Biometric Recognition @ Edge

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

Fundamental Premise of Biometrics

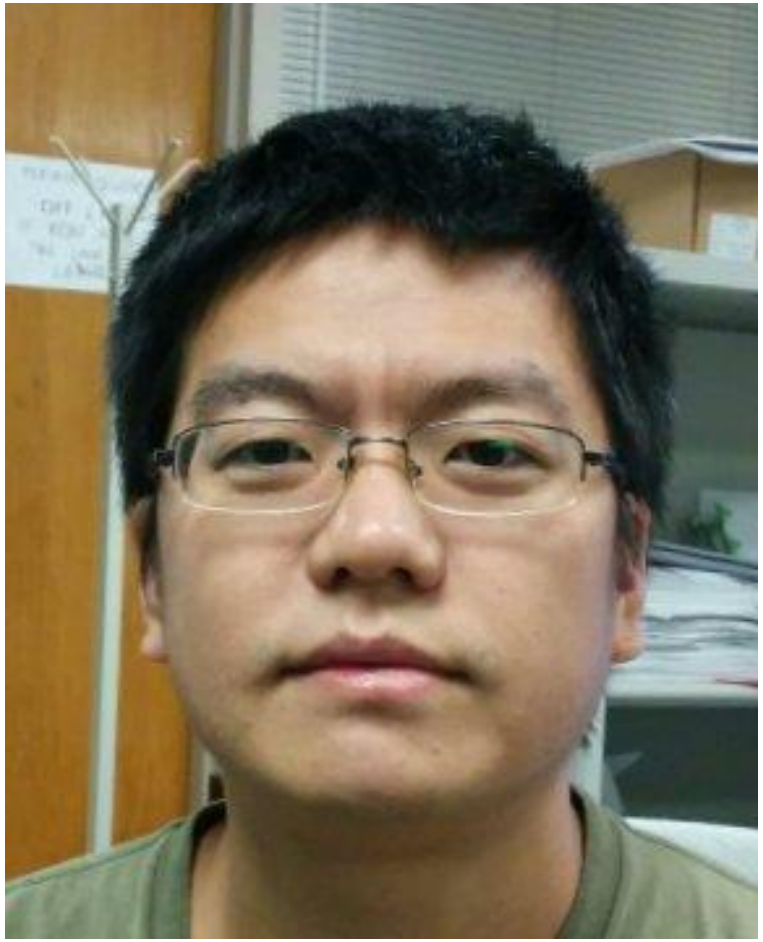
- **Individuality:** Different individuals have different biometric feature values *(Pankanti, Prabhakar and Jain, IEEE T-PAMI, 2002)*
- **Permanence:** Recognition accuracy does not change over time *(Yoon and Jain, PNAS, 2015)*
- **Desired: large intra-person similarity & small inter-person similarity**

http://www.theguardian.com/theguardian/2010/dec/05/barack-obama-doppelganger-ilham-anas

