

Fingermarks: Whodunnit?

Towards an Open-Source Matcher

Anil Jain

Kai Cao, Luan Nguyen, Tarang Chugh, Cori Tymoszek

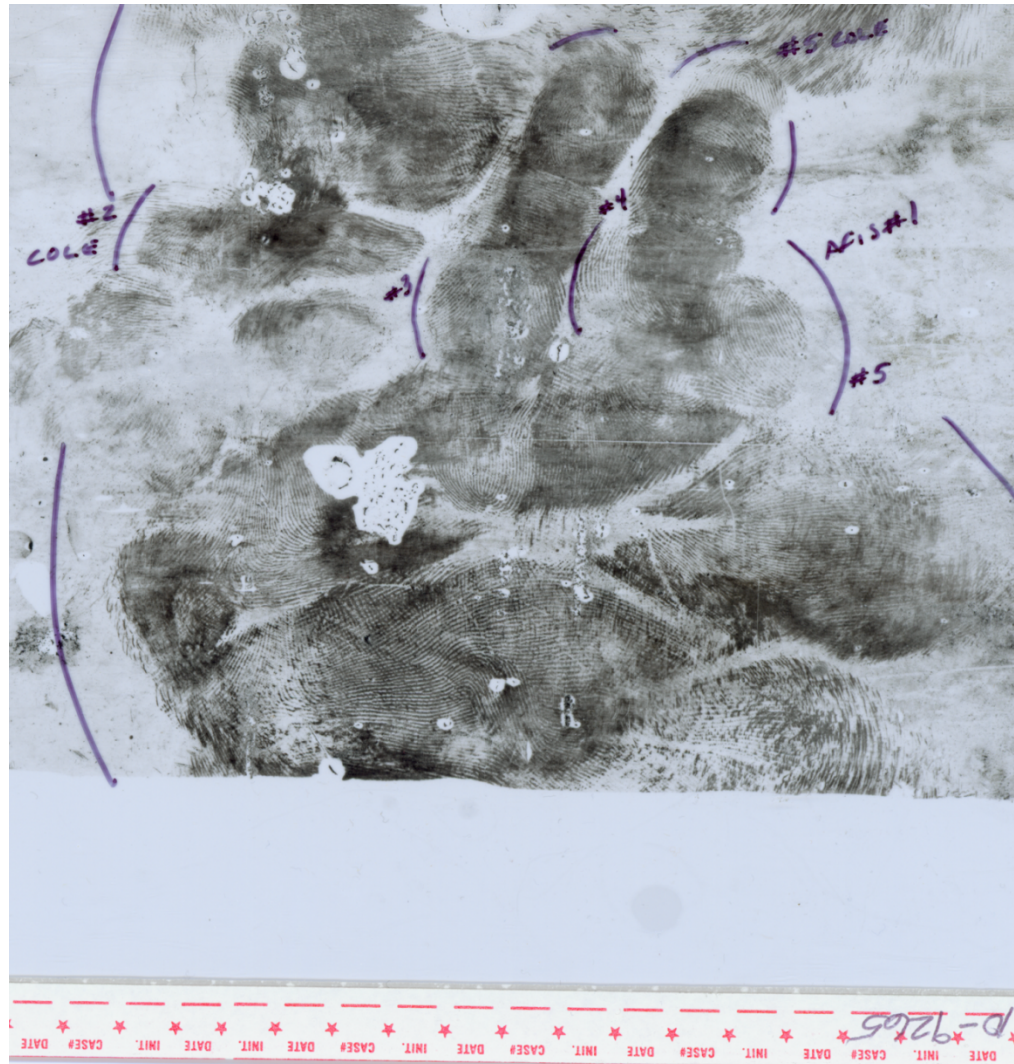
Michigan State University

February 21, 2018



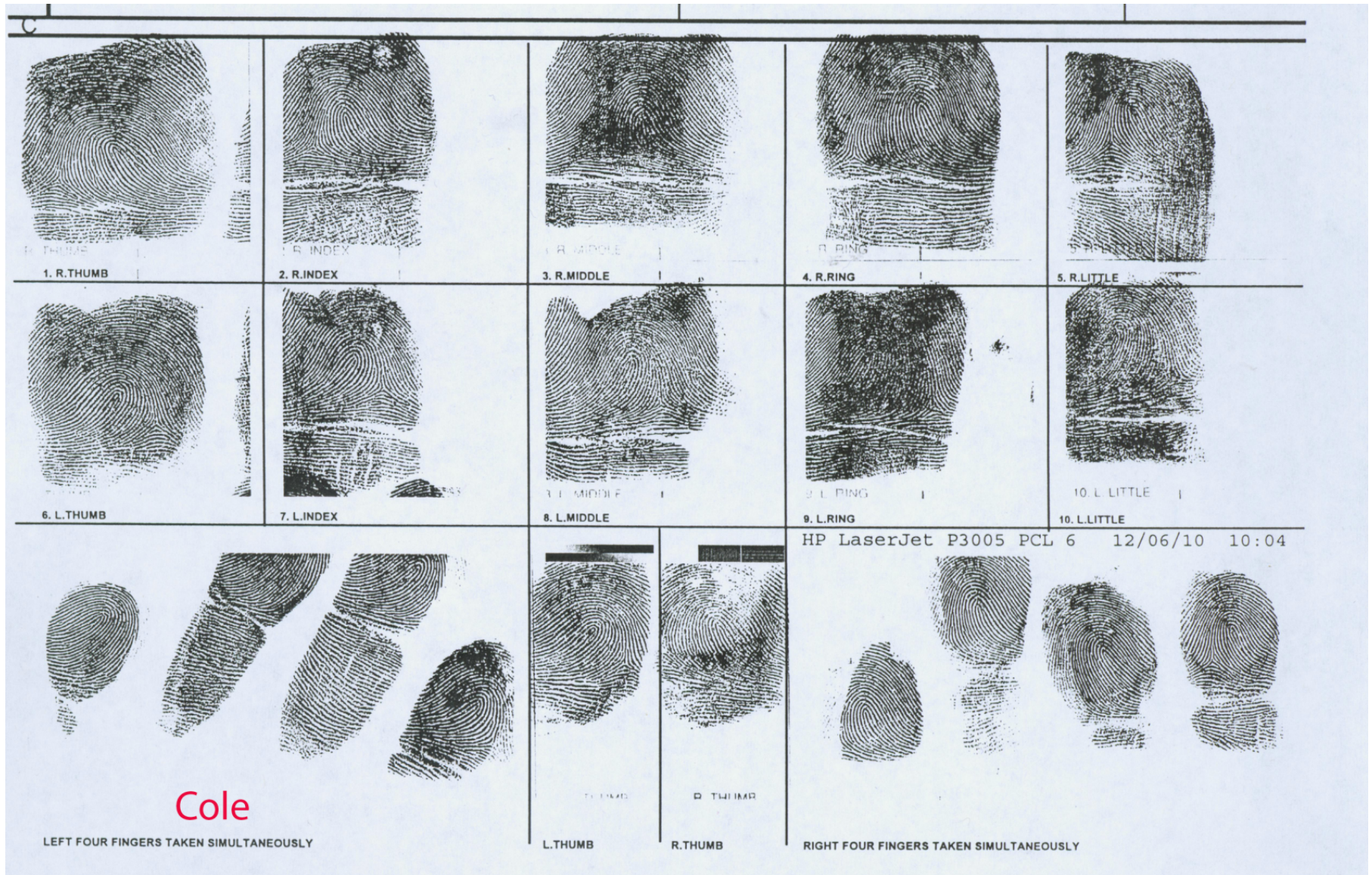
'COURSE MY FINGERPRINTS WERE EVERYWHERE
—WODGER THINK THESE ARE — SAUSAGES?

