Forensic Pattern Recognition: Challenges and Opportunities

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MULTIFORESEE 2021

MULTI-modal Imaging of FOREnsic Science Evidence tools for Forensic Science Conference

Locard's Exchange Principle

Edmond Locard (1877–1966), a pioneer in forensic science, stated that *the perpetrator of a crime will bring something into the crime scene and leave with something from it*, *and that both can be used as forensic evidence.*

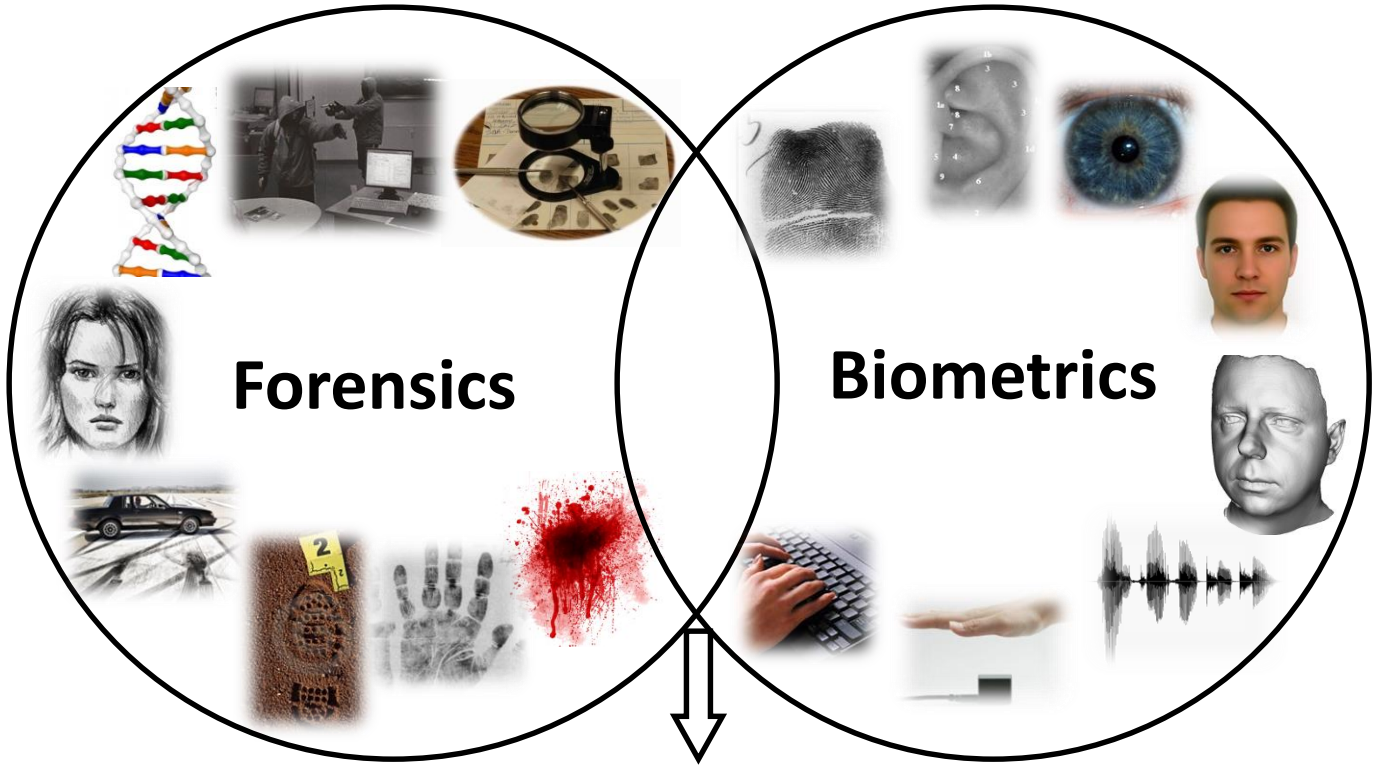
http://en.wikipedia.org/wiki/Locard%27s_exchange_principle

Forensic Evidence

"….. Not only his fingerprints or his footprints, but his hair, the fibers from his clothes, the glass he breaks, the tool mark he leaves, the paint he scratches, the blood or semen he deposits or collects. All of these and more, bear mute witness against him. This is evidence that does not forget. …..Only human failure to find it, study and understand it, can diminish its value."

Paul Kirk, Crime investigation: physical evidence and the police laboratory. Interscience Publishers, 1953

Biometrics Vs. Forensics



- Latent fingerprint
- Latent palmprint
- Fibers
- Explosive residue
- Paint chips
- DNA
- Tire marks
- Shoe prints
- Bite marks
- SMT

- 2D Face
- 3D Face
- Fingerprint
- Iris
- Speech
- Signature
- Gait
- Ear
- Palmprint
- Keystroke

- **Improve matching accuracy**
- **Automated matching methods**
- **Minimize human bias and sources of human error**
- **Validate basis for evidence**

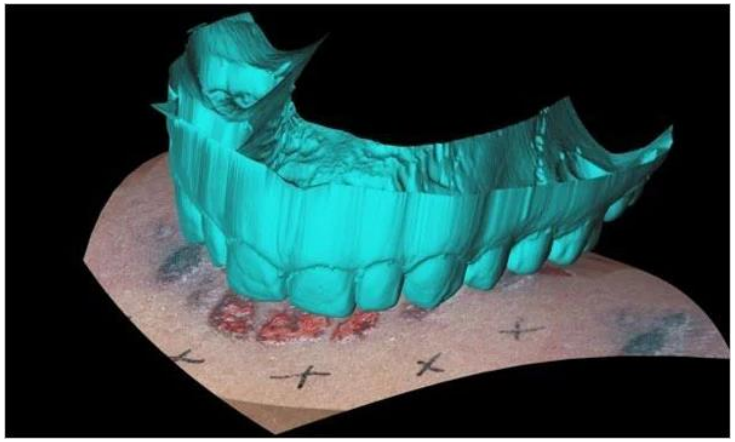
Forensics: Use of "trace evidence" from crime scenes to identify specific objects/persons

Biometrics: Identification of a living person by their body traits in "real time"

Jain and Ross, "Bridging the Gap: From Biometrics to Forensics", Philosophical Trans. The Royal Society B, August 2015

Experts Deride Bite Marks as Unreliable in Court (USA Today, June 16, 2013)

Forensic odontologist, Dr. Richard Souviron, testified at Theodore Bundy's murder trial that his unusual, mangled teeth were a match.



IMPRINTED A bite left on a victim helped Swiss prosecutors gain a conviction in 2003.Credit...National Library of Medicine

- At least 24 convicted or charged men have been exonerated since 2000 due to bite-mark evidence
- There is no definitive proof that teeth can be matched to a bite into human skin

Outline

- Tattoo-ID
- Composite to photo matching
- Latent fingerprint matching
- Altered fingerprint detection

Tattoos

- **2015 Harris Poll:** About 30% of Americans have at least one tattoo; among those with any tattoos, 70% have two or more.
- **Why do people get tattoos?** attention, self-expression, rebellion, visual display of a personal narrative, identification with a group.
- **Tattoos provide clue for victim and suspect identification**

(a)

(b)

(c)

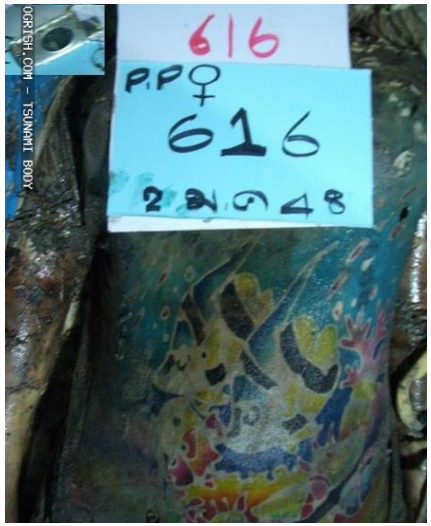
(d)