Similarity Score: 0.993 0.992 0.992 0.991 0.256

Essence of Biometrics: Pairwise Similarity

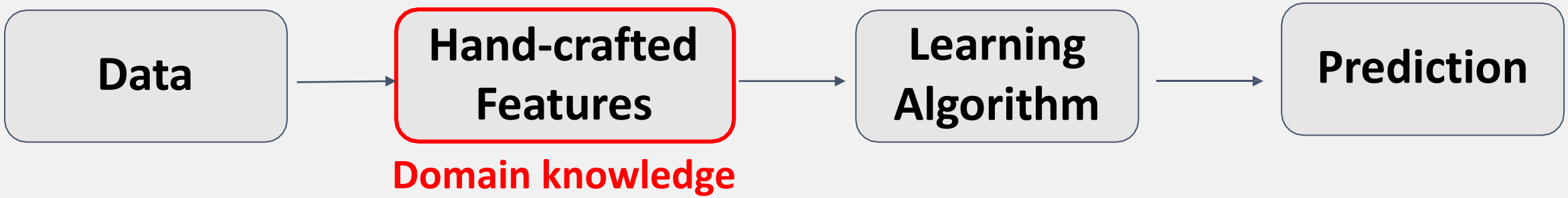
Probe



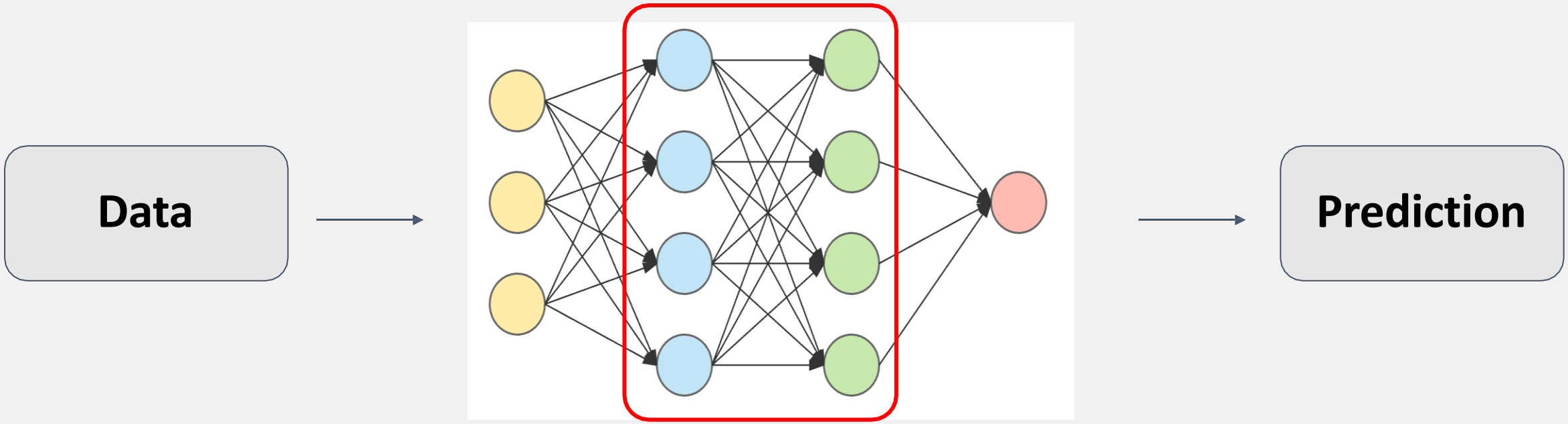
Gallery

Challenge: Salient representation and robust similarity measure

Representation

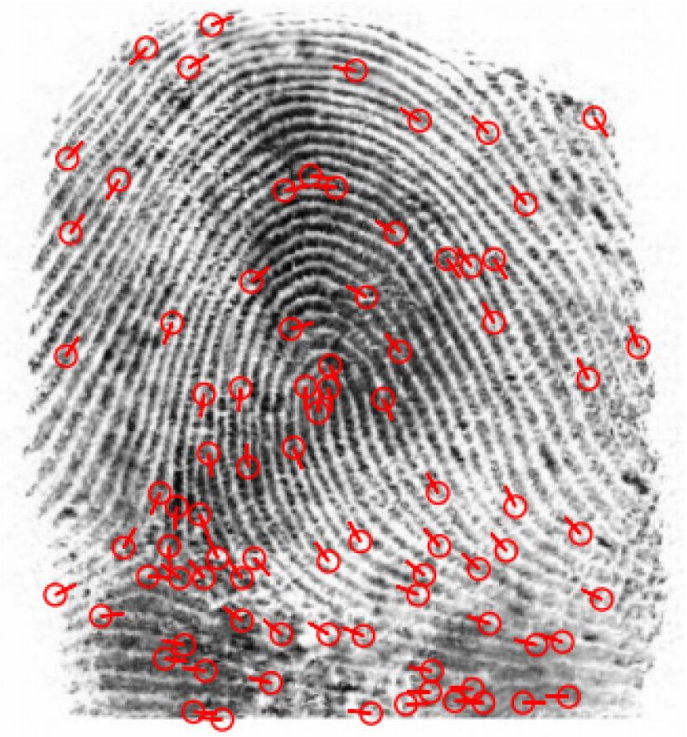


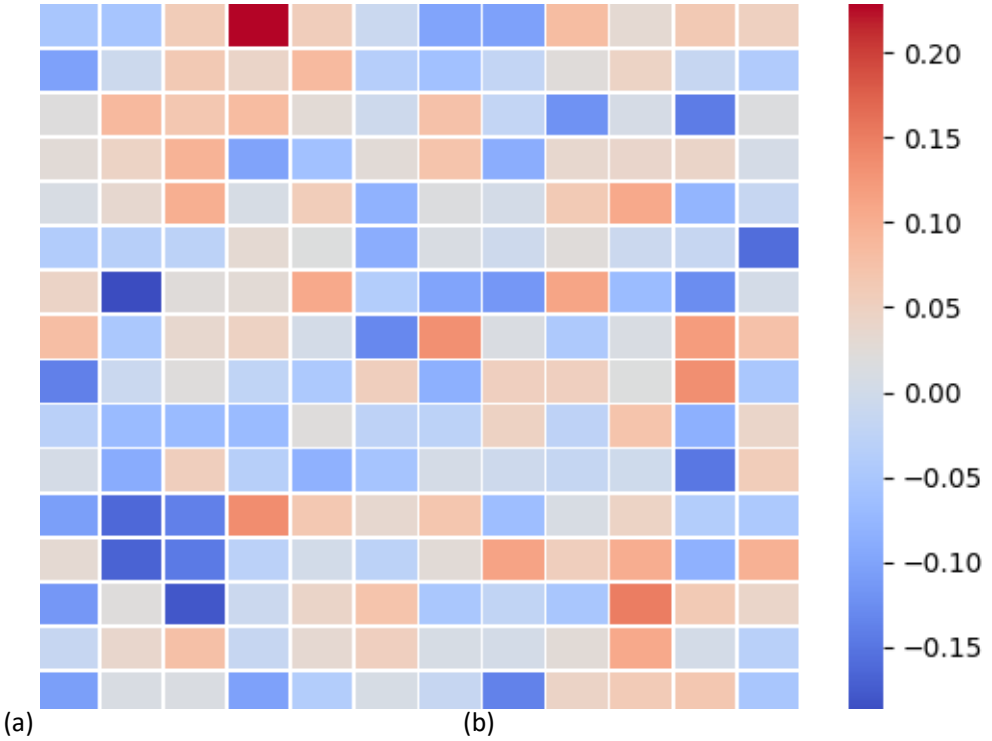
Domain knowledge



Representation Learning

Fingerprint Representation





Minutiae and embedding (192-dim); faster to compare embeddings

*Engelsma, Cao and Jain, "Learning a Fixed-Length Fingerprint Representation", IEEE Trans. on Pattern Analysis and Machine Intelligence, 20**19***

Representation Fusion

Query

DeepPrint Search

Top K candidates

COTS updates rankings

Candidates

Fusion of data-driven and knowledge-driven representations: Rank-1 improves from 99.45% to 99.48%

Biometrics is About Applications

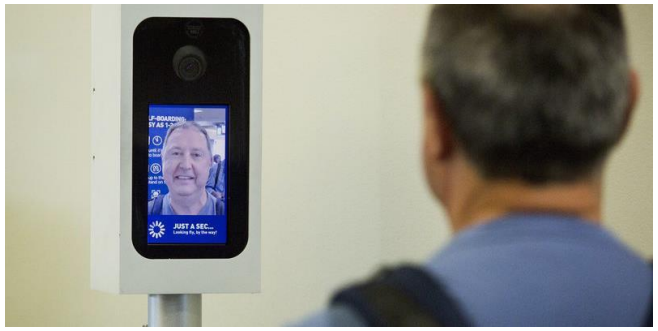
"Biometrics does not start with data and end with models/predictions. Rather, it starts with a problem faced by a real-world entity and ends with an action having an impact on that entity."

Courtesy, Karthik Nandakumar, MBZUAI

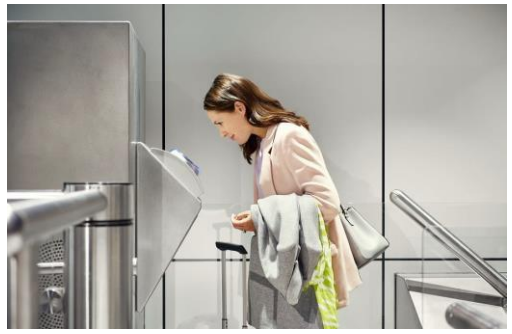
Biometric Applications

Three Most Popular Biometric Traits

Incheon, South Korea: Smart Entry



Australia: SmartGate



Amsterdam: Privium border passage

High accuracy in NIST evaluations; large legacy databases

http://www.homestaykorea.com/?document_srl=73667&mid=bbs_koreainfo_news
https://tottnews.com/tag/smart-gates/
https://www.idemia.com/news/multi-biometrics-future-border-control-2016-04-21

Understand Application Requirements

- Authentication (1:1) or identification (1:N)
- Attended or unattended mode of operation
- Contact or contactless acquisition
- Desired accuracy
- Required throughput (time to authenticate/search)
- Guarantee of system security and user privacy
- Robust to user behavior
- Biometric module integration (TouchID, FaceID)
- Return on investment (RoI)

Customer-Facing Touchless 1:N Systems

Clear: attended contactless identification large throughput; expedited airport security program; annual fee; 1:N open-set search

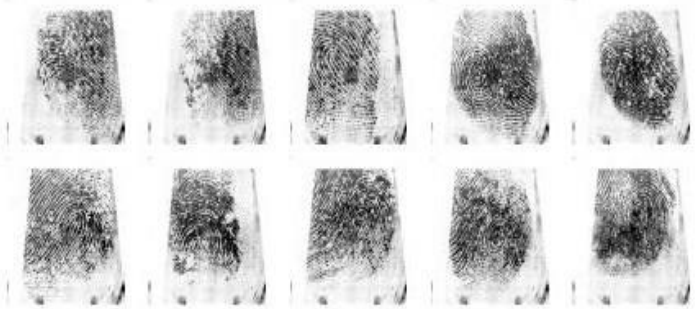
Amazon One: unattended contactless identification; better shopping experience in physical stores (Amazon Go, Whole Foods,..); usability; 1:N open-set search

Enjoy a faster, safer, touchless way through airport security, venue entrances, and beyond. (clearme.com)

https://www.theverge.com/2020/10/1/21496673/amazon-one-palm-reading-vein-recognition-payments-identity-verification