Fingermarks

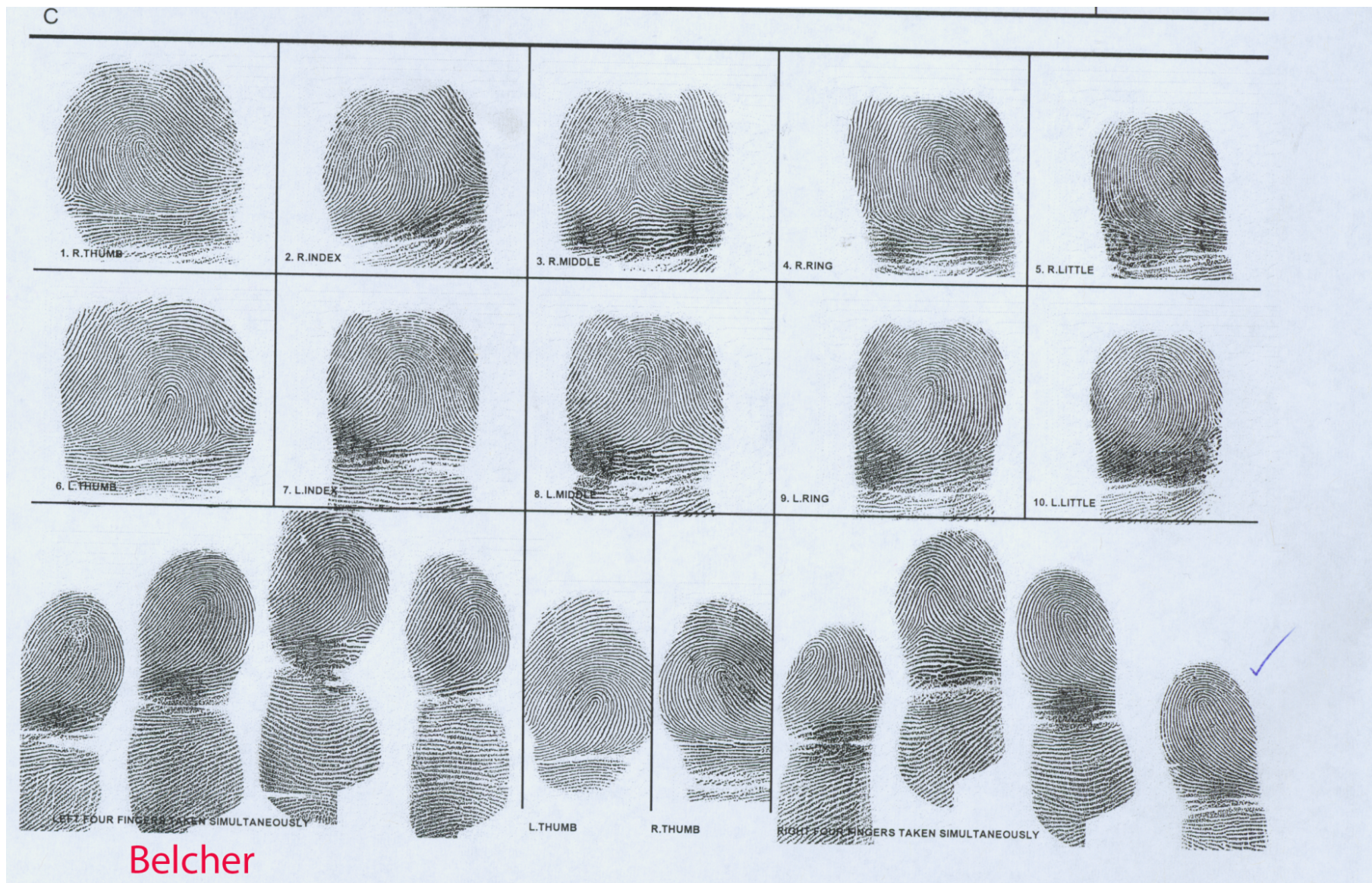


Burglary & Entry case in Pittsburgh Township, Michigan (2010). Linked to 19 other cases; Hits made with Cole (examiner) and Belcher (AFIS) tenprints on file.

Cole Tenprint Card

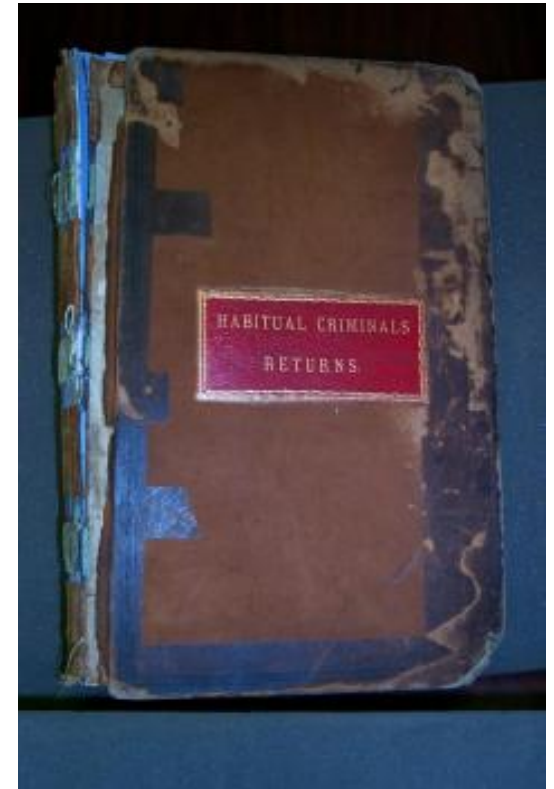


Belcher Tenprint Card



Habitual Criminal Act (1869)

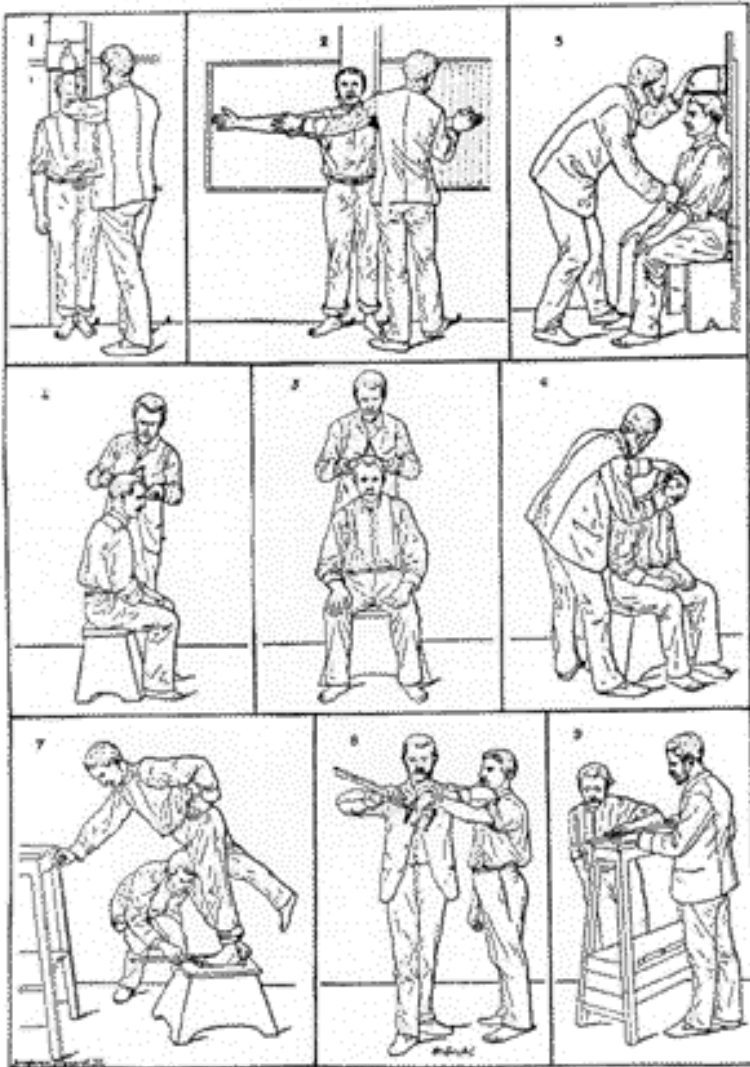
“What is wanted is a means of classifying the records of habitual criminal, such that as soon as the particulars of the personality of any prisoner (**whether description, measurements, marks, or photographs**) are received, it may be possible to ascertain readily, and with certainty, whether his case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