(a) Tattoo on the "Iceman", a 5200-year-old frozen mummy, (b) 18th street gang tattoo, (c) religious tattoo, (d) tattoo related to 9/11 terrorist attack

https://theharrispoll.com/tattoos-can-take-any-number-of-forms-from-animals-to-quotes-to-cryptic-symbols-and-appear-in-all-sorts-of-spots-on-our-bodies-some-visible-in-everyday-life-others-not-so-much-but-one-thi/

Victim Identification

- Tattoo may be the only clue to identify victims



(a)

(b)

(c)

(d)

Tattoo on (a) Asian tsunami (2004) victim, (b) victim of 9/11 terrorist attack, (c) body of an unidentified murdered woman, and (d) body part found in a Florida state park

Suspect Identification

(a)

(b)

(c)

(d)

Gang tattoos of (a) Latin kings and (b) Family stones; (c) teardrop criminal tattoo (person has killed someone or had a friend killed in prison); (d) spider within a web tattoo (drug addict or a thief)

Facial Tattoo Caught in CCTV 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/

Looking for shirtless, heavily-tattooed suspect

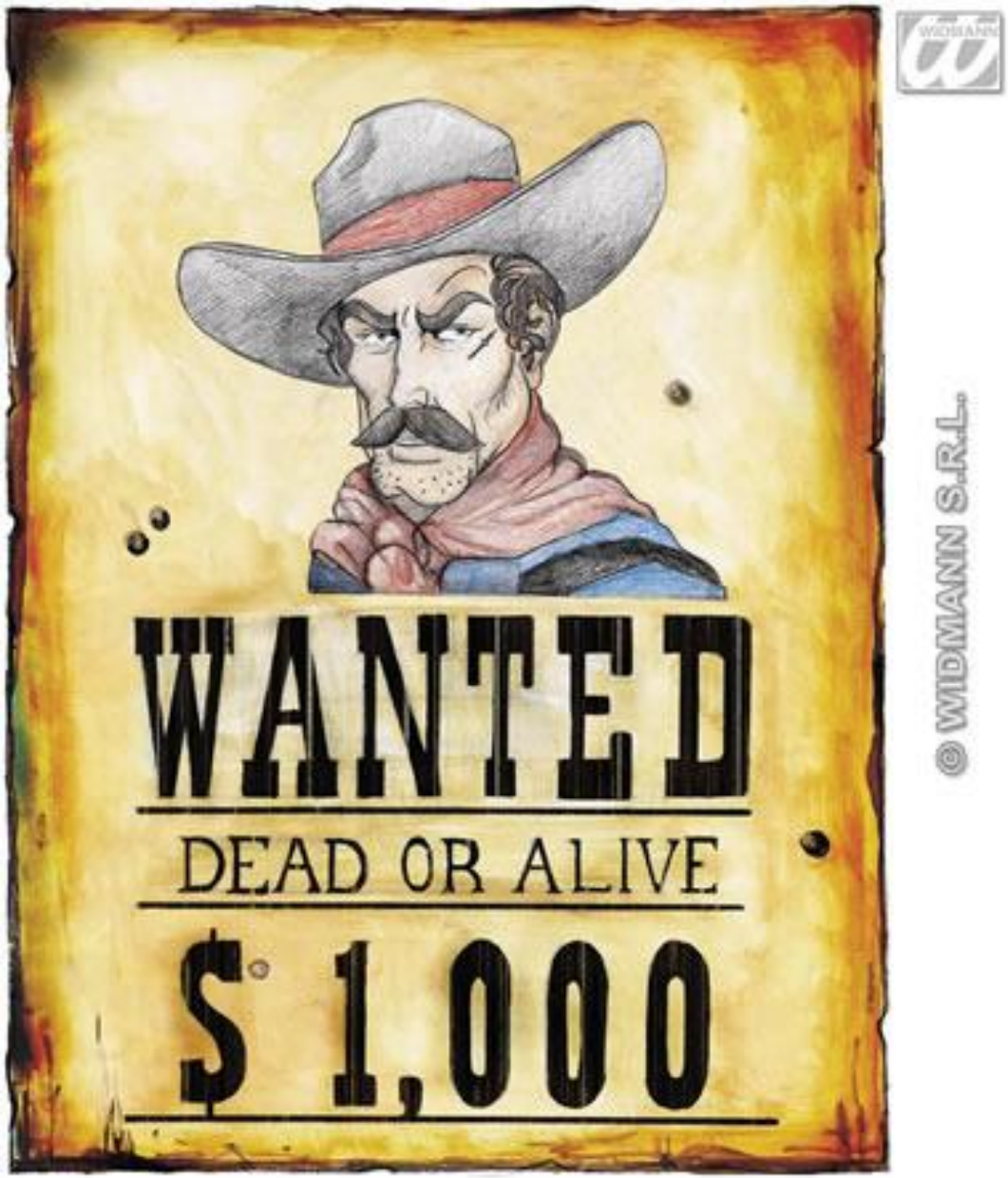
"Investigators are looking for the man who broke into a car dealership and damaged several vehicles… They noted the suspect has numerous tattoos on his forearms. One tattoo, on his right elbow, is of the North Star."*

* ***CBS 6 News***. PICTURES: Investigators seek shirtless, heavily-tattooed suspect, May 4, 2012 (http://wtvr.com/2012/05/04/pictures-investigators-seek-shirtless-heavily-tattooed-suspect/)

Licensed to Morpho

Lee, Tong, Jin and Jain, "Image Retrieval in Forensics: Tattoo Image Database Application", IEEE Multimedia, 2012.

Matching Composites to Face Images

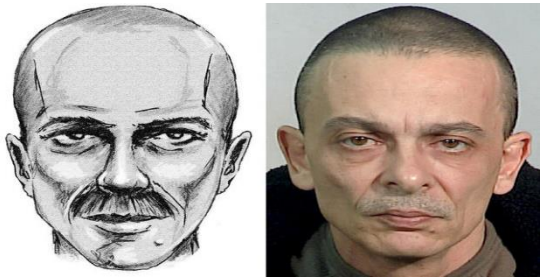


Fighting Crime With Pencil and Paper

Juan Perez, Detective and Artist with NYPD, creates sketches based on victims' descriptions

Pleaded Guilty: After the release of a sketch in the sexual abuse case of a 9-year-old girl in the East Village in April, the police arrested Rene Otero.

Charged With Murder: A sketch of a suspect was released after a man was shoved in front of a subway train. Erika Menendez was arrested a day later.



Now in Prison: In the case of Steven Pappas, a sketch led to his identification. He is serving time for kidnapping and sexual assault.

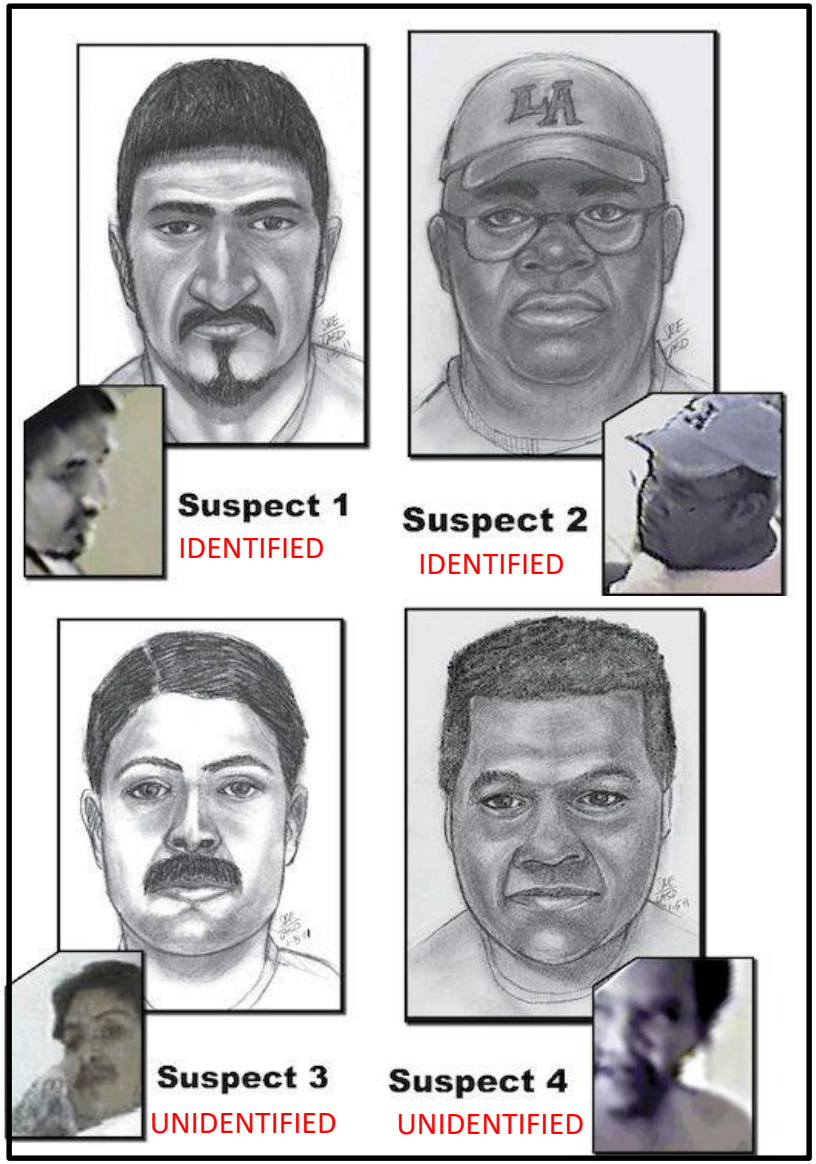
http://www.nytimes.com/2013/08/19/nyregion/still-finding-value-in-the-vanishing-art-of-police-sketches.html?pagewanted=all&_r=1&