Aadhaar: World's Largest Biometric System

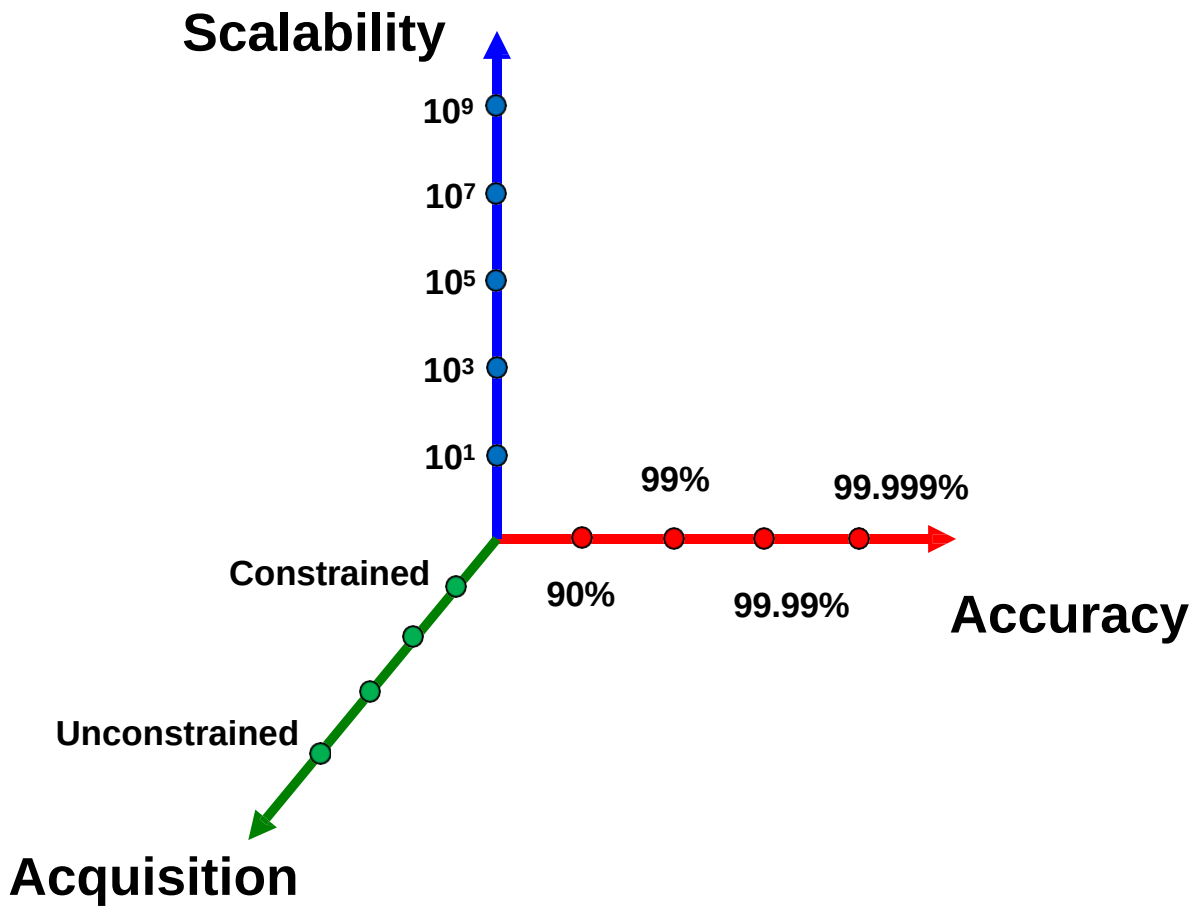
Minimal documentation
Needed for enrollent