Bertillon System (1882)



(L. Brown)

Height	1m 79.6	Head l'gth	19.8	L. Foot	27.1	Circle	leh	Age	22	Born in	
Eng. H'ght	5-10 3/4	Head width	16.3	L. Mid. F.	11.2	Periph Z		Apparent Age			
Outs. A	1m 75.5	Cheek width	14.4	L. Lit. F.	8.7	leh-Mel		Nativity	Louisville, Ky.		
Trunk	94.9	R. Ear	6.8	L. Fore A.	46.6	Pecul		Occupation	Shoemaker		

Remarks Incident to Measurement

DESCRIPTIVE

Inclu.	Becky	Profile	Ridge	Vox	R. Ear		Beard	Shaved
Height	M	Base	(Ear)	Root			Hair	Black
Width	Br	DIMENSIONS			Teeth	Upper front	Complexion	M. Dark
Pecul		Length	Projection	Breadth		lower	Weight	165
		Pecul					Build	M. Slim

BUREAU OF IDENTIFICATION
Department of Police,
Tulane Ave. and Saratoga St.
New Orleans, La.

Measured July 1 1913
By Geo. F. Harris

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

Friction Ridge Patterns

“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.”

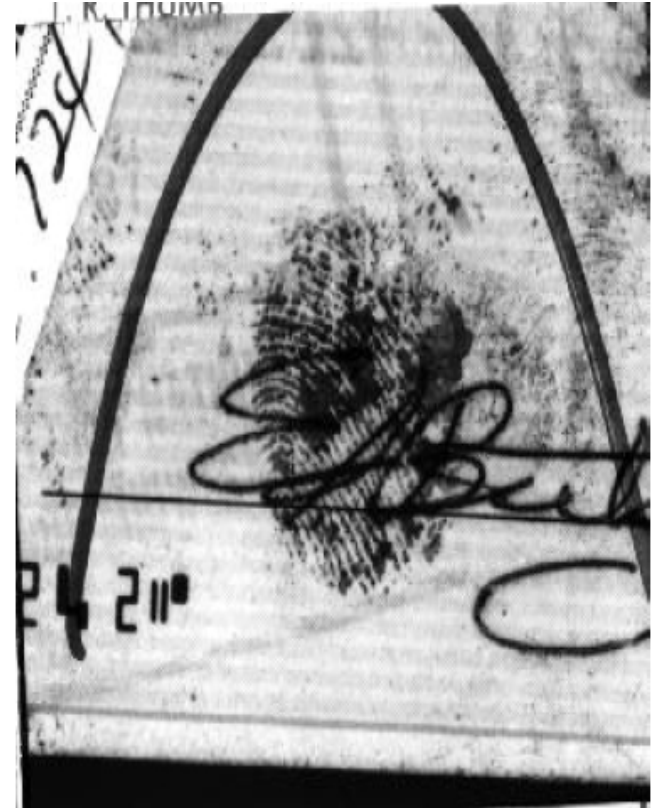
Francis Galton, Nature, June 28, 1888

Rolled, Slap and Fingermarks

APPLICANT		LEAVE BLANK <i>Leave Blank</i>		TYPE OR PRINT ALL INFORMATION IN BLACK LAST NAME FIRST NAME MIDDLE NAME <i>Teacher, Theresa C.</i>		FBI LEAVE BLANK <i>Leave Blank</i>	
SIGNATURE OF PERSON FINGERPRINTED		ALIASES AKA <i>Formerly: Theresa Smith</i>		O R I NY921940Z NYSTED Dept-FPU ALBANY, NY		DATE OF BIRTH DOB <i>12/31/70</i>	
RESIDENCE OF PERSON FINGERPRINTED <i>318 School Street Hometown, NY 11111</i>		CITIZENSHIP <i>US</i>		SEX RACE HT WT EYES HAIR <i>F W 5'7" 155 Gr Bro</i>		PLACE OF BIRTH POB <i>Ohio</i>	
DATE <i>5/02/02</i>		SIGNATURE OF OFFICIAL TAKING FINGERPRINTS <i>Leave Blank</i>		LEAVE BLANK			
EMPLOYER AND ADDRESS (if applicable) <i>Smart Falls Central School Dist Smart Falls, NY 11111</i>		BIRTHDAY <i>Leave Blank</i>		CLASS <i>Leave Blank</i>			
REASON FINGERPRINTED <i>Leave Blank</i>		ARMED FORCES NO <i>Leave Blank</i>		REF <i>Leave Blank</i>			
		SOCIAL SECURITY NO <i>000-10-1111</i>					
		MARCELLANEOUS NO <i>Leave Blank</i>					

 1. R. THUMB	 2. R. INDEX	 3. R. MIDDLE	 4. R. RING	 5. R. LITTLE
 6. L. THUMB	 7. L. INDEX	 8. L. MIDDLE	 9. L. RING	 10. L. LITTLE
 LEFT FOUR FINGERS TAKEN SIMULTANEOUSLY		 RIGHT FOUR FINGERS TAKEN SIMULTANEOUSLY		

IDENTIX TP600 1259
ADS004228-LEX004229



TP-to-TP Search: De-duplication

Left Hand

Thumbs

Right Hand

Query



Reference
database

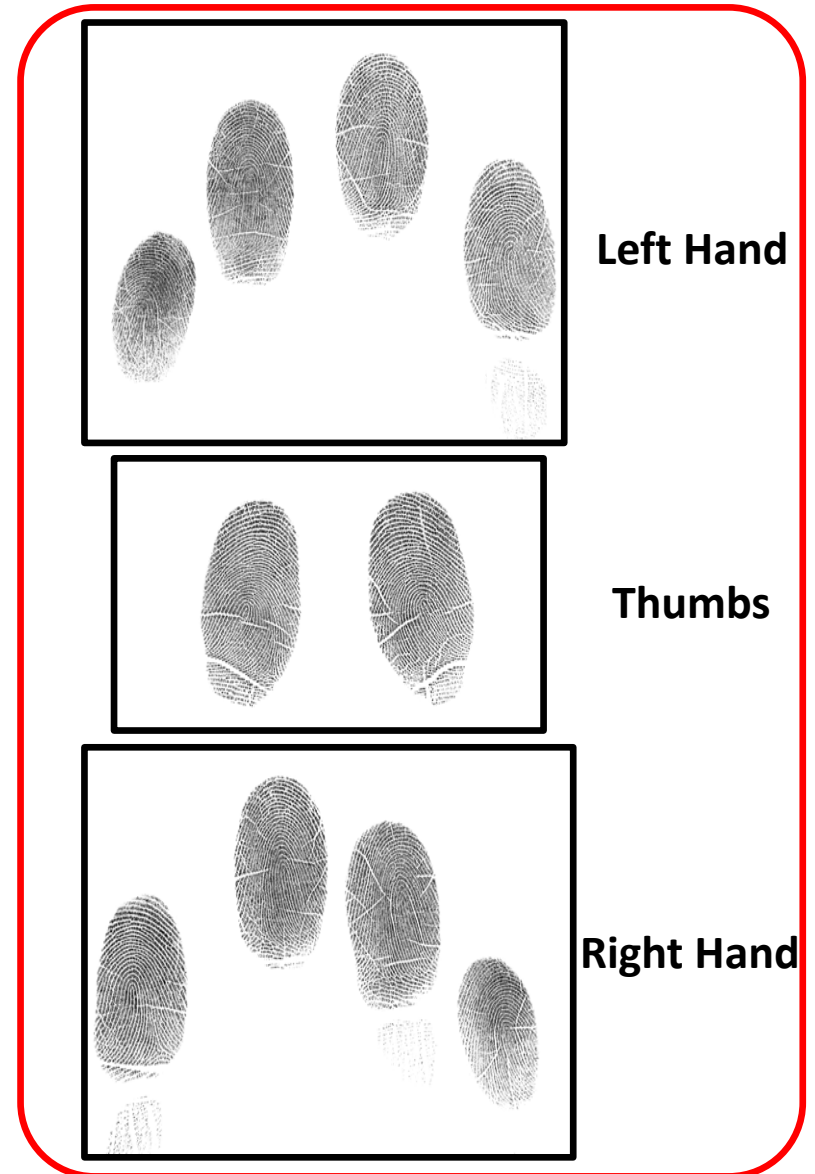


FBI has over 100M tenprints (rolled and slap) and Aadhaar has over 1B slap tenprints

Latent-to-TP Search: Whodunnit?