Sketch from Video

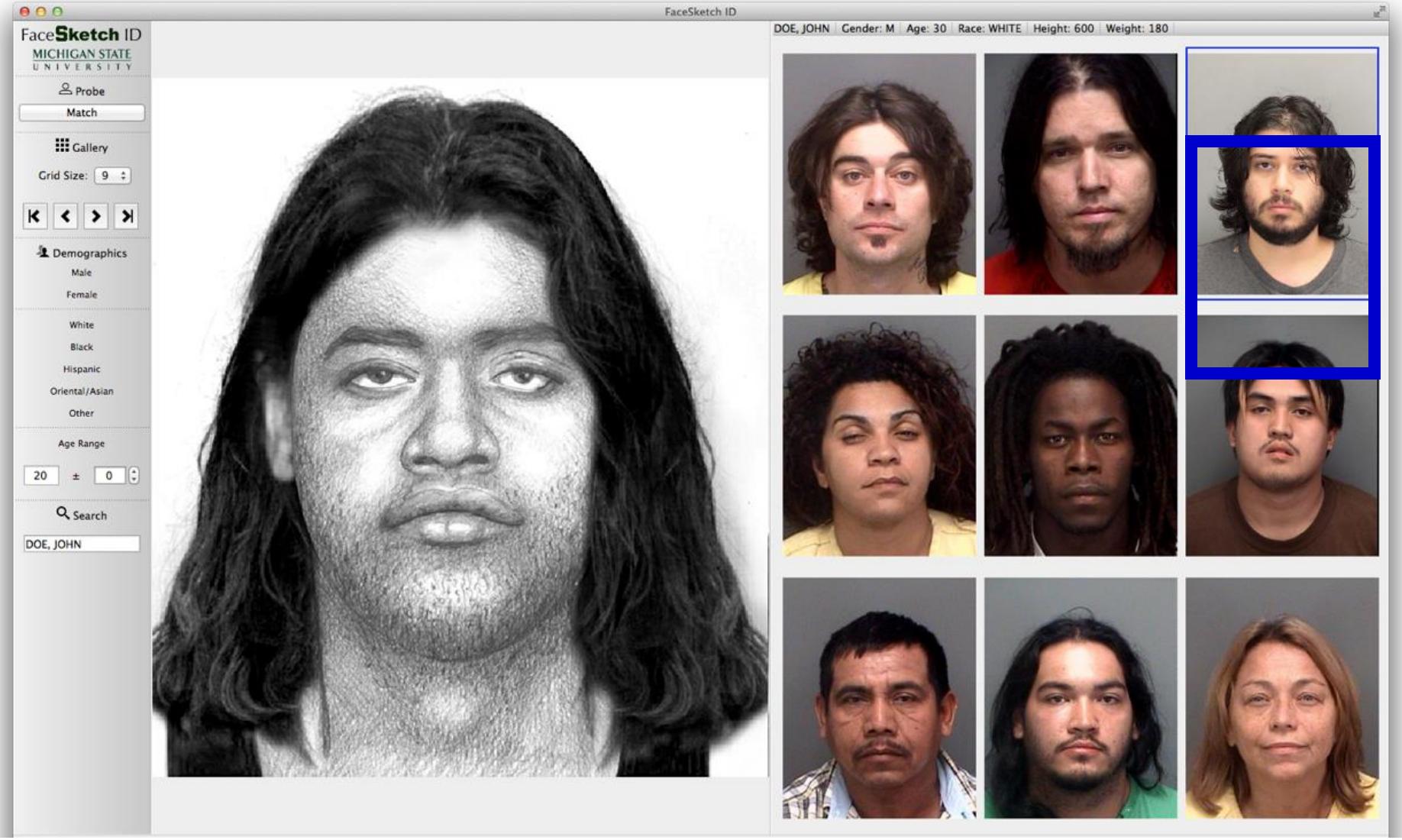
The New York Times

Los Angeles Officials Identify Video Assault Suspects

"Composite drawings of four of the suspects have been made based upon video images"



FaceSketch-ID System



Licensed to Morpho

Han, Klare, Bonnen, Jain, "Matching Composite Sketches to Face Photos: A Component-Based Approach", IEEE Trans Information Forensics and Security, 2013

Fingerprints

APPLICANT

LEAVE BLANK

Leave Blank

TYPE OR PRINT ALL INFORMATION IN BLACK

LAST NAME NAM FIRST NAME MIDDLE NAME

Teacher, Theresa C.

FBI LEAVE BLANK

Leave Blank

SIGNATURE OF PERSON FINGERPRINTED

RESIDENCE OF PERSON FINGERPRINTED

318 School Street
Hometown, NY 11111

DATE

5/01/02

SIGNATURE OF OFFICIAL TAKING FINGERPRINTS

EMPLOYER AND ADDRESS

(if applicable)
Smart Falls Central School Dist
Smart Falls. NY 11111

REASON FINGERPRINTED

Leave Blank

ALIASES AKA

Formerly:
Theresa Smith

OCA

NY9219402
NYSTED Dept-FPU
ALBANY, NY

DATE OF BIRTH DOB

12/31/70

CITIZENSHIP CTZ

US

SEX RACE HGT WGT EYES HAIR PLACE OF BIRTH POB

F W 5"7" 155 Gr Bro Ohio

YOUR NO. OCA

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FBI NO.

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ARMED FORCES NO. MNU

Leave Blank

SOCIAL SECURITY NO. SOC

000-10-1111

MISCELLANEOUS NO. MNU

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CLASS

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REF

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1. R. THUMB 2. R. INDEX 3. R. MIDDLE 4. R. RING 5. R. LITTLE

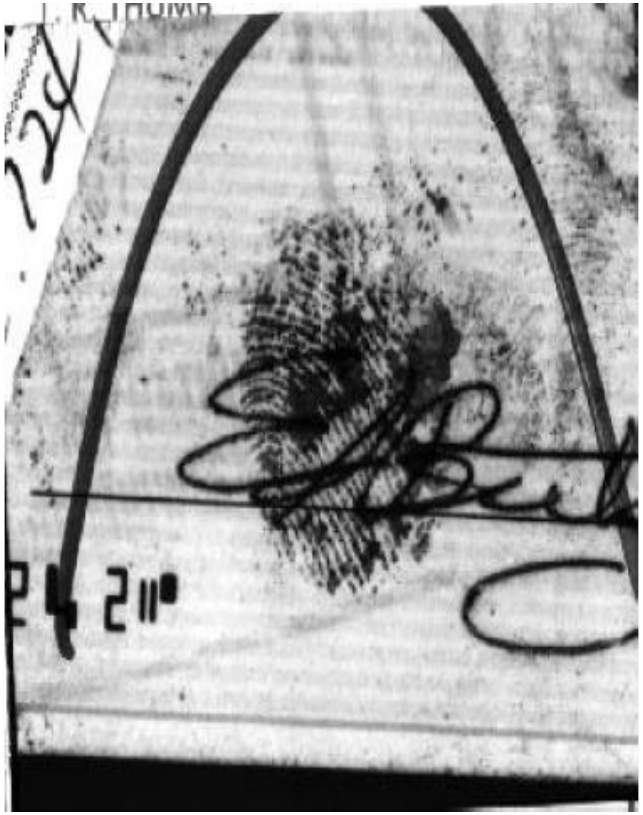
6. L. THUMB 7. L. INDEX 8. L. MIDDLE 9. L. RING 10. L. LITTLE