Enrollment (1.5 billion in gallery); de-duplication

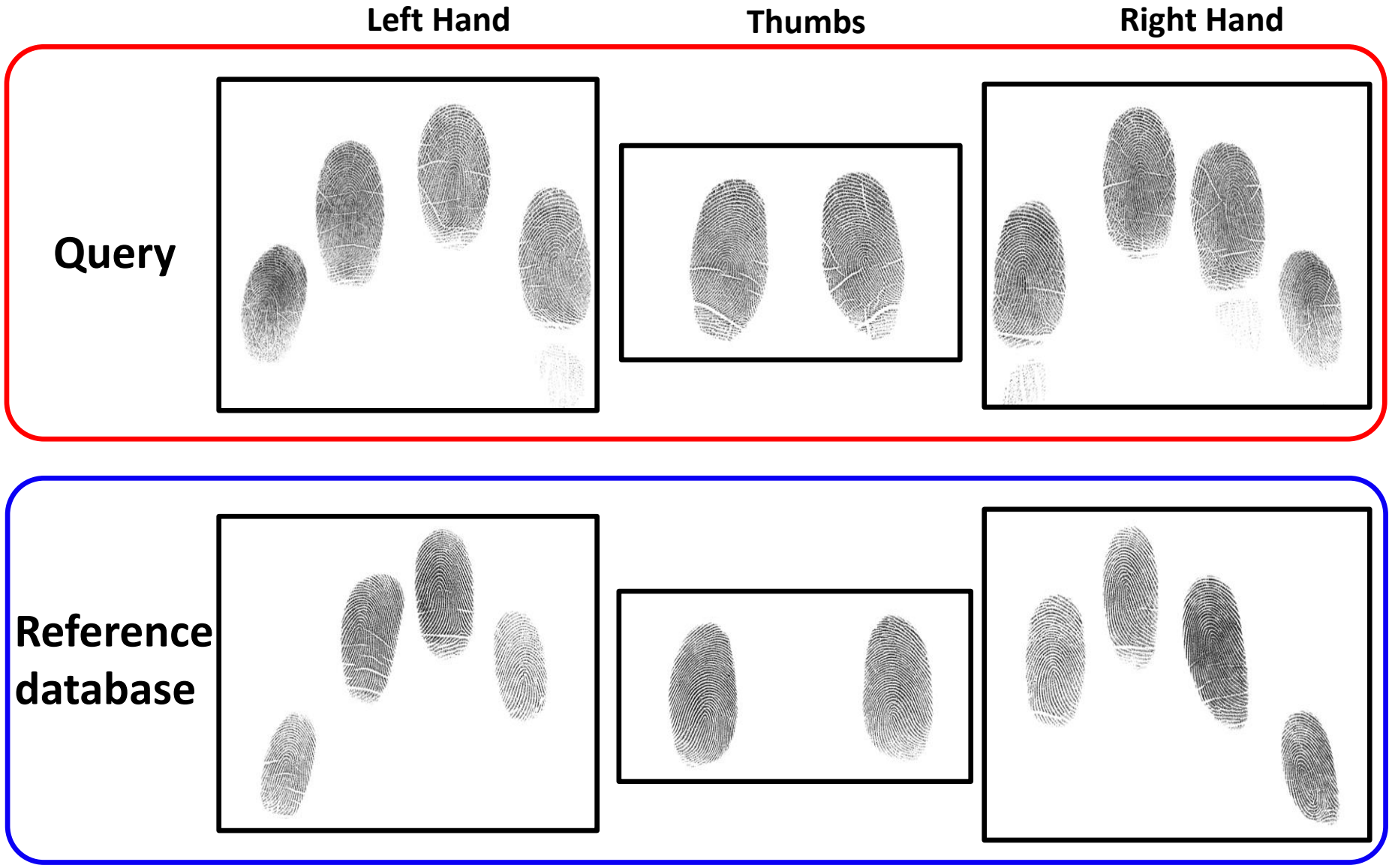
~50 million authentications/day

Biometric Recognition @ Edge



Edge use cases operate at the extremes of one or all of these three axes

TP-to-TP Comparison: Background Search



Challenge: Gallery size from a few millions to over a billion; fast response

Latent-to-TP Comparison: CSI

Crime scene latent