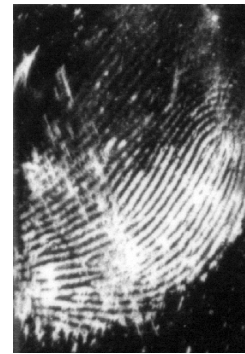
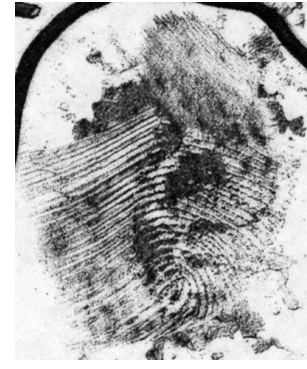
FBI conducted ~20K latent searches in Jan. 2017 alone



TP-to-Latent Search: Cold Cases



New suspect booking

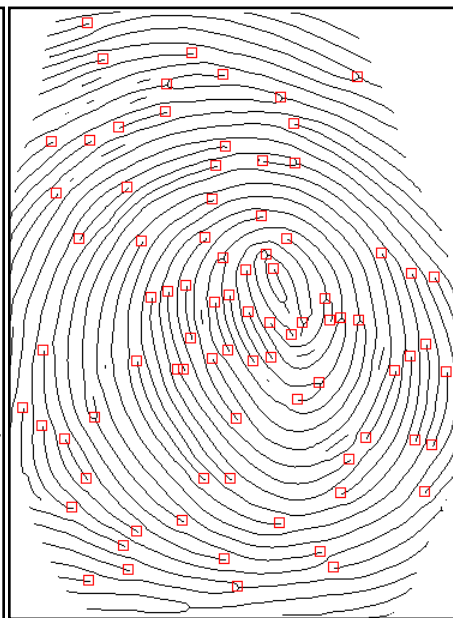
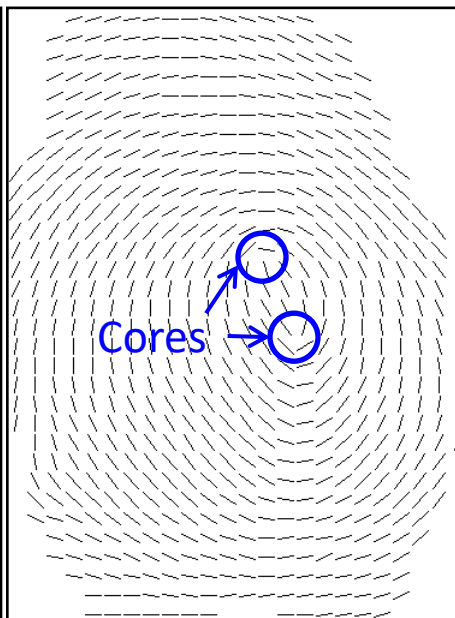


Latents from cold cases

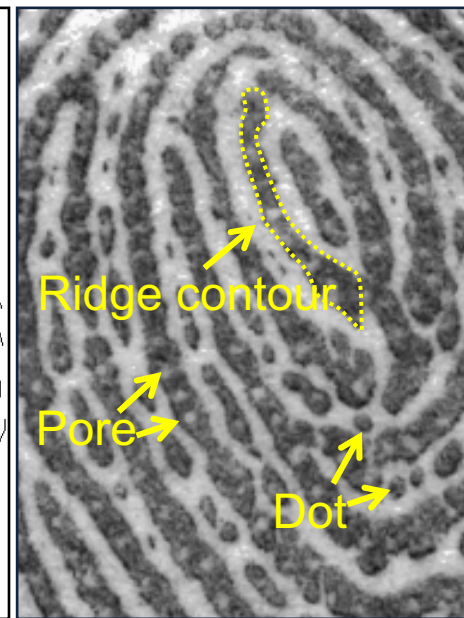
Fingerprint Features



Level 1
Global ridge flow



Level 2
Local ridge property



Level 3
Fine ridge details

Fingerprint Recognition: 1960s



Courtesy: James Blanchard, Michigan State Police

Michigan AFIS: 1989



1989 statistics: 725K TP database; 4.8K TP-to-TP searches; no latent-to-TP search; 15K comparisons/sec. (Courtesy, Scott Blanchard, MSP)

Michigan AFIS: 2017



**2017 Statistics: 4M TP database; 650K TP-to-TP 5.6K latent-to-TP transactions
Avg. search time for TP search: 5.3 sec; avg time for latent search: 42.9 sec.**

Anil K. Jain, ICB 2018

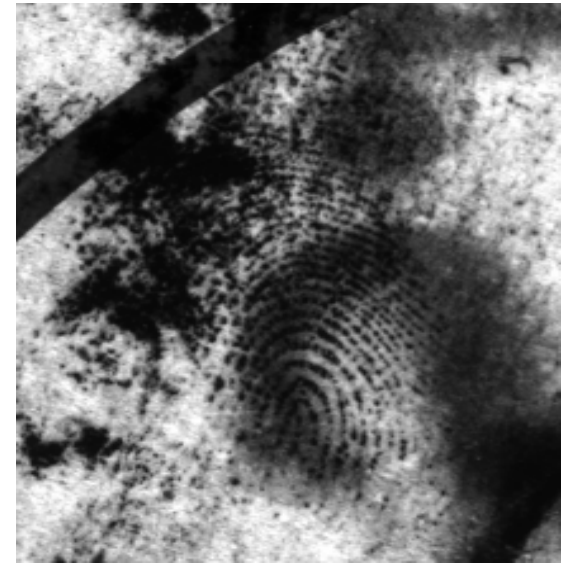
AFIS Performance



Rolled



Plain



Latent

- Lights-out rank-1 hit rate
 - Plain: 99.3%
 - **Latent: 67.2% (70.2% with image + markup)**

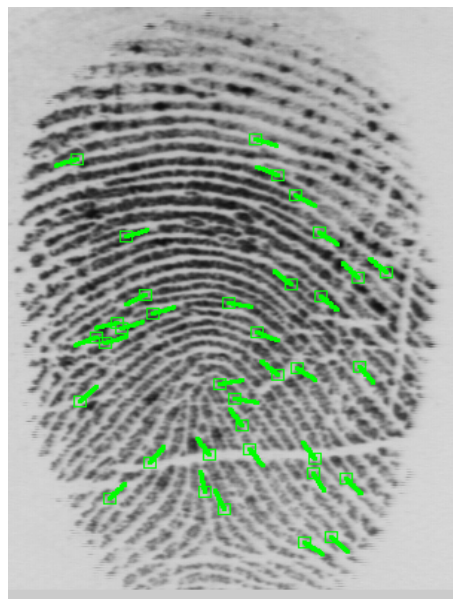
[1] C. Watson, G. Fiumara, E. Tabassi, S. L. Cheng, P. Flanagan, W. Salamon. Fingerprint Vendor Technology Evaluation, NISTIR, 8034, 2012.

[2] M. Indovina, V. Dvornychenko, R. Hicklin, and G. Kiebusinski. ELFT-EFS Evaluation of Latent Fingerprint Technologies: Extended Feature Sets [Evaluation# 2], NISTIR, 7859, 2012.