IDENTIX TP600 1259

LEFT FOUR FINGERS TAKEN SIMULTANEOUSLY L. THUMB R. THUMB

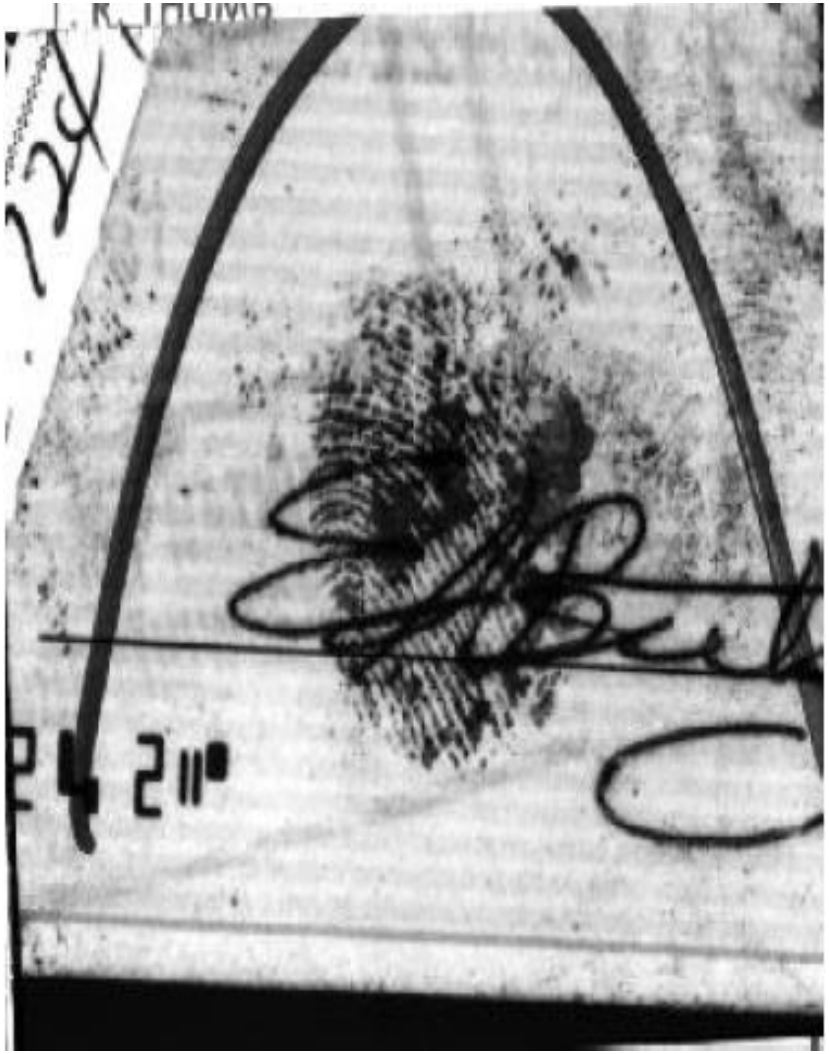
ADS004228.LEX004229

RIGHT FOUR FINGERS TAKEN SIMULTANEOUSLY



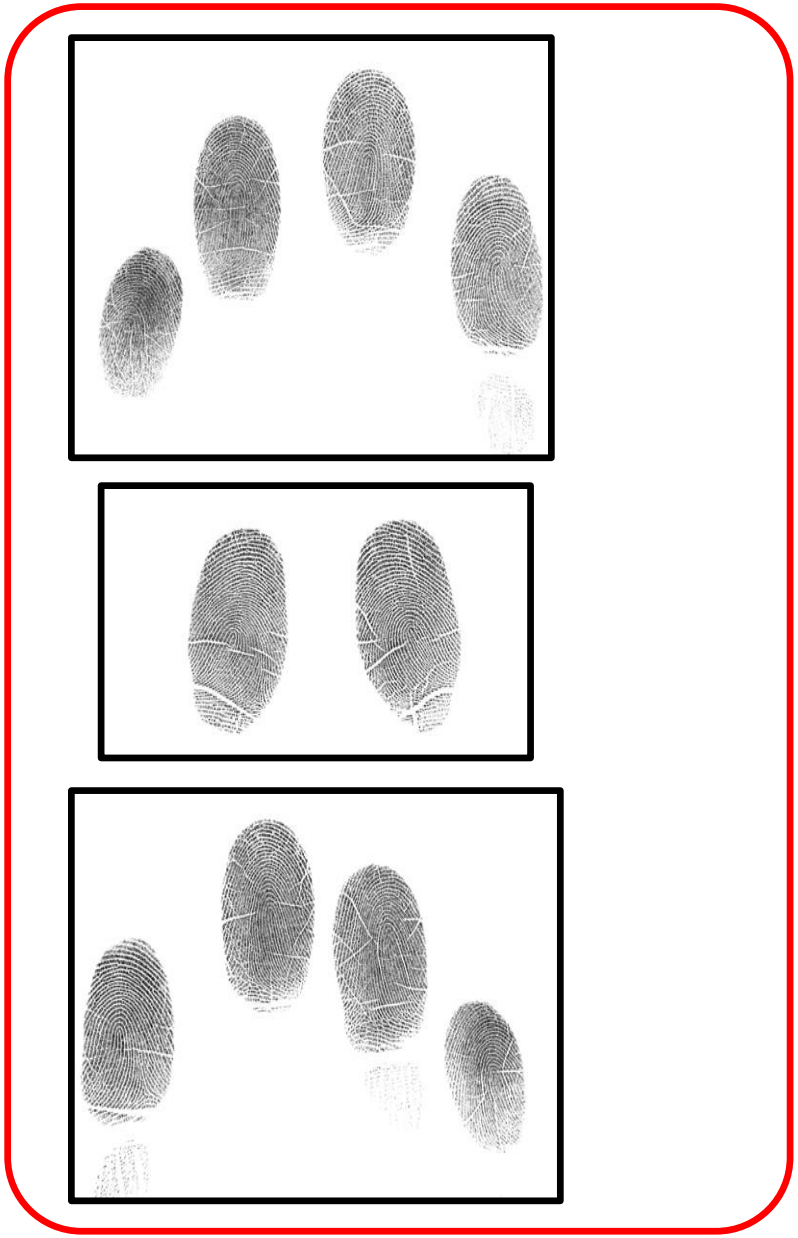
Rolled, Slap (TP) & Latents (fingermarks)

Who Left the Mark?



The most common forensic evidence

Latent-to-TP Search



FBI conducted ~36K latent searches in May, 2021

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)

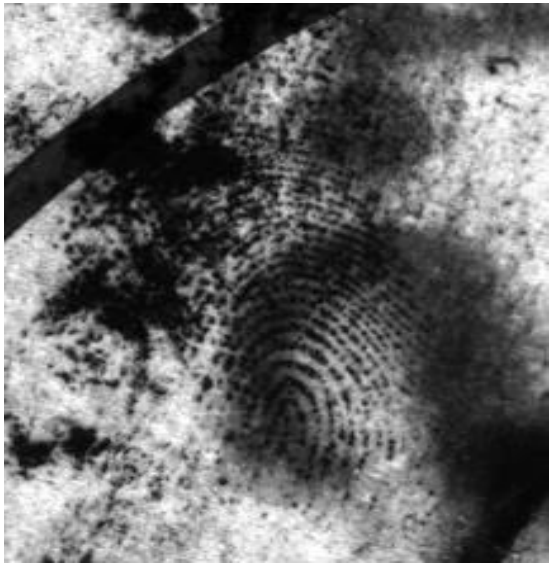
Michigan AFIS: 2017

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.