Left Hand

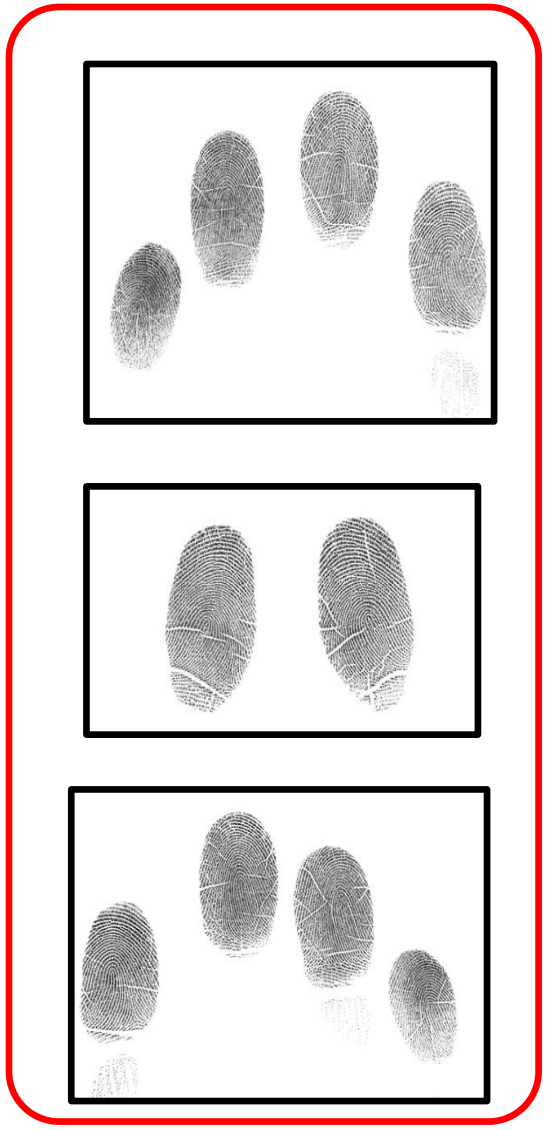
Thumbs

Right Hand

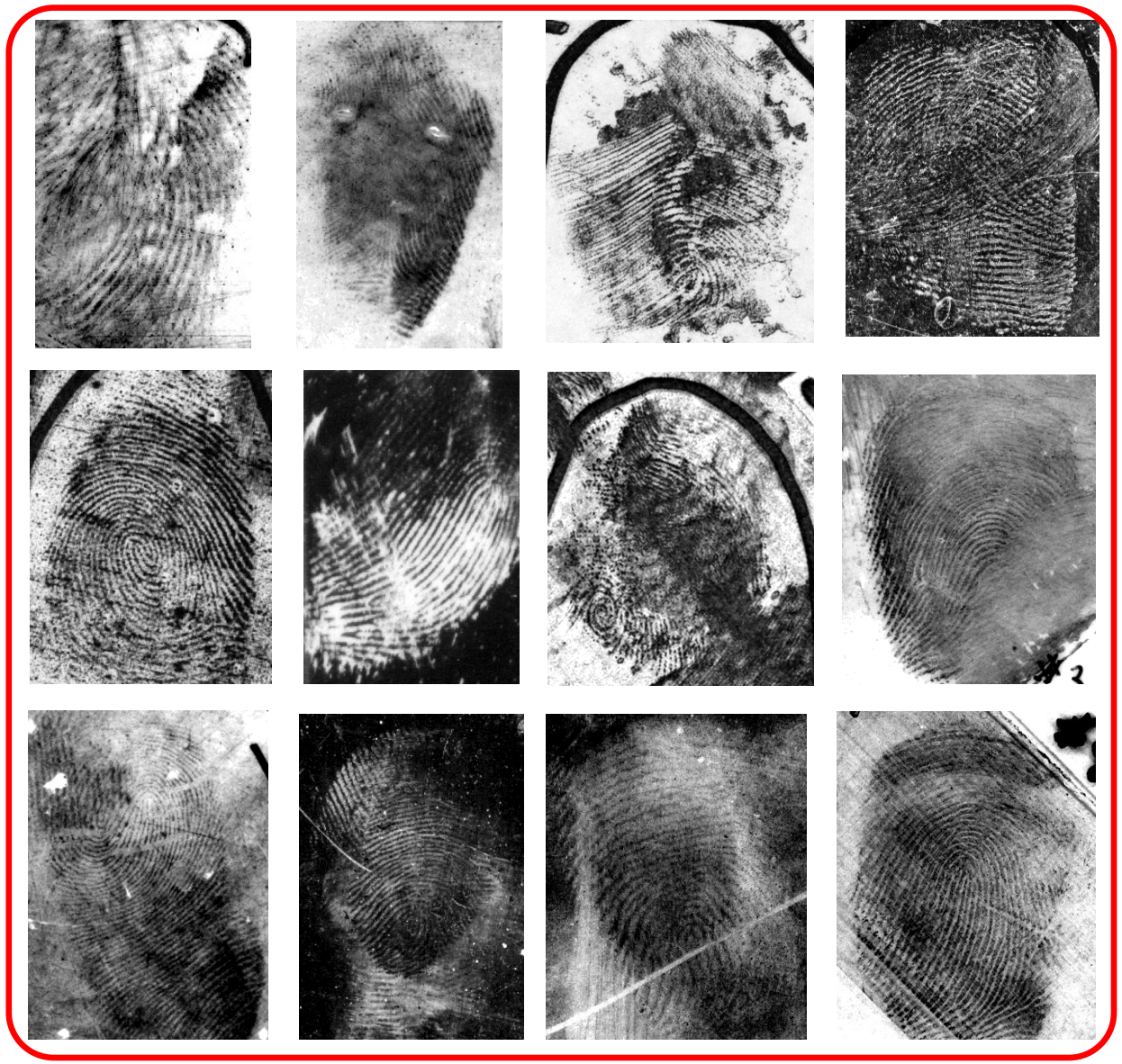
Tenprint database

NIST ELFT reported Rank-1 accuracy of only 67%

TP-to-Latent Comparison: Solve Cold Cases



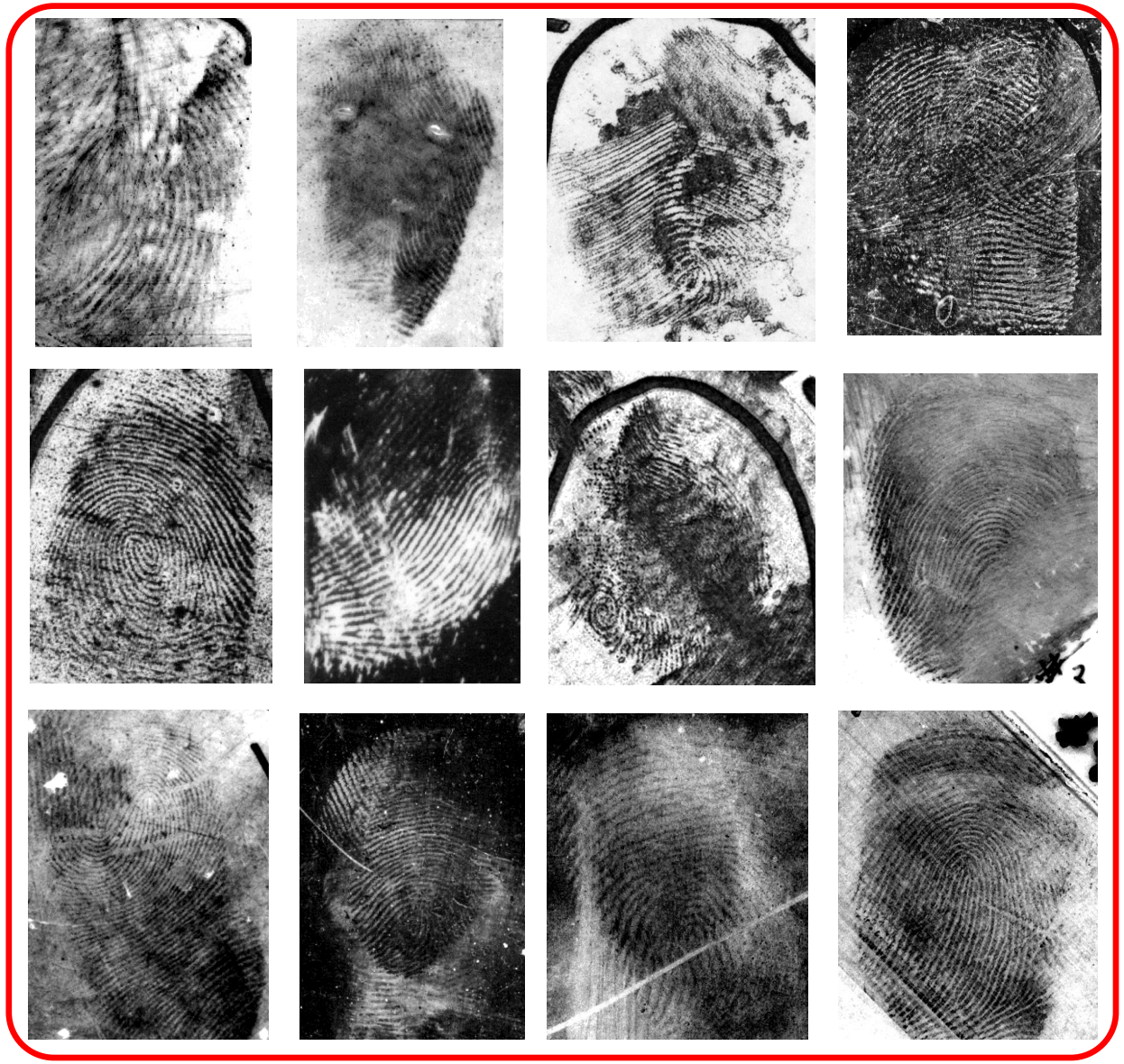
New suspect booking



Latents from cold cases

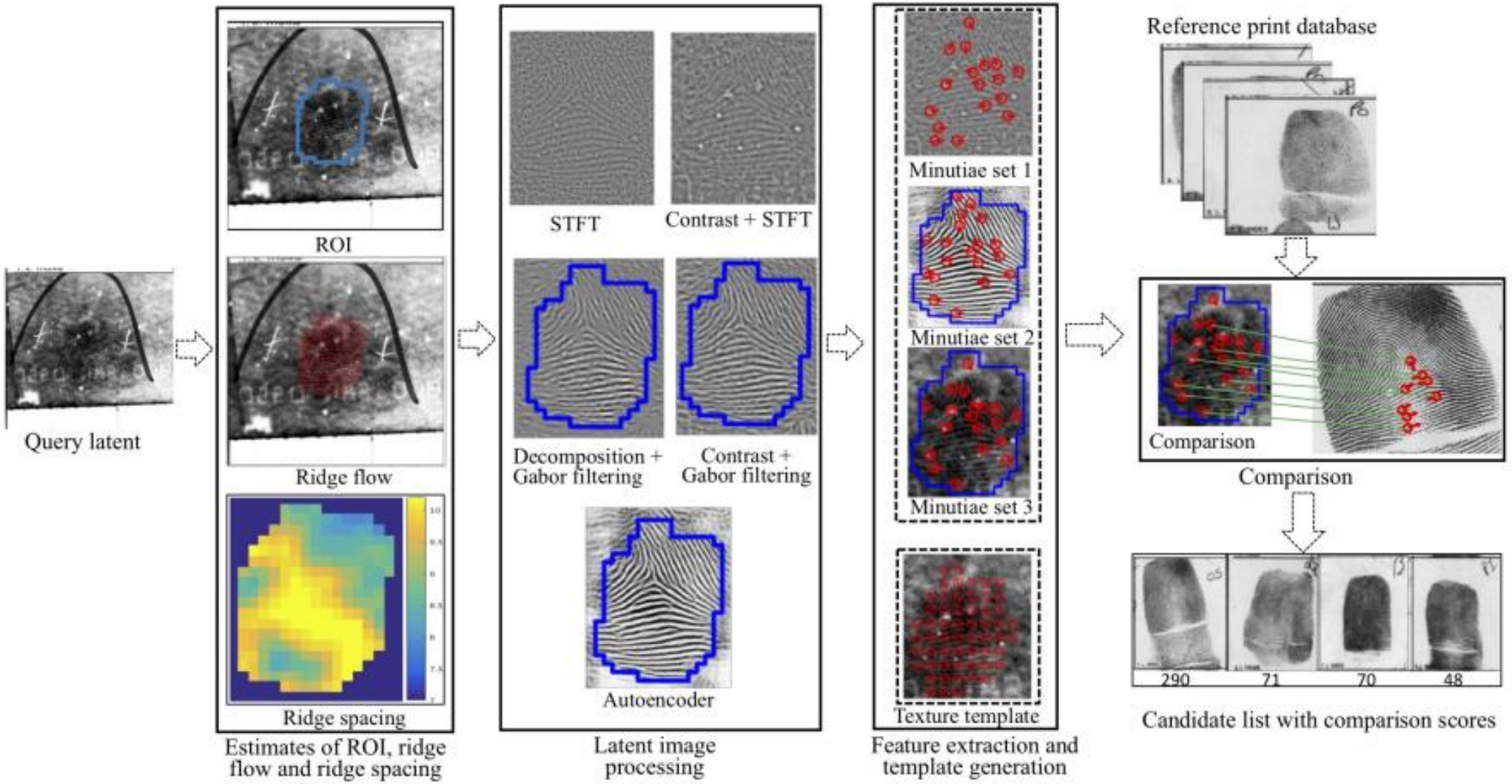
Latent-to-Latent Comparison: Link Cold Cases