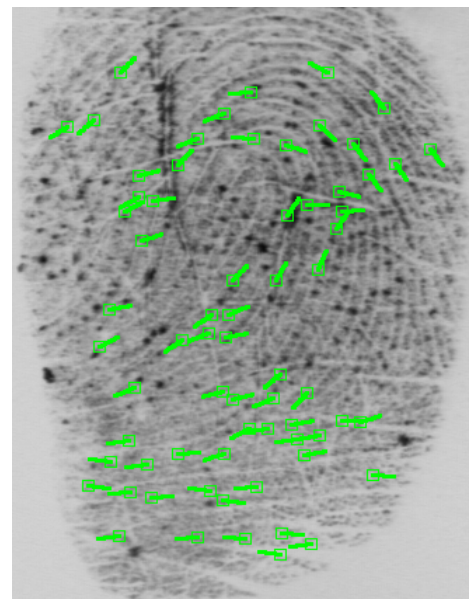
Source of Error: Image Quality



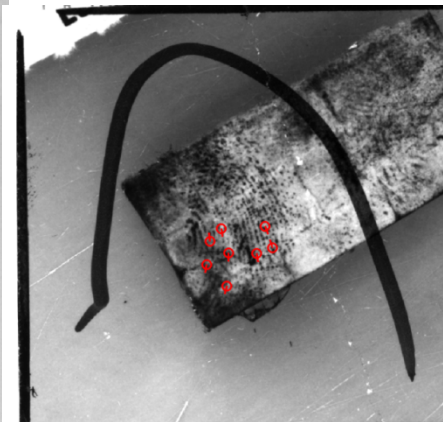
No. of false minutiae = 0



No. of false minutiae = 7



No. of false minutiae = 27

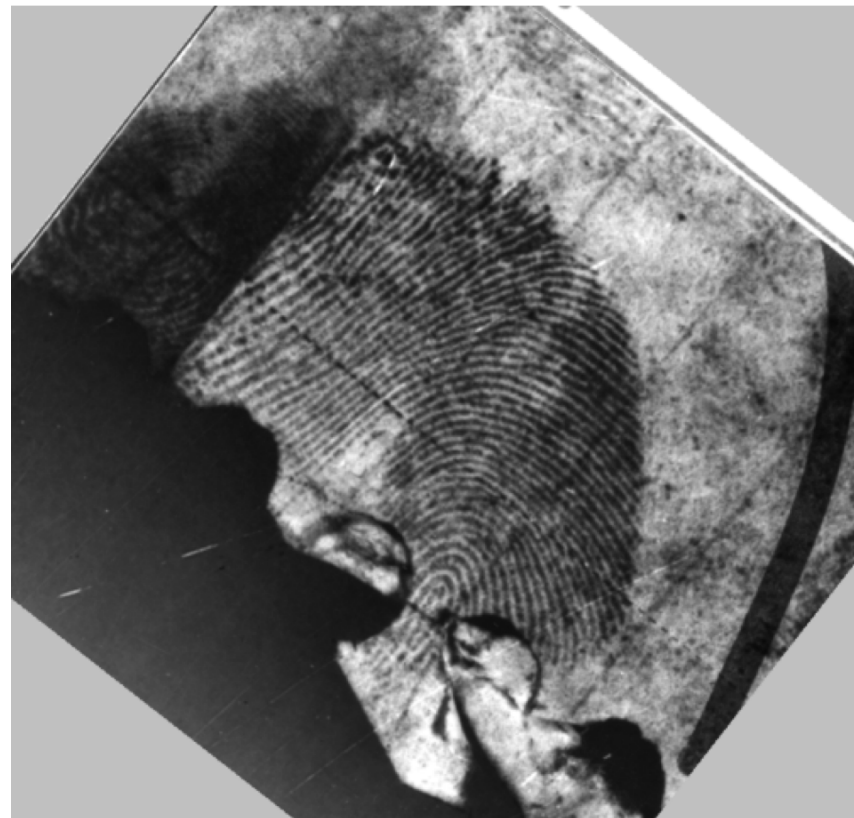


Very few minutiae

Challenges With Latents



Background noise



Distorted ridge structure

Who Left the Mark?



The most common forensic evidence

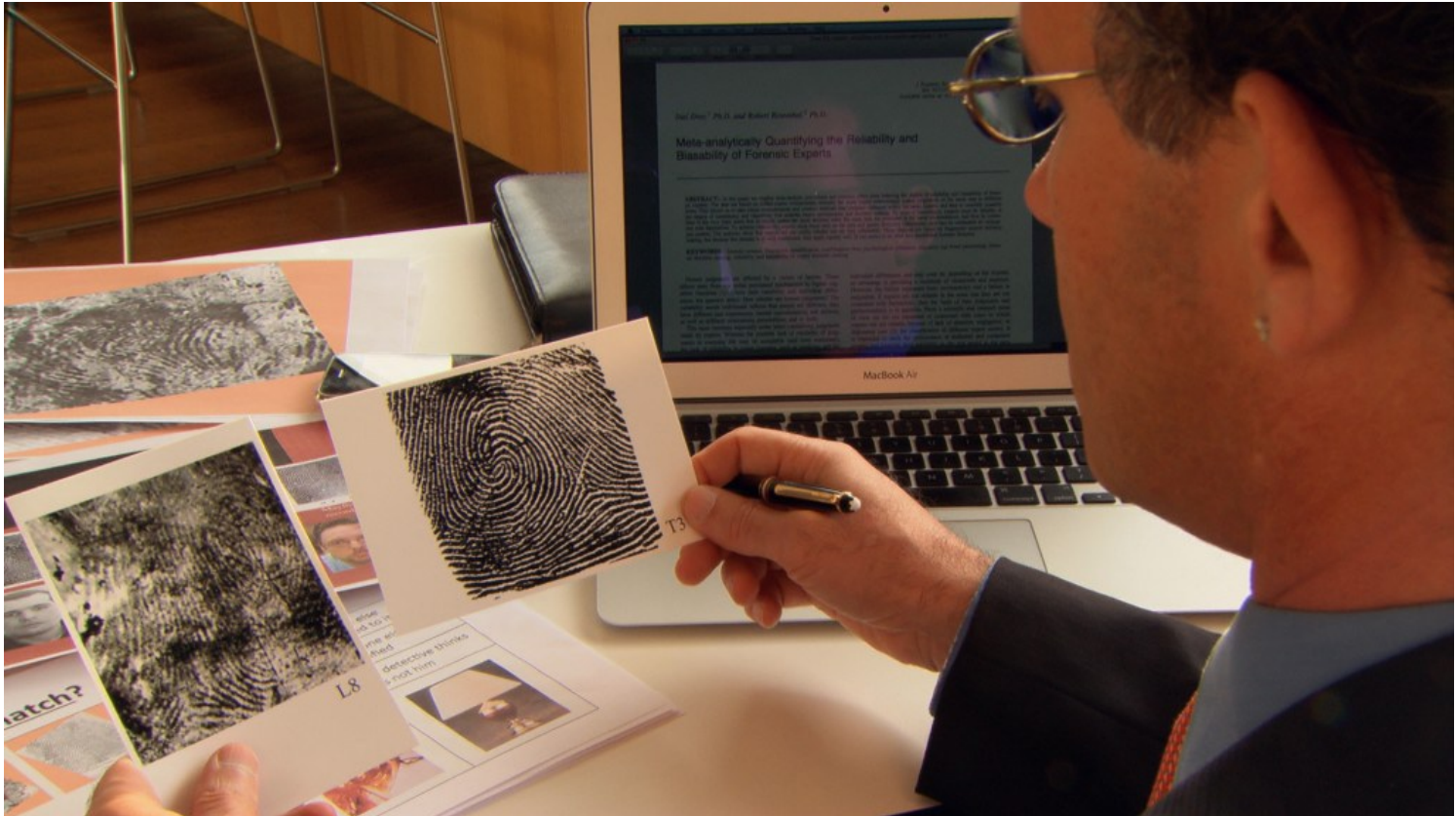
Fingerprint Evidence: An Expert's Confidence

At the trial of Dennis Gunn, charged with murder and robbery, Inspector Fowler said he was in charge of the fingerprint bureau of the New South Wales police for 17 years, and was for some time in the same work at Scotland Yard. His own bureau had 70,000 sets of prints (10 fingers each). Scotland Yard had about 250,000 sets. In all his experience he had never seen two sets of prints alike, unless made by the same person. From the fingerprints submitted to him in the present case he picked a half-print of one finger out of 1010 prints recorded on 101 different forms made by 101 different people. The forms were not marked in any way. Inspector Fowler said: "I am more convinced that Gunn handled the revolver and cashbox than if I had actual sight of him handling them."

