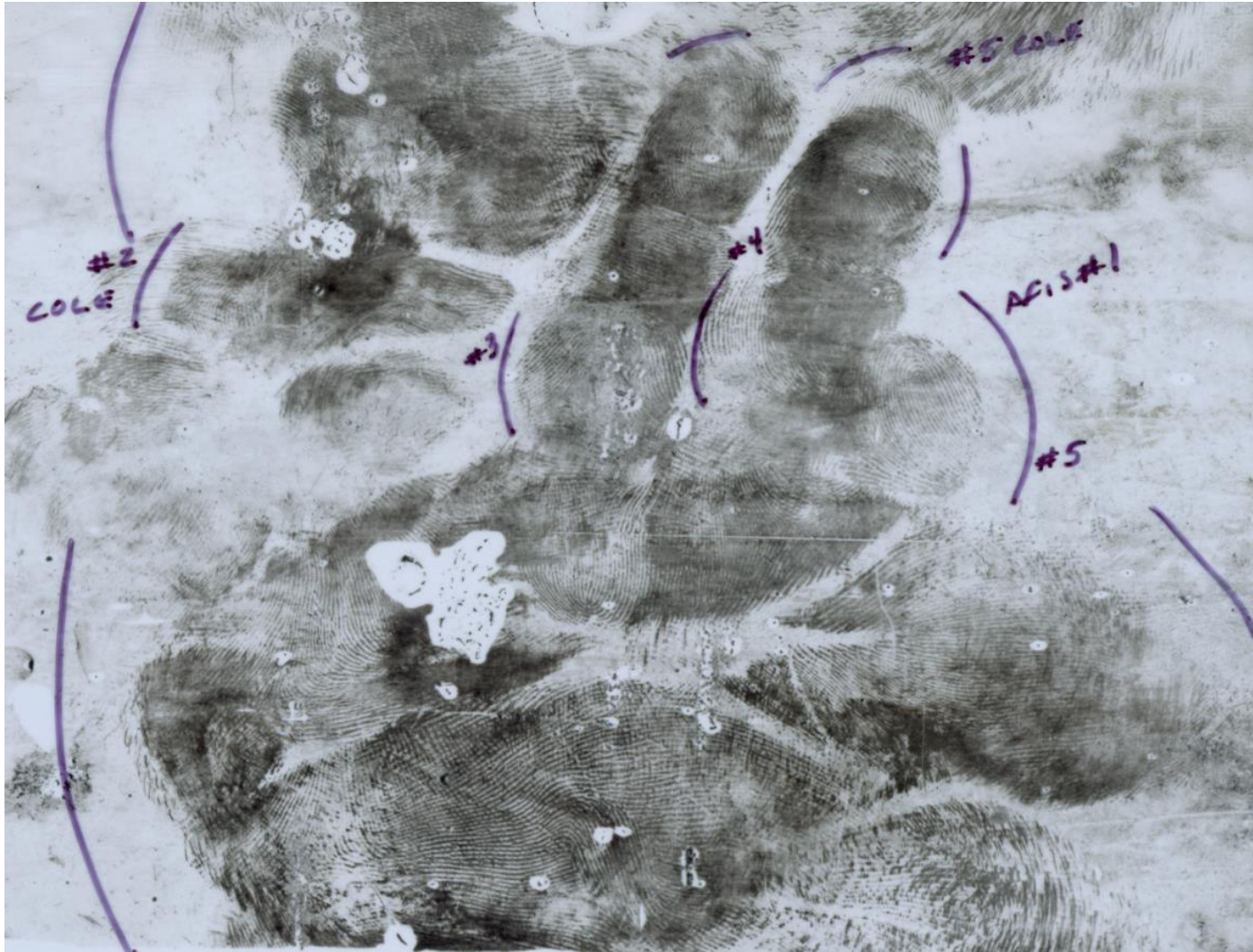


Rank: 6

Score: 2.45



Overlapping Latents: Man in the Lo



Burglary & Entry case in Pittsburgh Township, Michigan (2010). Linked to 19 other cases; Hits made with Cole (examiner) and Belcher (AFIS) tenprints on file.