AFIS Performance

Rolled

Plain

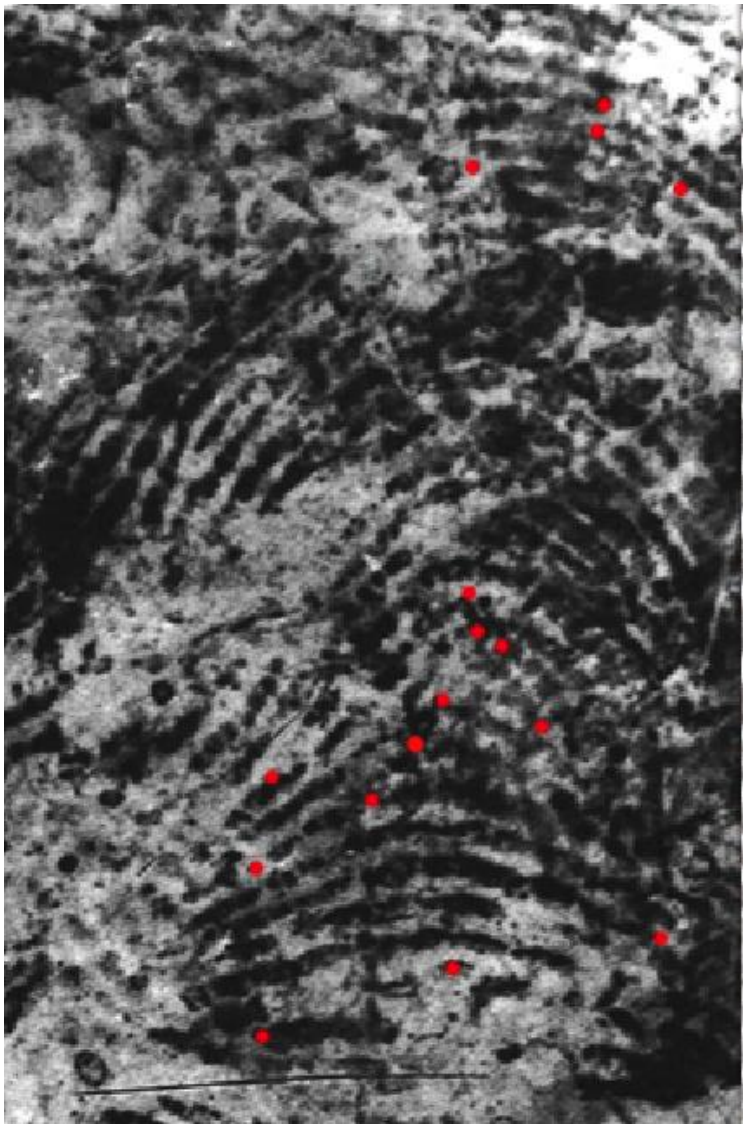


Latent

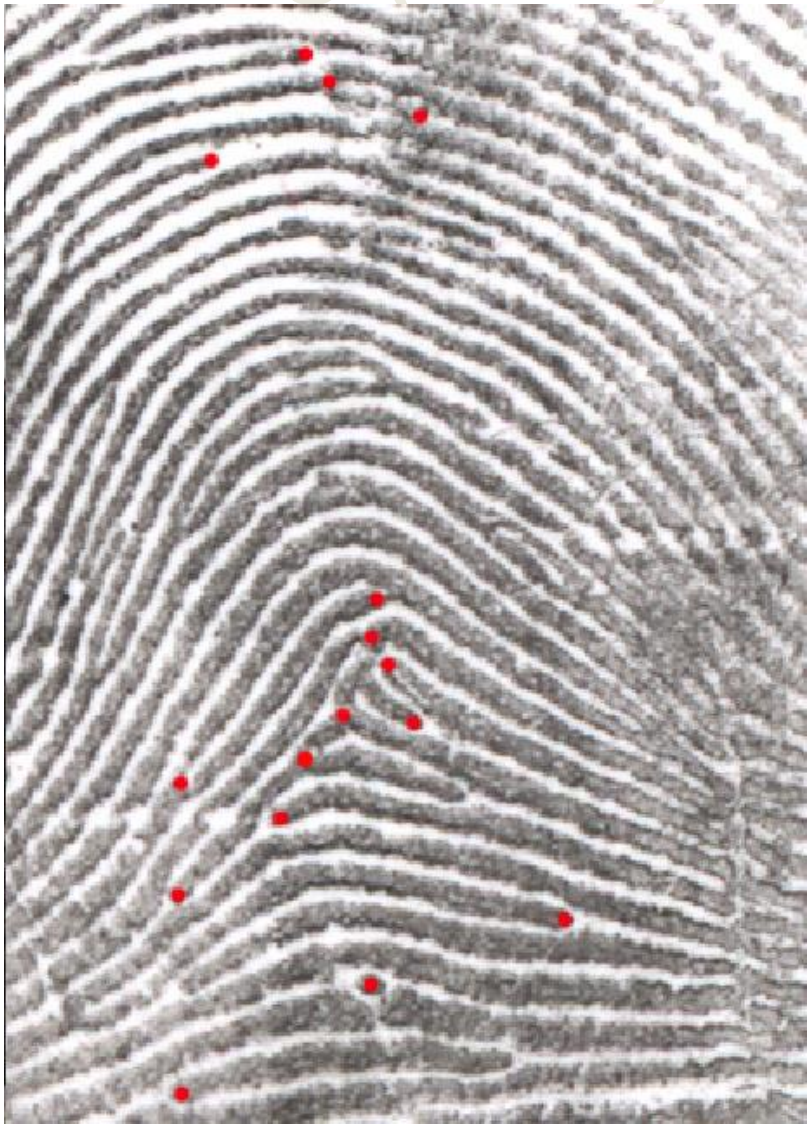
- 1 to 1 verification accuracy: 99.3%
- 1 to 5M search accuracy: FNIR = 0.11% @FPIR = 0.001 (NIST FpVTE, Dec 2014)
- Latent: 67.2% (70.2% with image + markup)

[1] Watson, Fiumara, Tabassi, Cheng, Flanagan, Salamon. Fingerprint Vendor Technology Evaluation, NISTIR, 8034, 2012
[2] Indovina, Dvornychenko, Hicklin, Kiebuzinski. ELFT-EFS Evaluation of Latent Fingerprint Technologies: Extended Feature Sets [Evaluation# 2], NISTIR, 7859, 2012

Madrid Train Bombing (2004)