New Crime scene latent



Latents from cold cases

MSU Latent AFIS



MSU latent matcher + COTS matcher boosts COTS rank-1 performance on NIST SD27 from 68% to 71%

Cao, Nguyen, Tymoszek and Jain, "End-to-End Latent Fingerprint Search", IEEE Trans. on Information Forensics and Security, 2019

PrintsGAN: Fingerprint Image Generator

- Largest open dataset: NIST SD302 (N2N); 2K fingers, 25K images
- PrintsGAN generates realistic fingerprints (multiple impressions per finger); identity of training data is not leaked

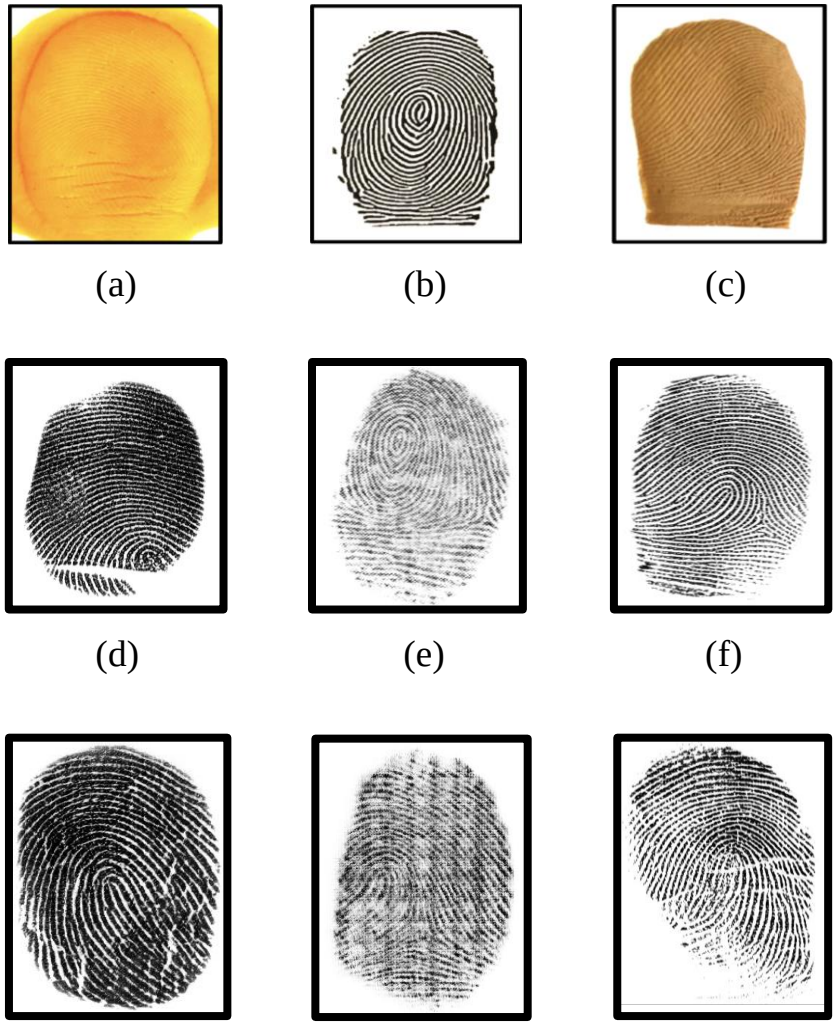
- Model trained with N2N + 100K PrintsGAN images outperformed model trained just on N2N (From 73% to 87% Rank-1 for NIST SD4)

Engelsma, Grosz and Jain, "PrintsGAN: Synthetic Fingerprint Generator", arXiv:2201.03674, 2022

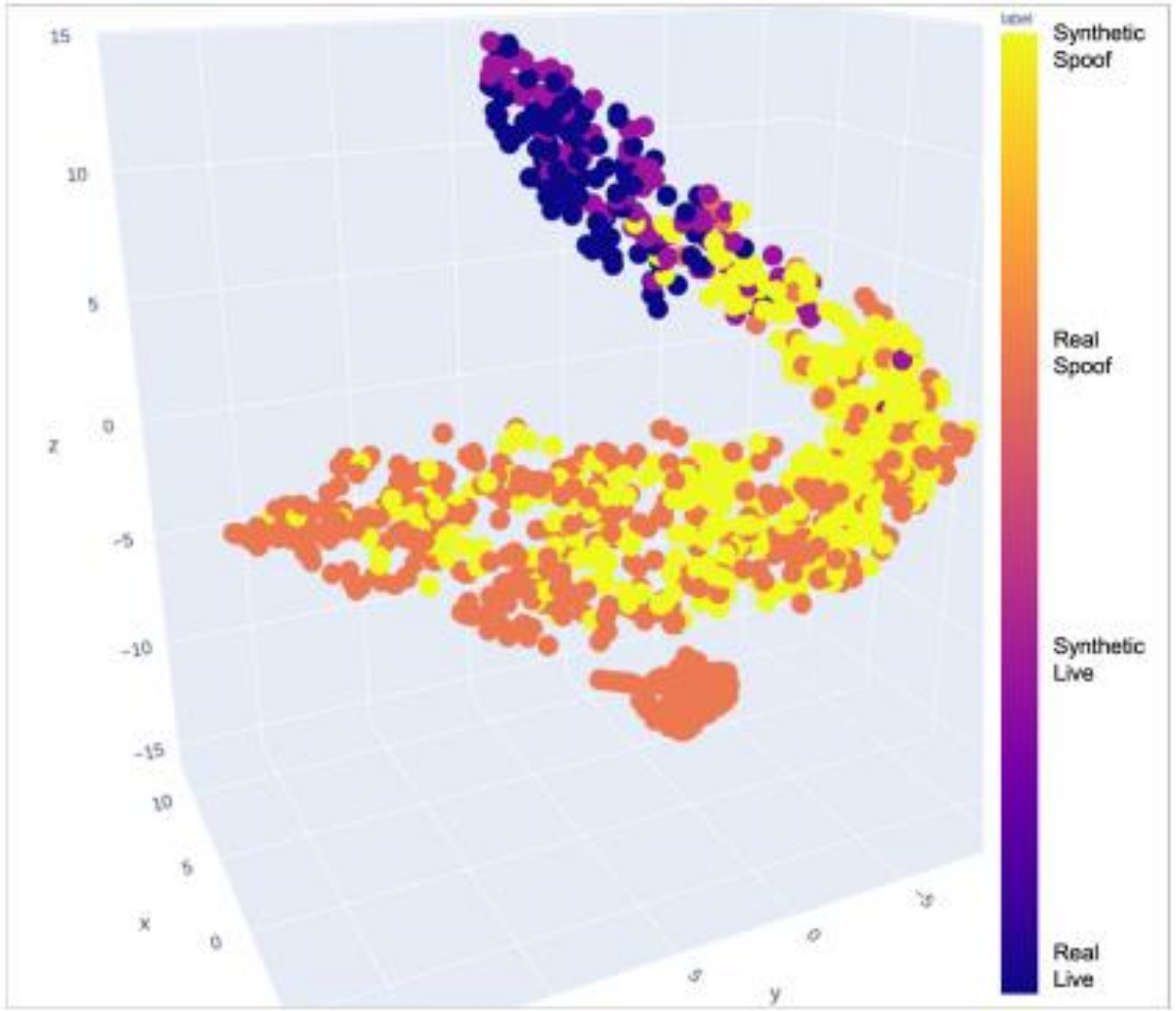
Real or Synthetic

Real or Synthetic

SpoofGAN: Fingerprint Spoof Image Generator



Playdoh (a), printed paper (b) and latex (c) fabricated spoofs; images of spoofs from CrossMatch (d-f); SpoofGAN images (g-i)