How Well do Examiners Perform?



Cognitive Bias

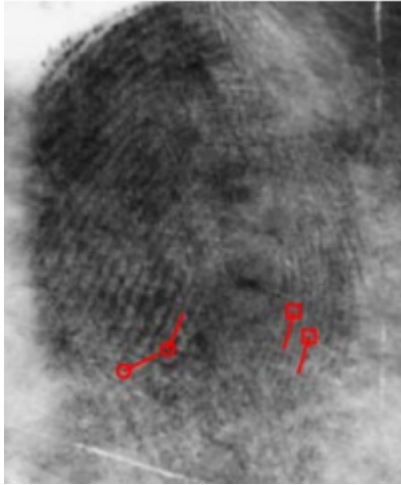


*Itiel Dror's argument is that experts can be swayed by “**cognitive bias**”: what they knew (or thought they knew) about the case in front of them*

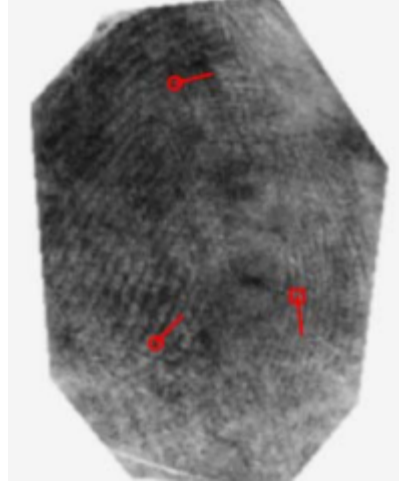
<https://www.pbs.org/wgbh/frontline/article/can-unconscious-bias-undermine-fingerprint-analysis/>

Anil K. Jain, ICB 2018

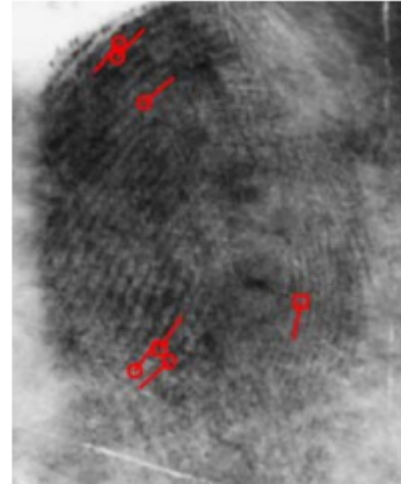
Inter-examiner Variations



Markup 1
(Rank 80)



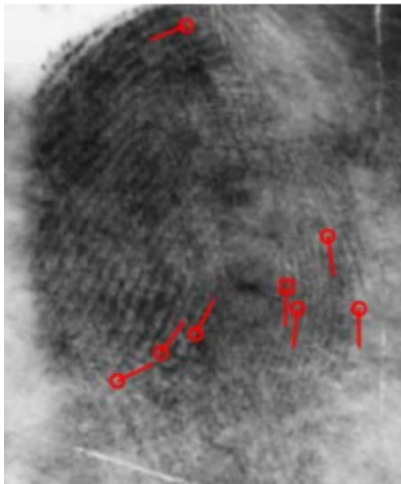
Markup 2
(Failed to match)



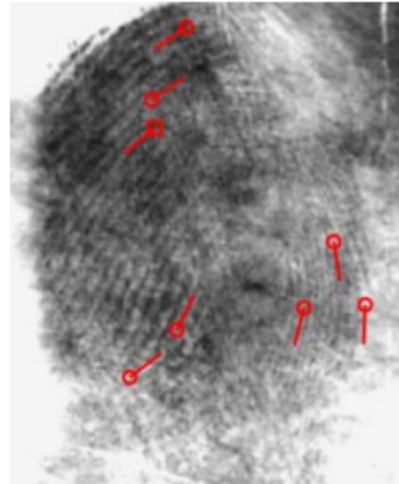
Markup 3
(Rank 45)



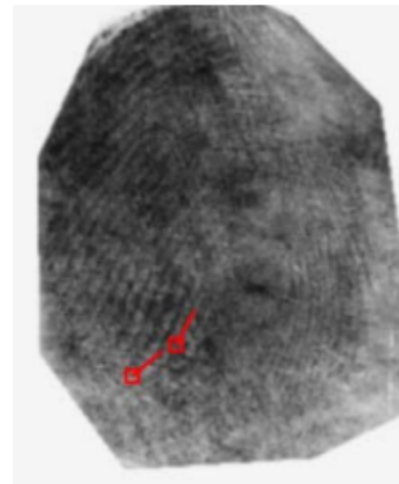
True mate
Rank with fusion: 2



Markup 4
(Rank 7)

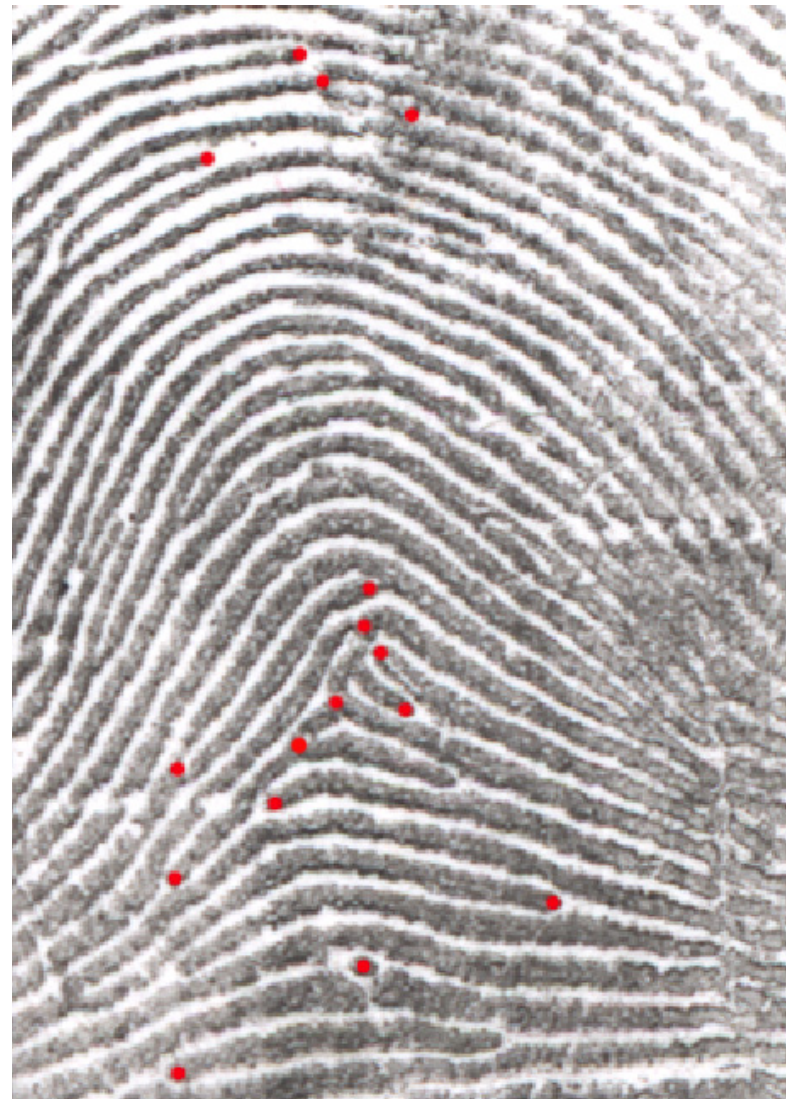
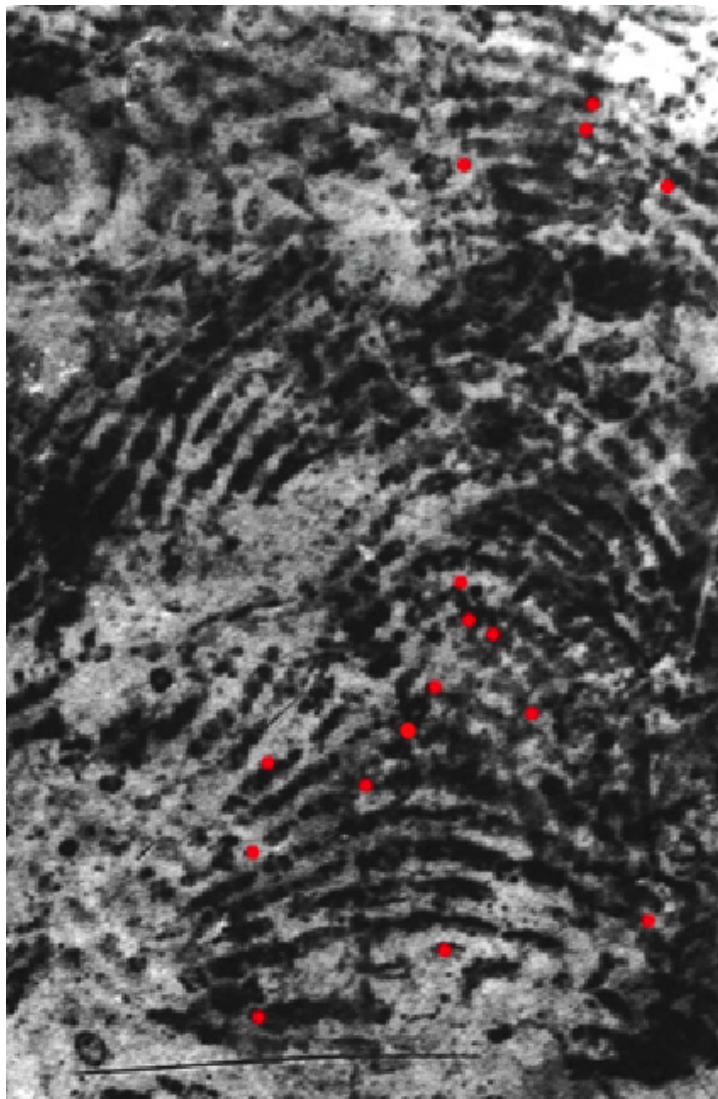