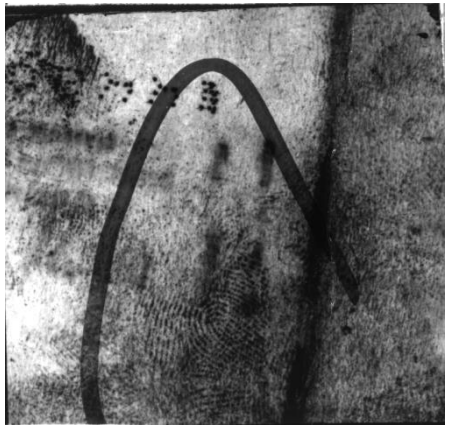
Partial print on a duffel bag



Brandon Mayfield's prints in file

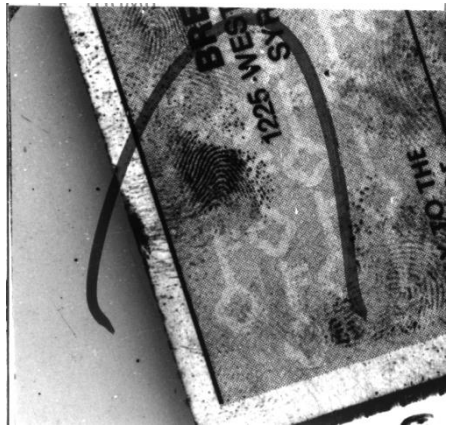
Challenges in Latent Recognition

Reliable feature extraction

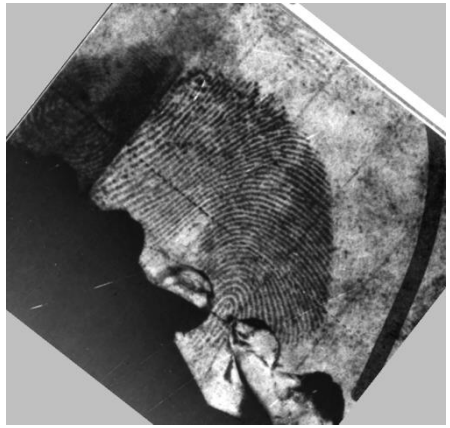


Unclear ridges

Complex background



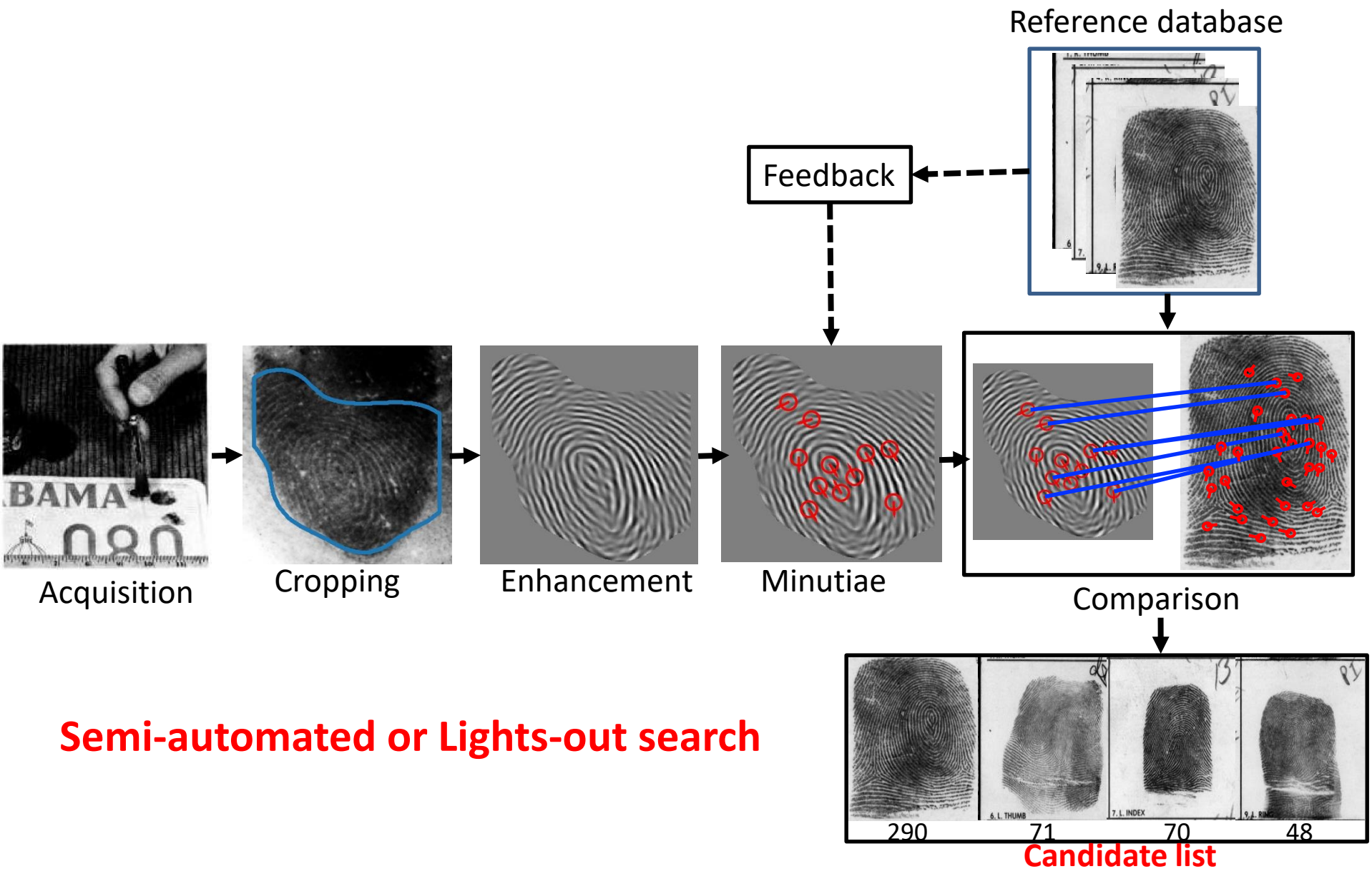
Partial fingerprint



Large distortion

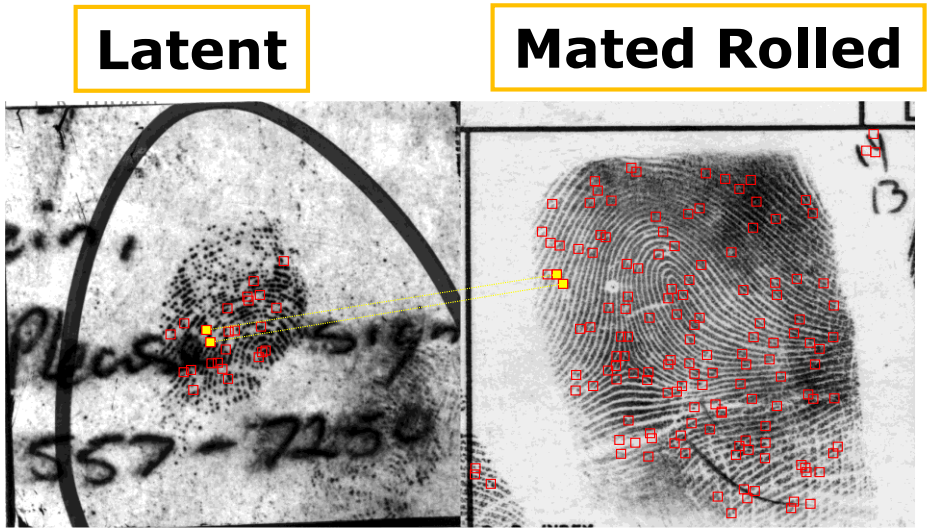
Robust feature matching

Automated Latent AFIS

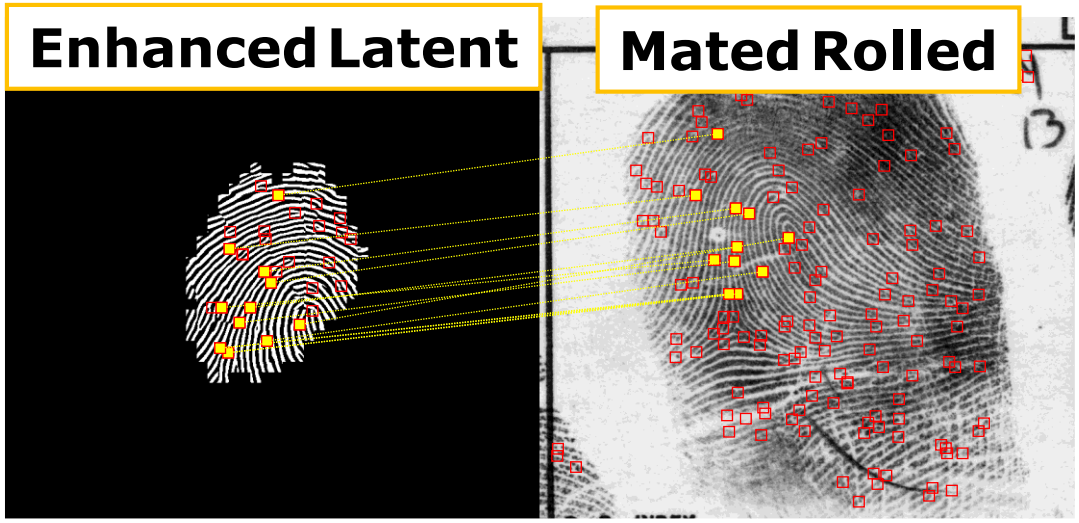


Semi-automated or Lights-out search

