Biometric Recognition
Challenges in Forensics

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http://biometrics.cse.msu.edu

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Biometric Technology Takes Off

By THE EDITORIAL BOARD, NY Times, September 20, 2013

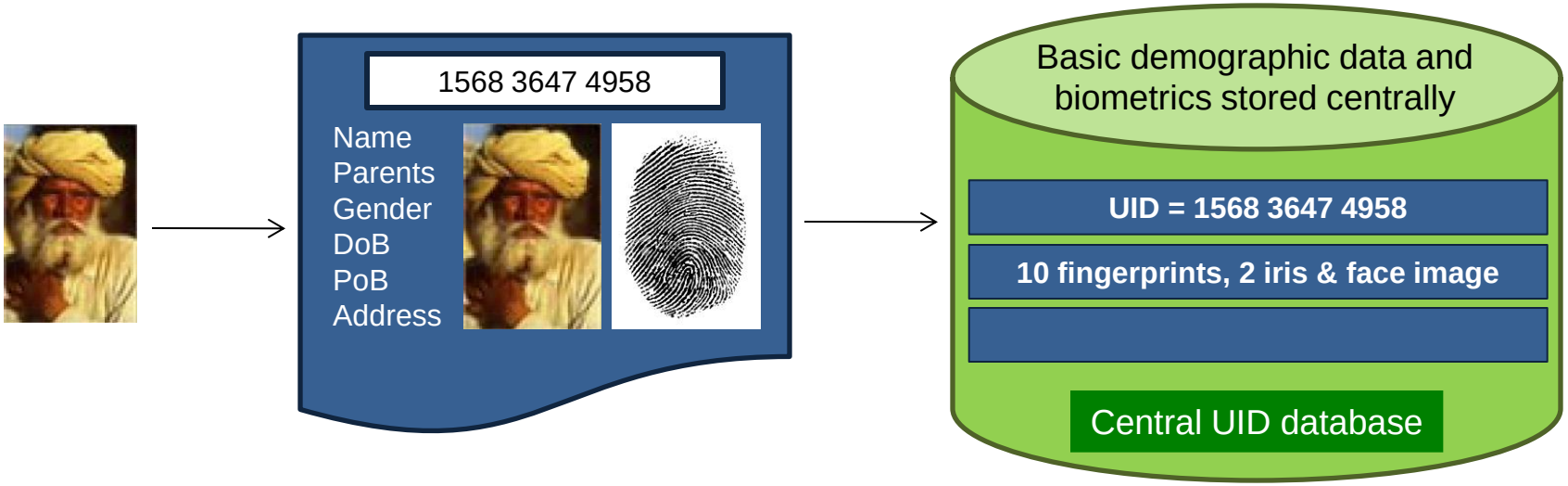
"The use of biological markers like fingerprints, faces and irises to identify people is rapidly moving from science fiction to reality."

Outline

- Biometric recognition
  - Traits, uniqueness, persistence
- Applications
  - Deduplication, border crossing, access control
- Challenges in forensics
  - Non-cooperative, unconstrained scenarios
  - Sketch to photo matching, latent fingerprints, fingerprint alteration, scars, marks & tattoos