Markup 5
(Rank 57)



Markup 6
(Rank 12,971)

Wrongful Conviction

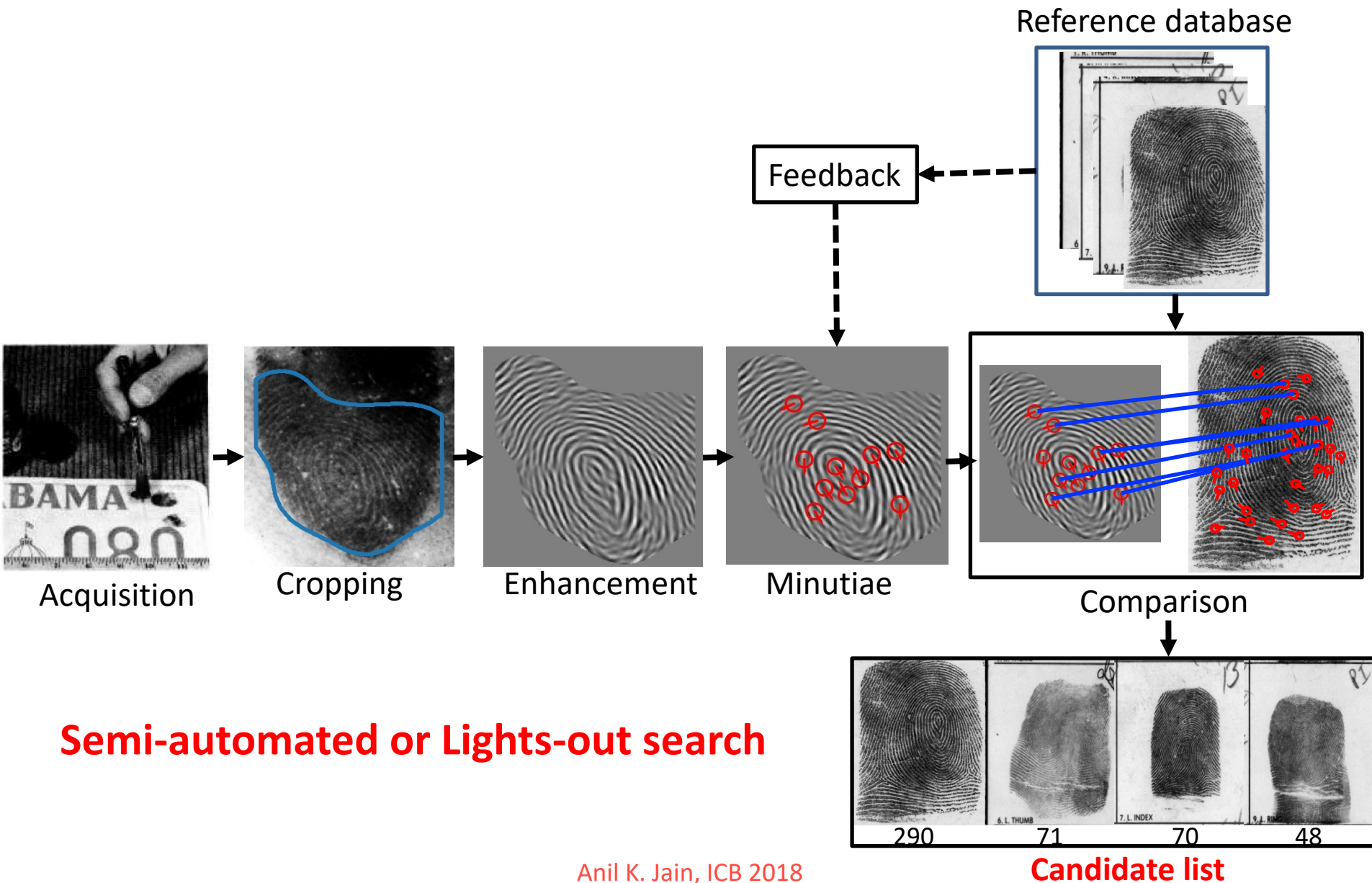


Brendan Mayfield was wrongly incarcerated of the Madrid train bombing (2004)

DNA Exonerations in the United States

- **1989:** The first DNA exoneration took place
- **20 of 354** people exonerated were on death row
- **39 of 354:** Pled guilty to crimes they did not commit
- **70%:** Involved eyewitness misidentification
- **41%** were a cross-racial misidentification
- **184: DNA exonerations by the Innocence Project**