Successful Match

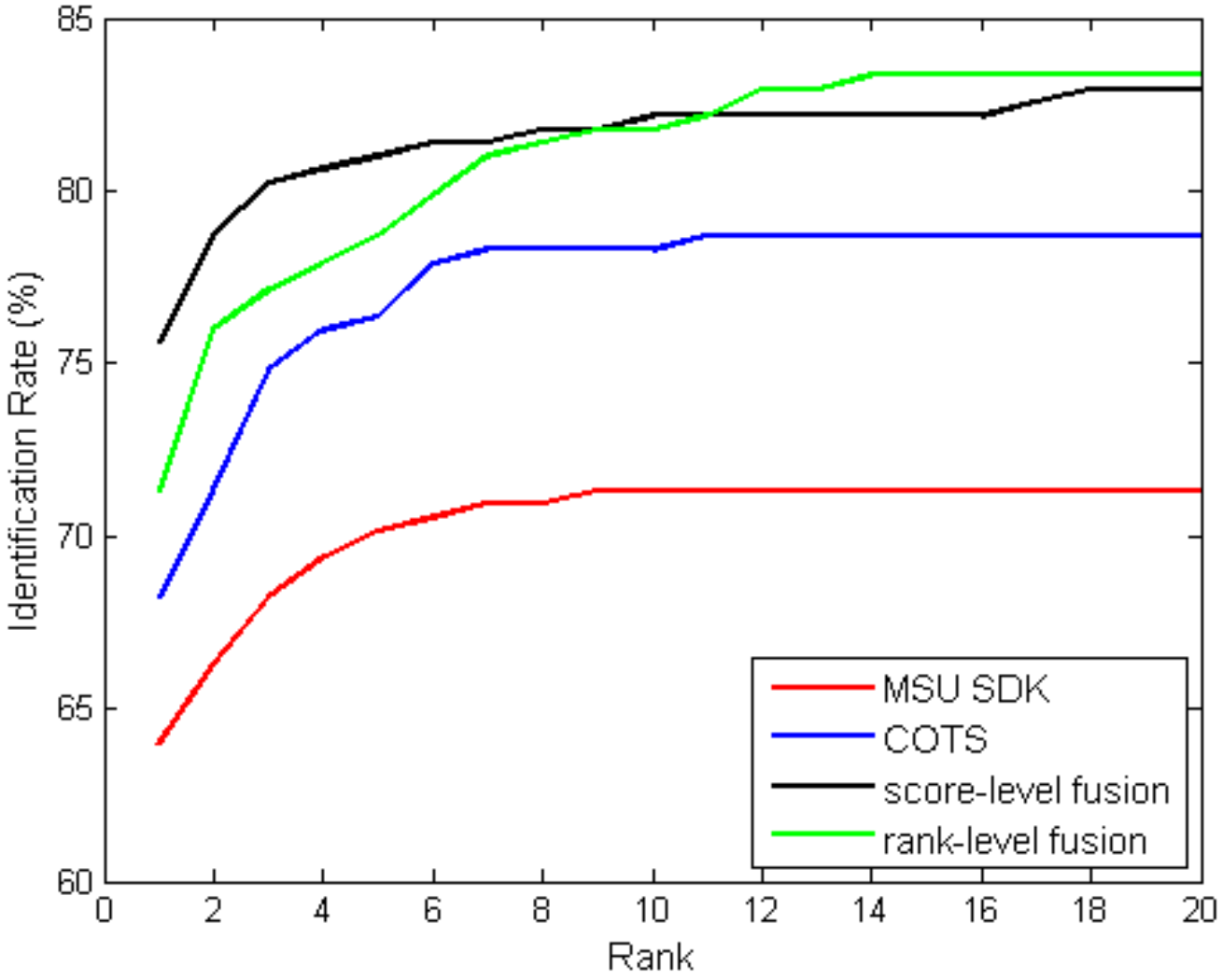


Matched minutiae = 2
Similarity score = 3



Matched minutiae = 13
Similarity score = 38

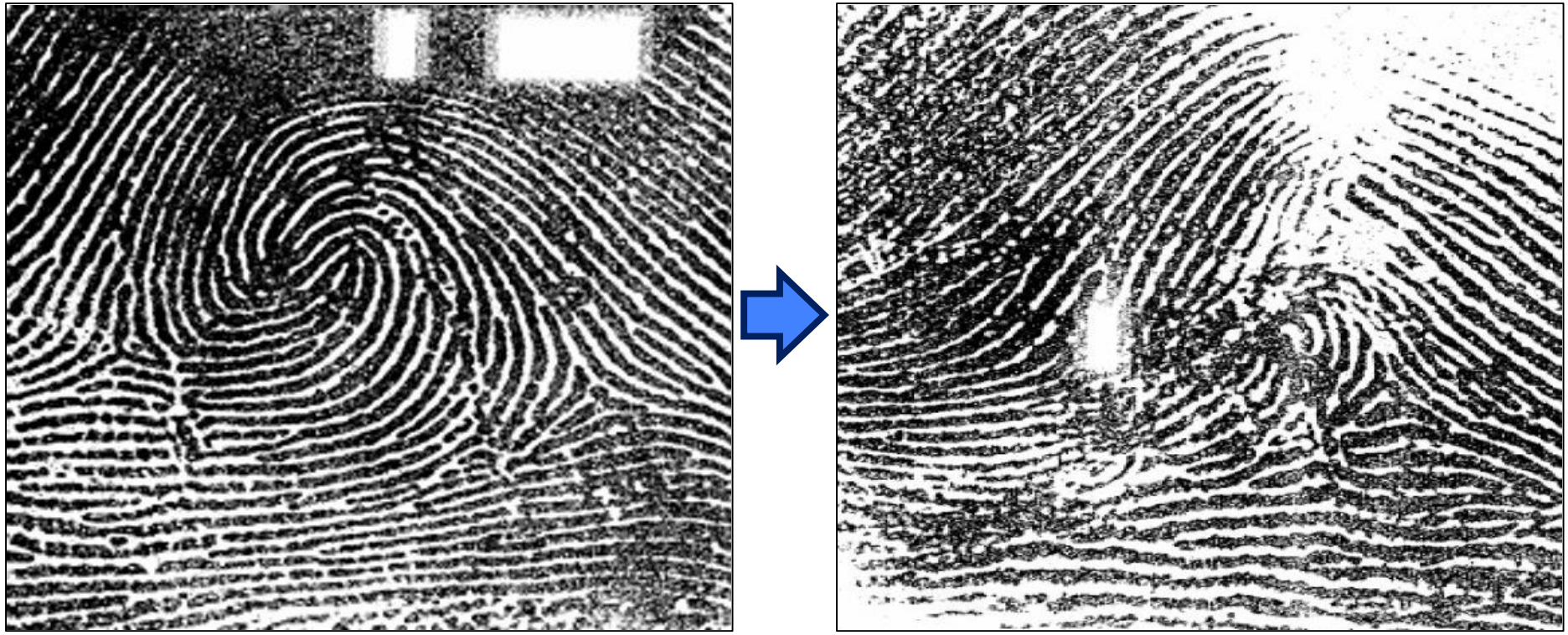
MSU Latent Matcher Performance



NIST SD27:
258 latents matched to 100K rolled prints

Kai Cao and Anil Jain, "Automated latent fingerprint identification", IEEE Trans. PAMI, 2018
K. Cao, D. Nguyen, C. Tymoszek and A. K. Jain, "End-to-End Latent Fingerprint Search", IEEE Trans. Information Forensics and Security, DOI 10.1109/TIFS.2019.2930487, 2019.