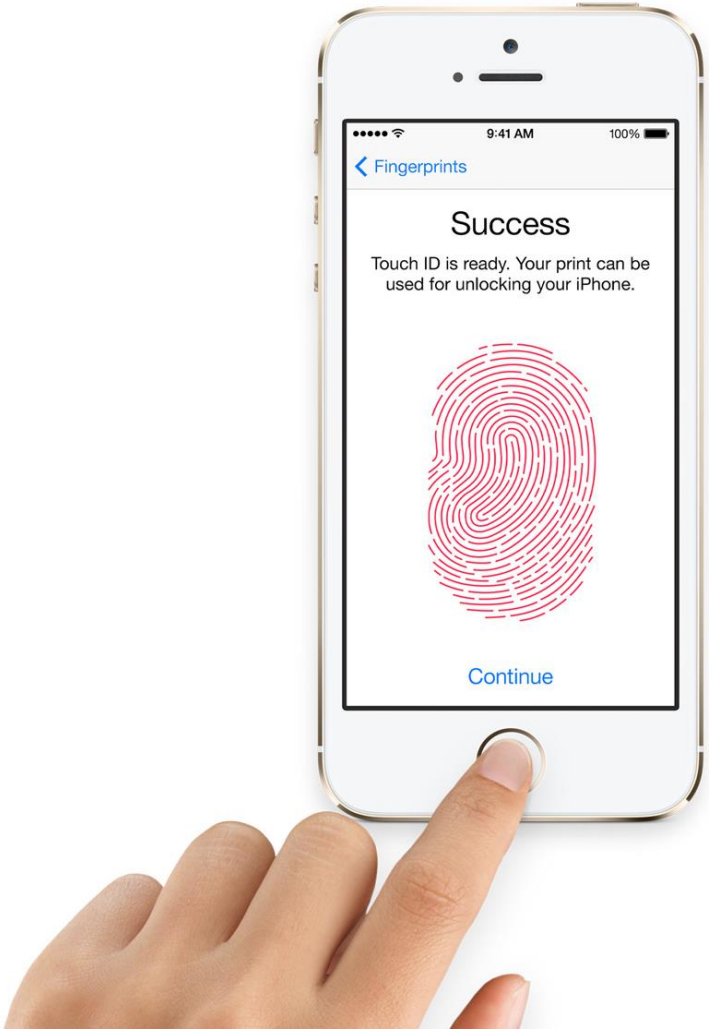
Aadhar

"Issue a unique identification number (UID) to Indian residents that can be used to eliminate duplicate and fake identities."



UIDAI has issued ~560 million Aadhaar numbers as of Jan 2014

Mobile Phone Security



Joseph Van Os / Getty Images

By 2014, more cell phone accounts than people; $1 Trillion in mobile payments

http://www.siliconindia.com/magazine_articles/World_to_have_more_cell_phone_accounts_than_people_by_2014-
http://blog.unibulmerchantservices.com/mobile-payments-volume-to-total-nearly-1-trillion-by-2014/
http://www.cbsnews.com/8301-205_162-57602236/apple-announces-new-iphone-5s-iphone-5c-ios-7-release-date

Why Biometrics?

People cannot be trusted based on credentials

About 300K British passports were lost or stolen in 2006

Most common pw: 123456,…

Stolen credit card numbers can go for as little as a quarter or as much as $45 each

http://www.nytimes.com/2013/12/20/technology/target-stolen-shopper-data.html?pagewanted=all&_r=0

iPhone 5S Fingerprint Sensor Hacked by Germany's Chaos Computer Club

http://www.theguardian.com/technology/2013/sep/22/apple-iphone-fingerprint-scanner-hacked?goback=%2Egde_68333_member_275746787#%21

Biometrics are not safe, says famous hacker team who provide video showing how they could use a fake fingerprint to bypass phone's security lockscreen

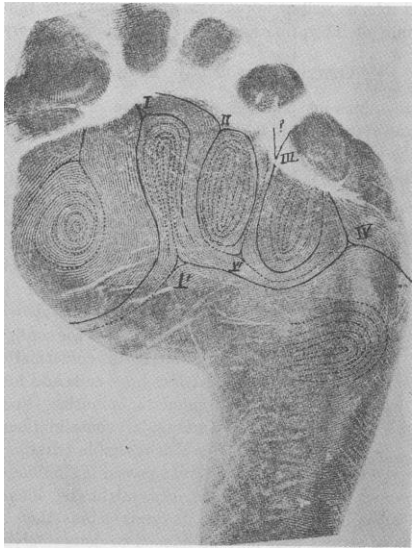
Multifactor Authentication

A combination of at least two of three components

- Something you have (token)
- Something you know (password)
- Something you are (biometrics)