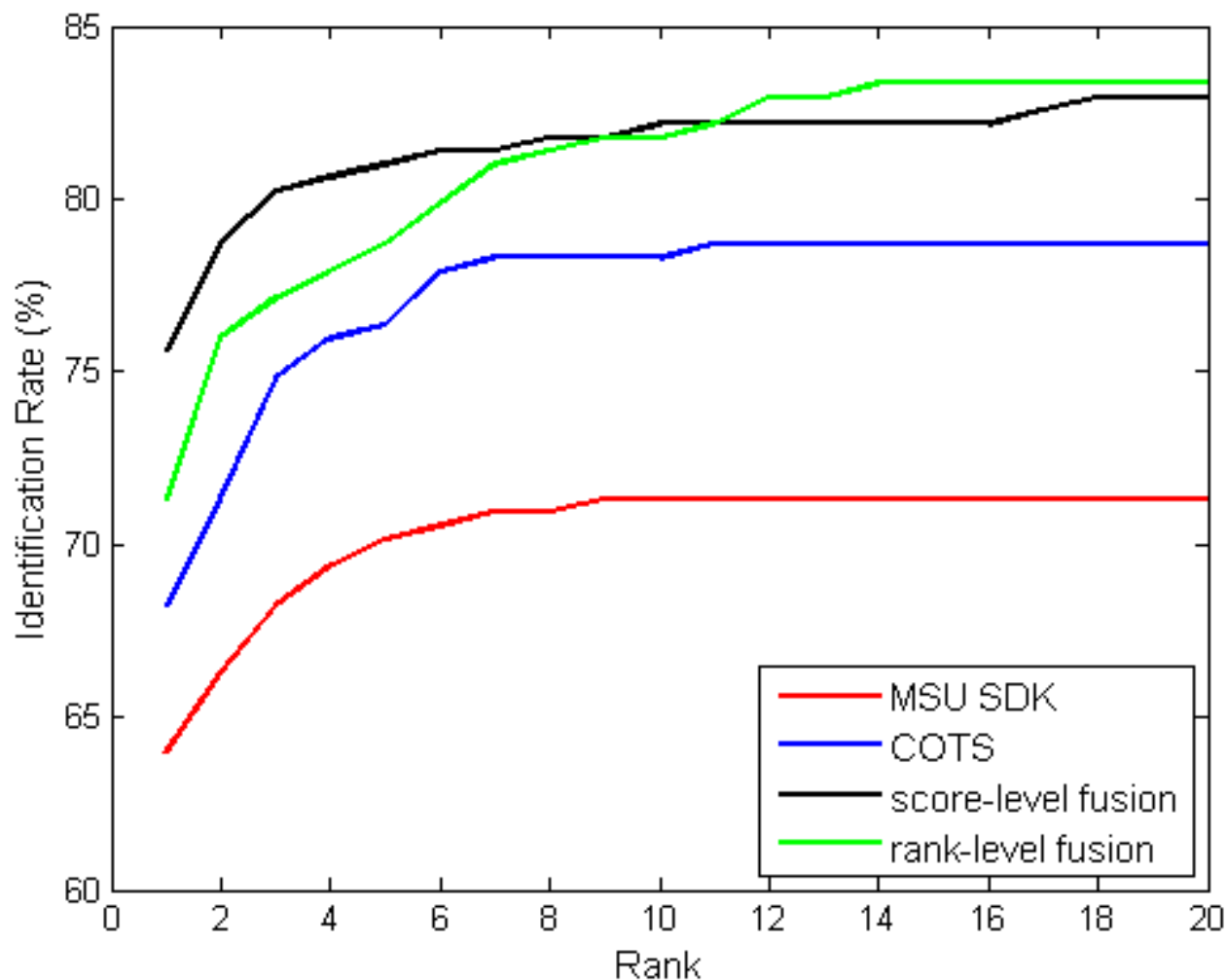
Automated Latent AFIS



MSU Latent AFIS



Recognition Performance



258 latents (NIST SD27) against 100K rolled prints

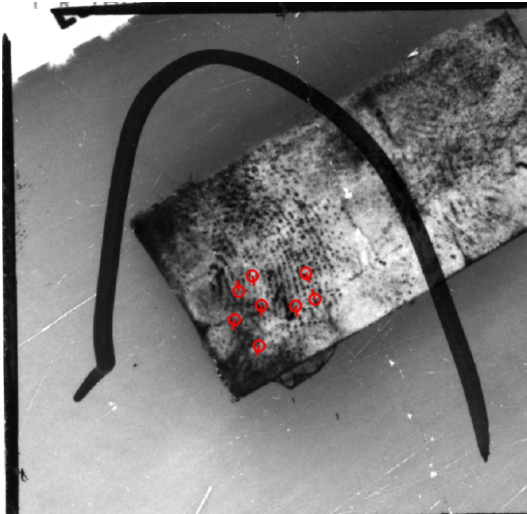
Kai and Jain, "Automated latent fingerprint identification", IEEE Trans. PAMI, 2018

Anil K. Jain, ICB 2018

What's Next?

- Improve search accuracy
- Lights-out capability
- Speedup
 - On an E5-2680@2.5GHz + (with 128GB RAM & 24 threads), comparing 1 latent against 100K rolled prints takes about 7 minutes
- Provide “true” similarity score at the output for probabilistic analysis

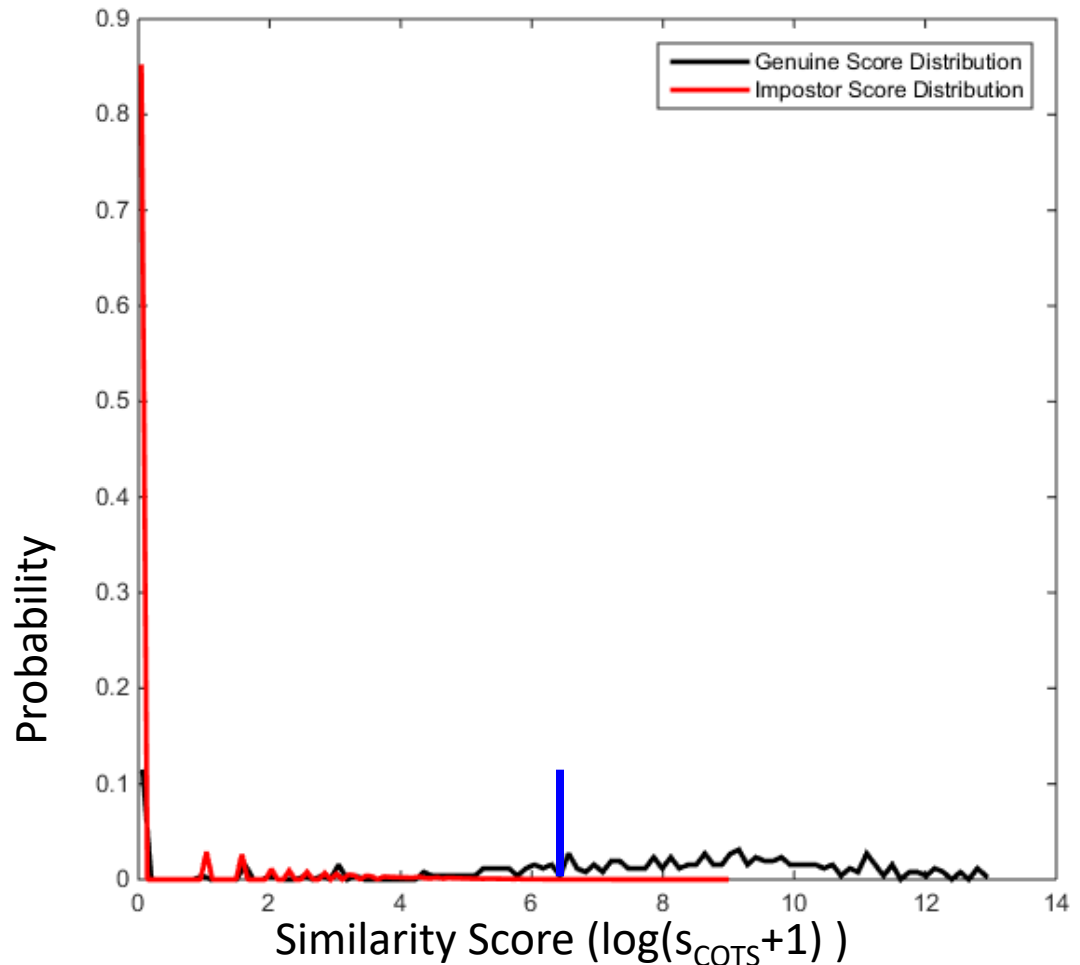
Confidence in Latent Comparison



latent (8 minutiae)



Rolled mate



Score = 6.54; retrieval rank = 1; score range: [0, 13.29]

Summary

- Fingermarks are the most frequently used forensic evidence
- Recognition accuracy for slap, rolled and touch fingerprints has improved to a level for large-scale deployments
- Fingerprint recognition needs to be improved
- We hope an open-source SDK would generate more interest from biometrics community