3D embeddings of real (synthetic) live and spoof images

Grosz & Jain, "SpoofGAN: Synthetic Fingerprint Spoof Images", arxiv:2204.06498v2, 2022

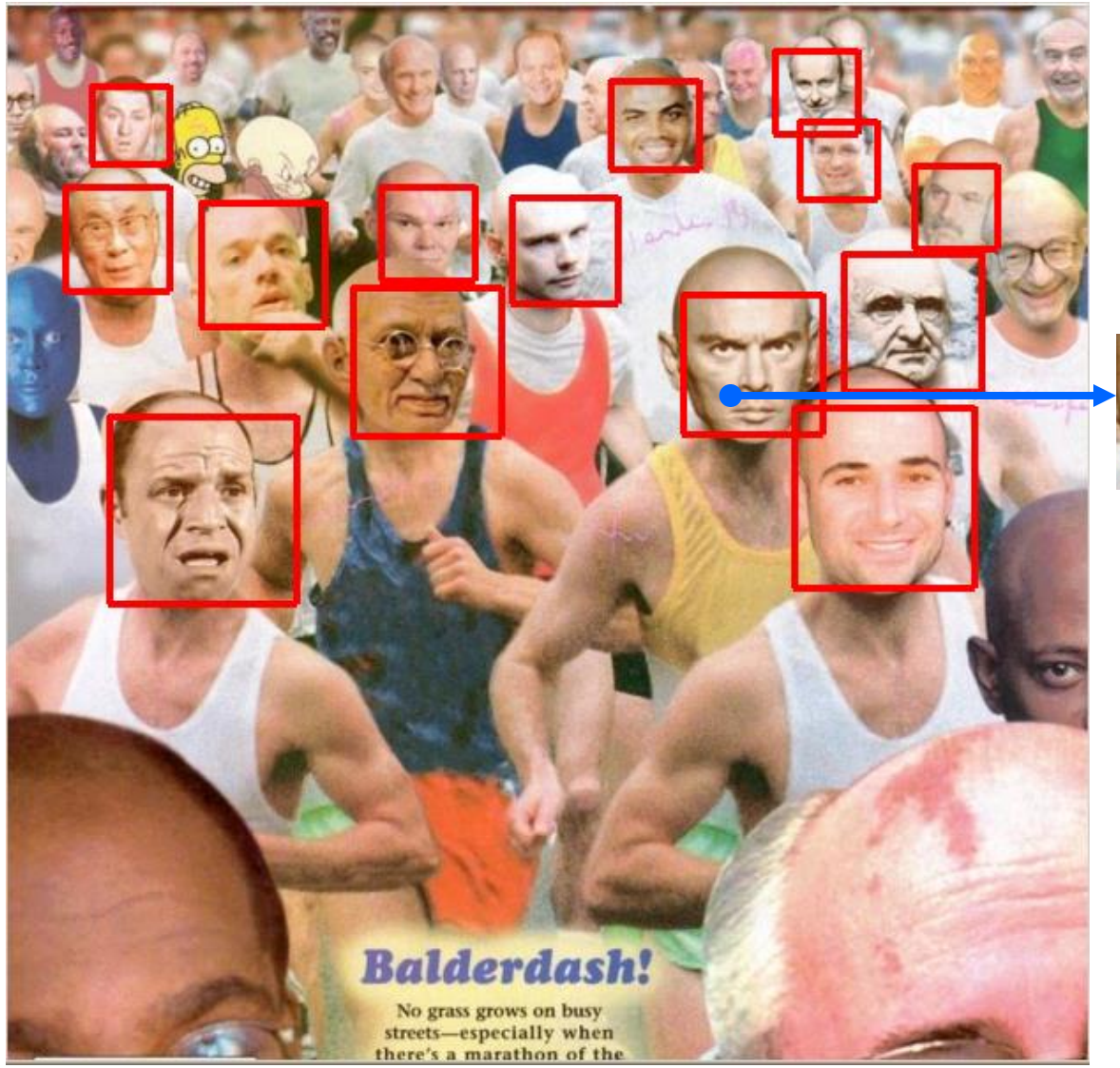
Face Search

Probe

Gallery

Search performance depends on quality of probe and gallery images

Face Recognition



?

1959

1960

1972

1973

Pose, illumination, expression, occlusion, facial covering; time gap

Time-Separated Constrained Faces

1999 (gallery)

2001 (0.99)

2007 (ID card, 0.79)

2011 (0.94)

2017 (Visa, 0.84)

2018 (ID card, 0.72)

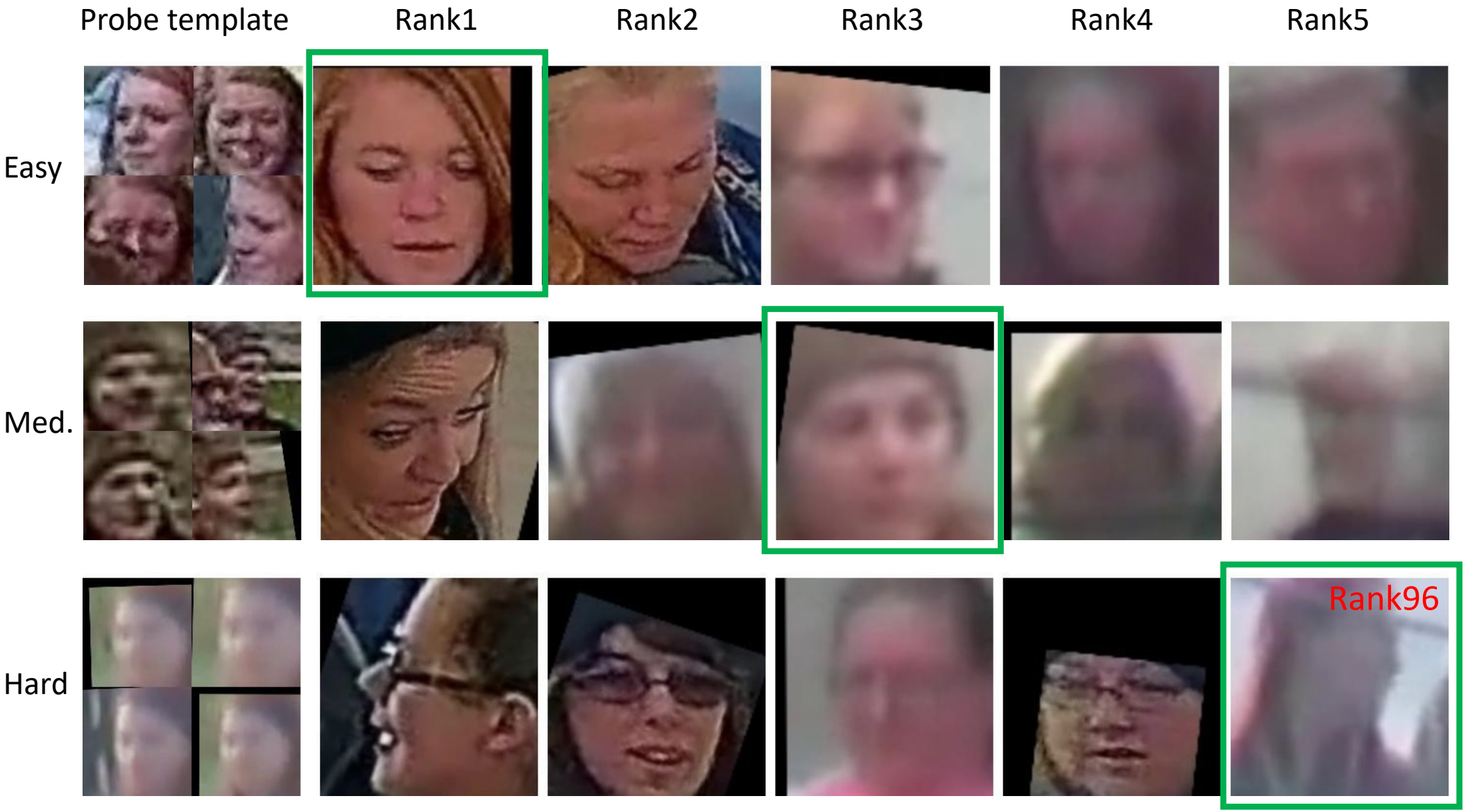
2021 (Passport, 0.75)