Friction Ridge Pattern

Ridged (friction) skin on fingers, palms & soles



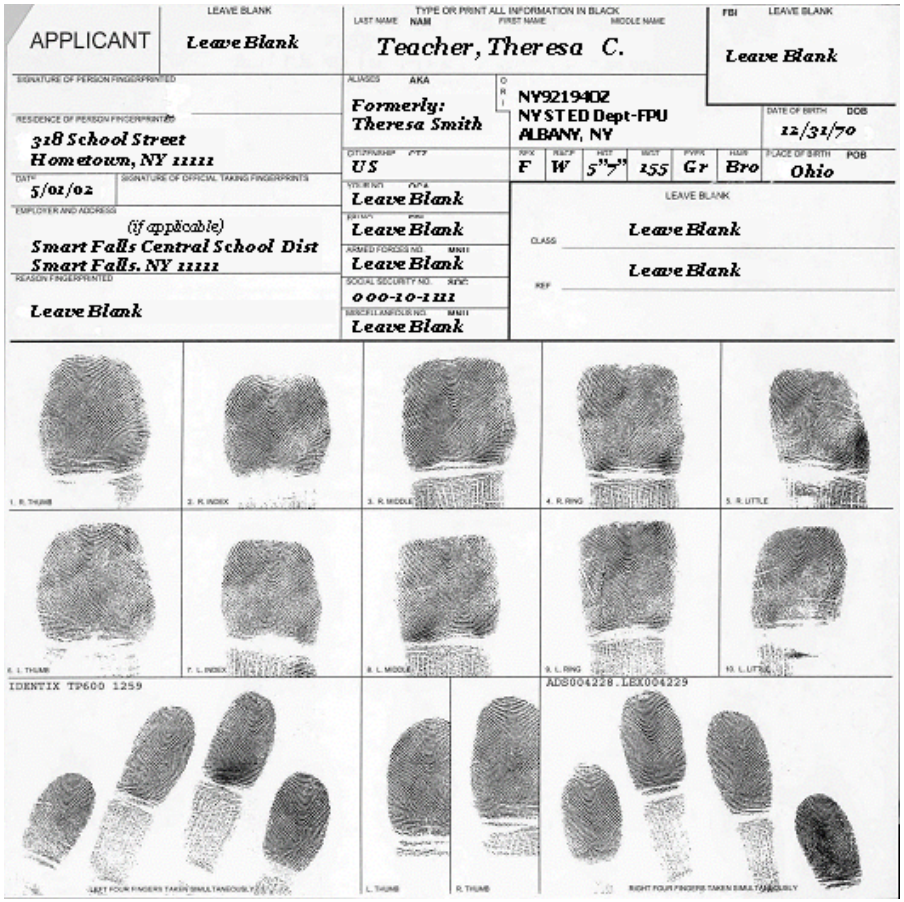
Cumins and Midlo, Finger Prints, Palms and Soles, Dover, 1961

"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."

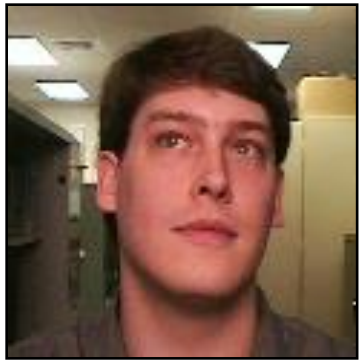
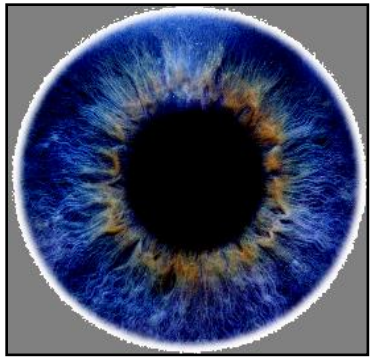
Francis Galton, Nature, June 28, 1888