Fingerprint Alteration

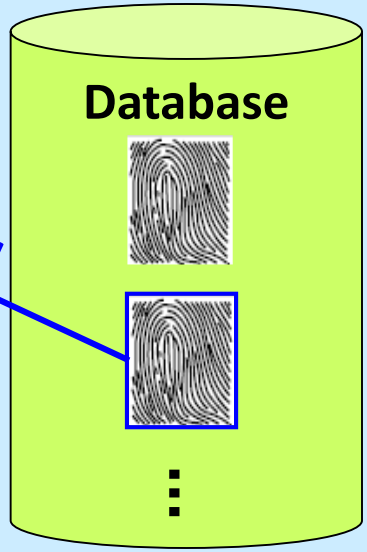


Gus Winkler (1933): Double-loop changed to left loop

Alteration vs. Spoofing

Fake Fingerprint

Matched



Adopt another identity

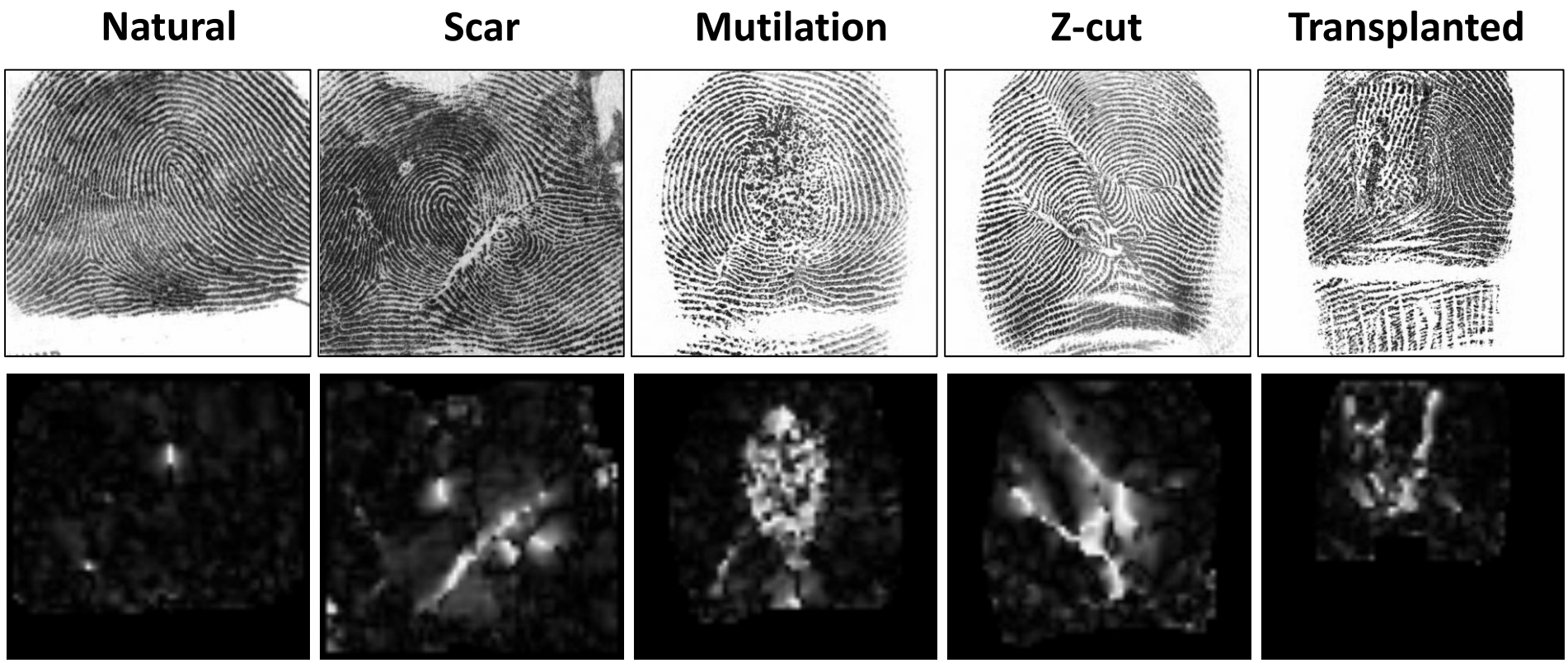
Altered Fingerprint

Not matched

?

Evade identification

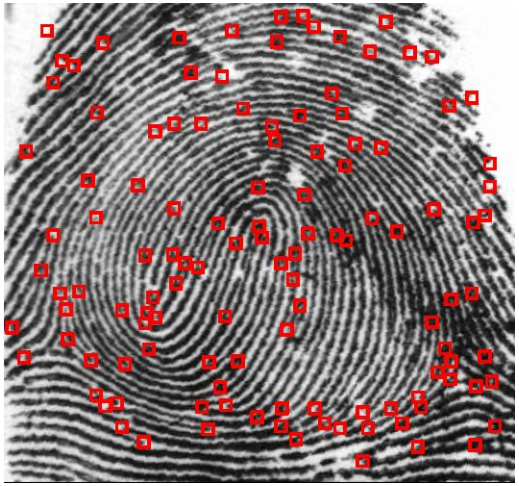
Orientation Field Discontinuity



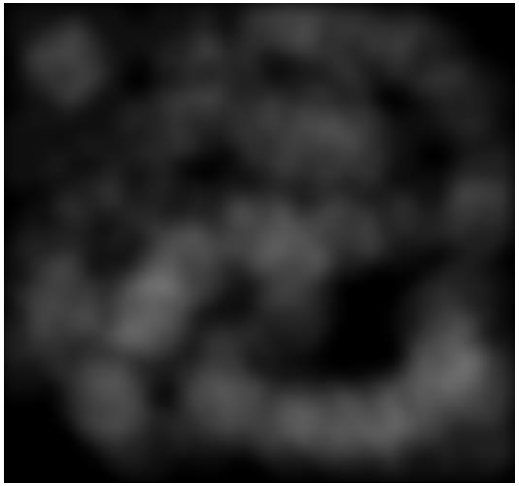
Minutiae Density Map

Natural Fingerprint

Minutiae

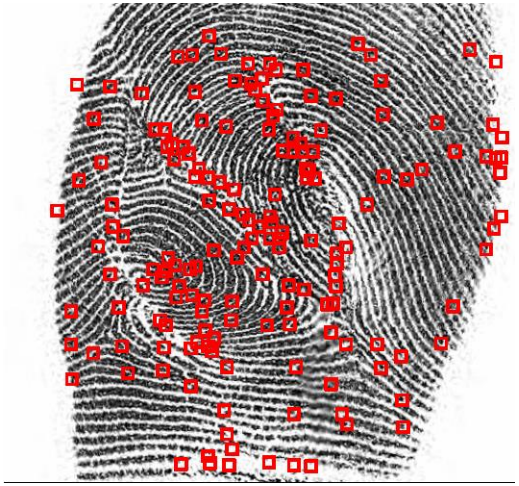


Minutiae Density Map

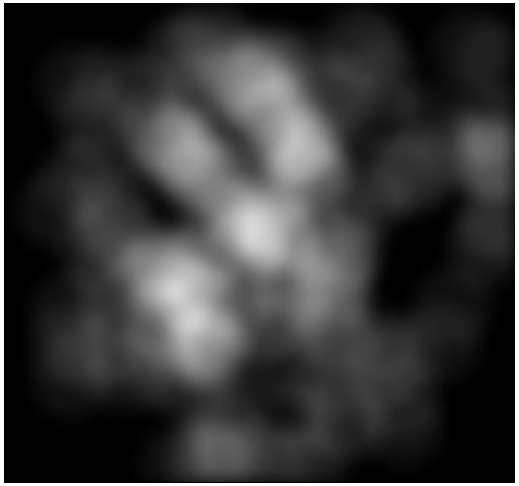


Altered Fingerprint

Minutiae



Minutiae Density Map



S. Yoon, J. Feng and A. K. Jain, "Altered Fingerprints: Analysis and Detection", IEEE Trans. PAMI, March 2012

Summary

- **Forensics domain offers a range of challenging problems to CV/ML/PR/biometric researchers**
- **Two challeges: (i) collaboration with domain experts; (ii) data for design and test of algorithms**
- **Open problems:**
  - **Establish a baseline to compute the match confidence**
  - **Interpretaility of the decision to convincing the courts**
  - **How to resolve differences in the decisions by the prosecutor and defense software**