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
“….. 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**

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

**Biometrics**
- 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)

- 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

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

Victim Identification

• Tattoo may be the **only clue** to identify victims

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

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

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/)
Matching Composites to Face Images
Fighting Crime With Pencil and Paper

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

Pleased 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.

Composite drawings of four of the suspects have been made based upon video images.
FaceSketch-ID System

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Fingerprints

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
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

- 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)


Partial print on a duffel bag

Brandon Mayfield’s prints in file
Challenges in Latent Recognition

- Unclear ridges
- Partial fingerprint
- Complex background
- Large distortion

Reliable feature extraction
Robust feature matching
Automated Latent AFIS

Semi-automated or Lights-out search
Successful Match

Latent

Mated Rolled

# Matched minutiae = 13
Similarity score = 38

Enhanced Latent

Mated Rolled

# Matched minutiae = 2
Similarity score = 3
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

Gus Winkler (1933): Double-loop changed to left loop
Alteration vs. Spoofing

Fake Fingerprint

Altered Fingerprint

Database

Matched

Adopt another identity

Not matched

Evade identification
Orientation Field Discontinuity

Natural  Scar  Mutilation  Z-cut  Transplanted
Minutiae Density Map

Natural Fingerprint

Minutiae

Minutiae Density Map

Altered Fingerprint

Minutiae

Minutiae Density Map

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Summary

• Forensics domain offers a range of challenging problems to CV/ML/PR/biometric researchers

• Two challenges: (i) collaboration with domain experts; (ii) data for design and test of algorithms

• Open problems:
  – Establish a baseline to compute the match confidence
  – Interpretability of the decision to convincing the courts
  – How to resolve differences in the decisions by the prosecutor and defense software