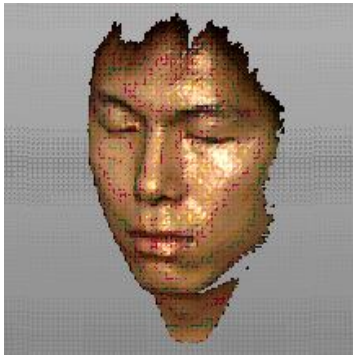
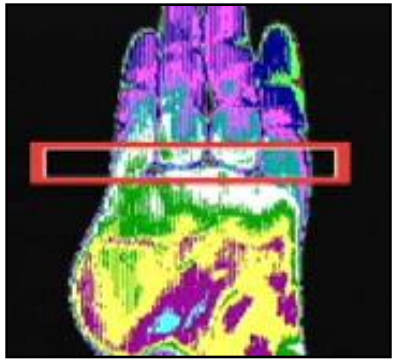
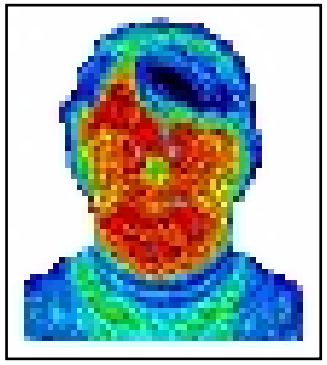
Fingerprints in Forensics

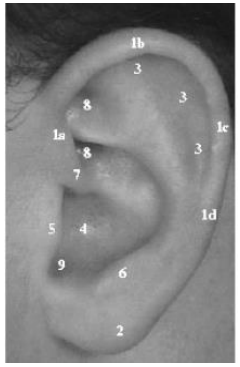
- Repeat Offenders: Compare rolled or slap tenprints
- Crime Scene evidence: Compare latents to tenprints

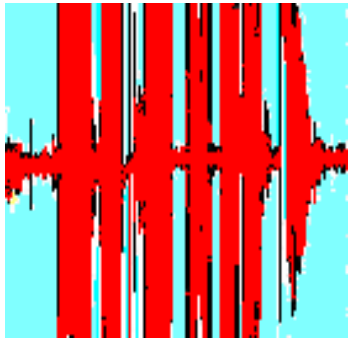
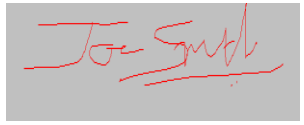
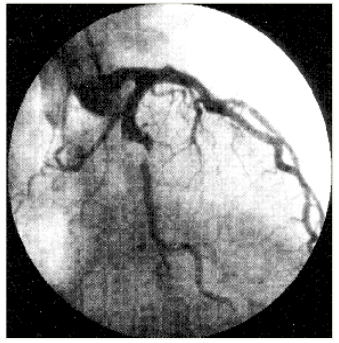


Biometric Traits



Uniqueness

Identical twins

Persistence

1881, age 7 **1890, age 17** **1913, age 40**

Herschel's fingerprints

Match scores: Age 7 vs. Age 17 = 6,217; Age 7 vs. Age 40 = 5,032; Age 17 vs. Age 40 = 5,997

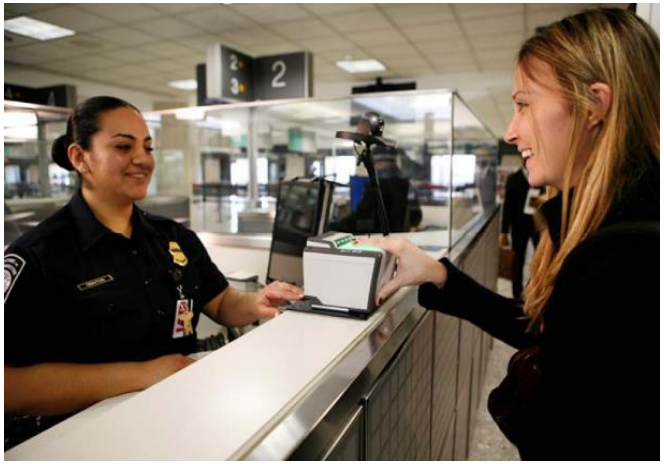
(Maximum score between fingerprints from two different fingers = 3,300)

Persistence

- Human body (and biometric traits) will age over time
- Can we devise an age-invariant template?