2022 (0.20)

Threshold @0.01% FAR = 0.345

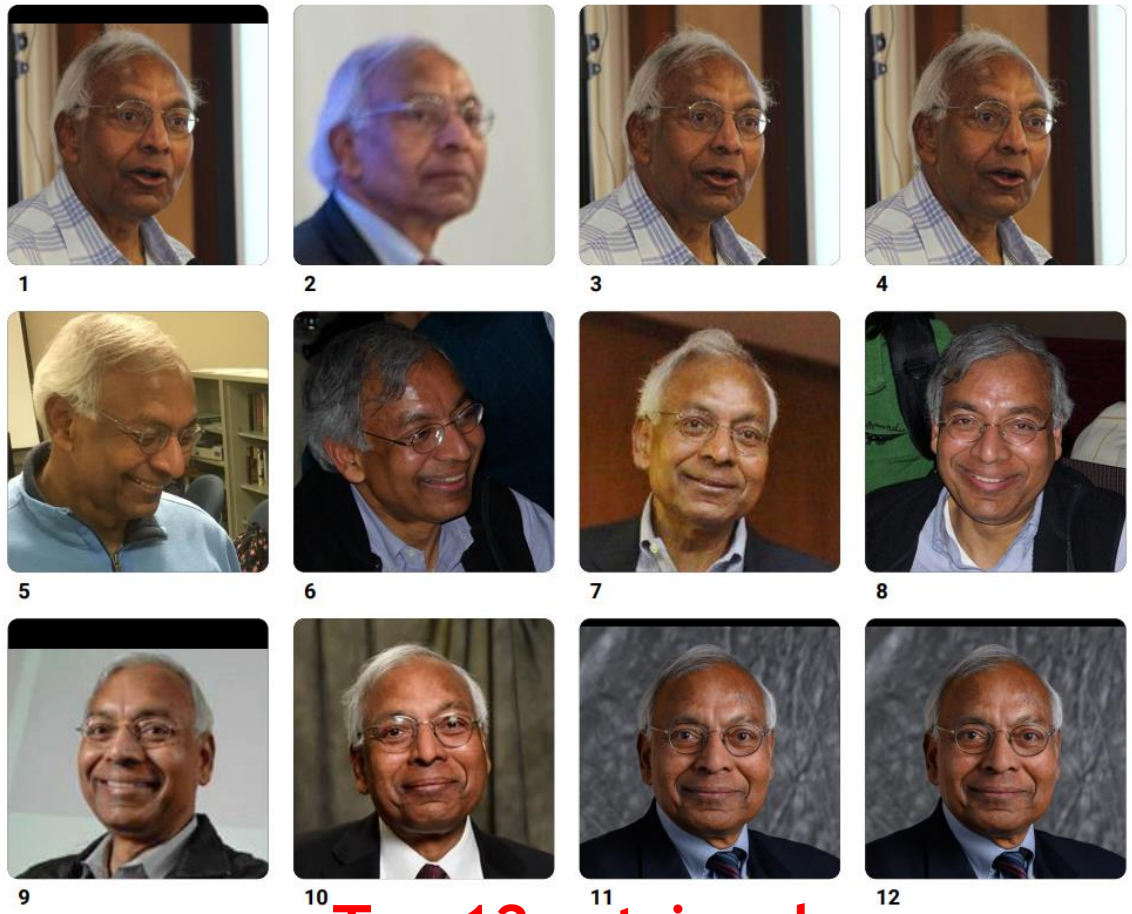
IJB-S Video2Still Protocol

IJB-S Video2Video Protocol



Clearview.AI Retrievals

Probe



Top 12 retrievals

Gallery size: 20 billion face images

Clearview.AI Retrievals

Original search image

Probe
(1970)

1

2

Image Index

1. Pioneering pattern recognition | College of Engineering. *https://www.egr.msu.edu/news/2018/12/04/pioneering-pattern-recognition* (MD5: b7cbc9670209d85fe488e155be883dc4)

2. Lynn F. Brumm Endowed Scholarship Honors Faculty Member | Giving to .... *https://givingto.msu.edu/stories/lynn-f-brumm-endowed-scholarship-honors-faculty-member* (MD5: f503dd0043d8bc2eac6ac9837214401e)

Top 2 retrievals

Gallery size: 20 billion face images

Wrongfully Accused by an Algorithm

(a)

MICHIGAN STATE POLICE

INVESTIGATIVE LEAD REPORT

LAW ENFORCEMENT SENSITIVE

THIS DOCUMENT IS NOT A POSITIVE IDENTIFICATION. IT IS AN INVESTIGATIVE LEAD ONLY AND IS NOT PROBABLE CAUSE TO ARREST. FURTHER INVESTIGATION IS NEEDED TO DEVELOP PROBABLE CAUSE TO ARREST.

BID DIA Identifier: BID-39641-19	Requester: CA Yager, Rathe
Date Searched: 03/11/2019	Requesting Agency: Detroit Police Department
Digital Image Examiner: Jennifer Coulson	Case Number: 1810050167 File Class/Crime Type: 3000

Probe Image	Investigative Lead
	

(b) Investigative Lead Report

FR system wrongfully identified (a) Robert William when the CCTV frame in (b) was searched against a 49M gallery; forensic experts did not conduct a manual examination of the candidate list

New York Times, "Wrongfully Accused by an Algorithm." https://www.nytimes.com/2020/06/24/technology/facial-recognition-arrest.html, 2020.

Summary

- Biometrics is intertwined with applications:
  - Law enforcement and forensics
  - Access control
  - Payment and benefits
  - Civil registration
  - Travel and immigration
- System requirements are application dependent
- Challenges: system integrity, data privacy (PII), unconstrained biometric capture, uncontrolled/unexpected user behavior
- Consequences of incorrect decision
- Biometric applications will continue to grow