Applications

- De-duplication (driver license, passport,..)
- Border crossing (U.S.- Visit)
- Access control (physical, logical)

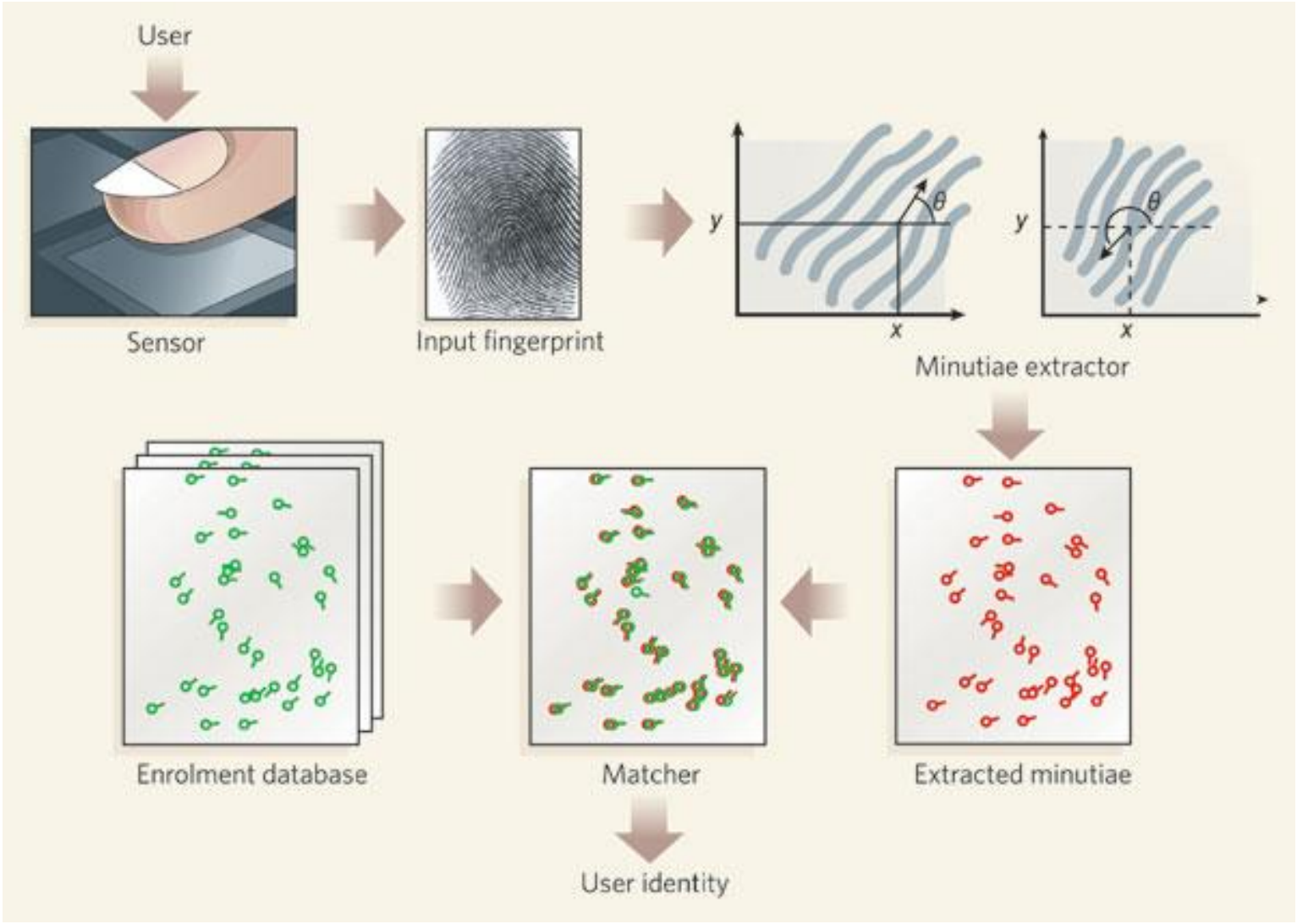


US-VISIT

Disney Parks

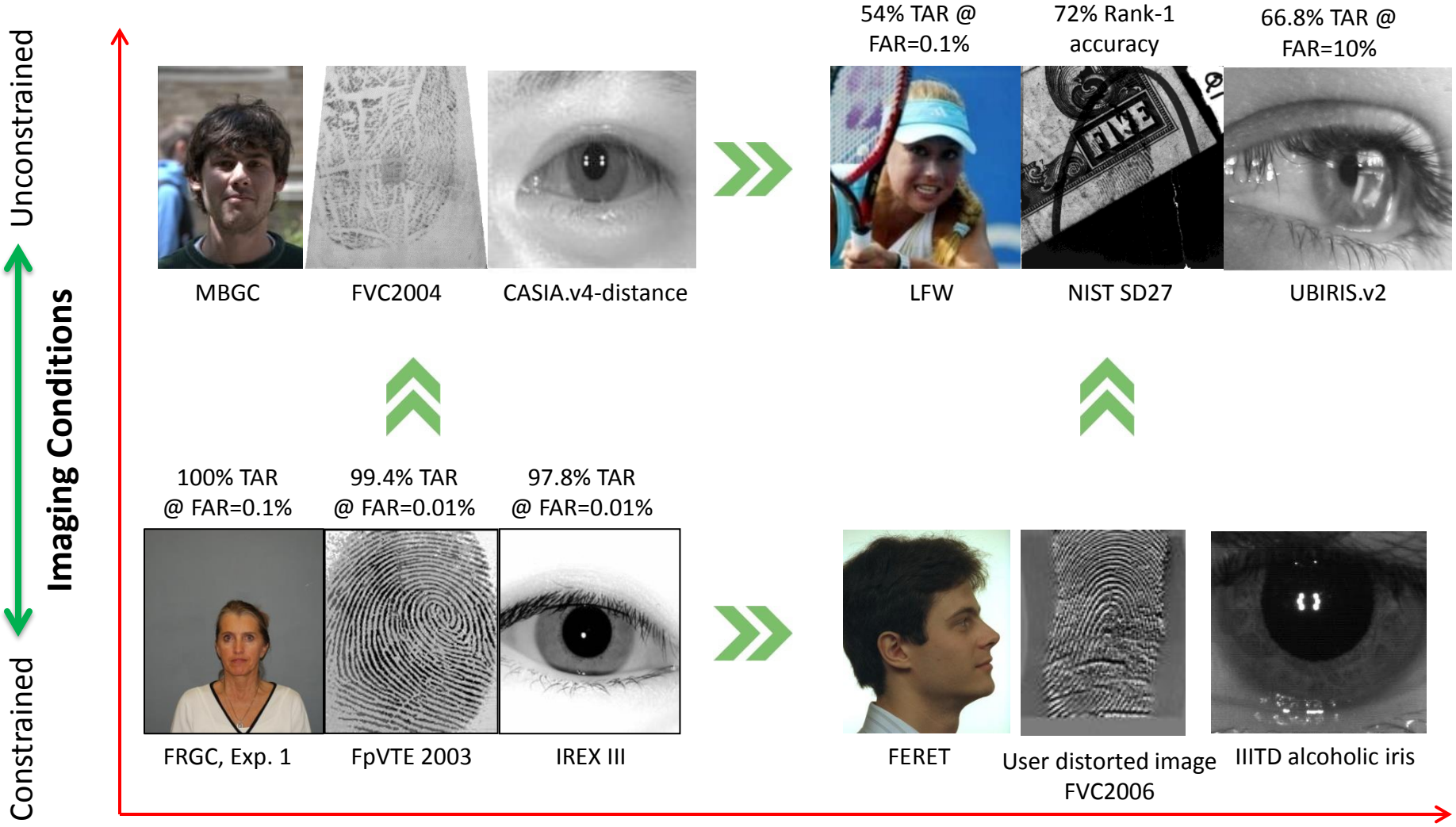
Coalmine in China

Biometric Recognition System

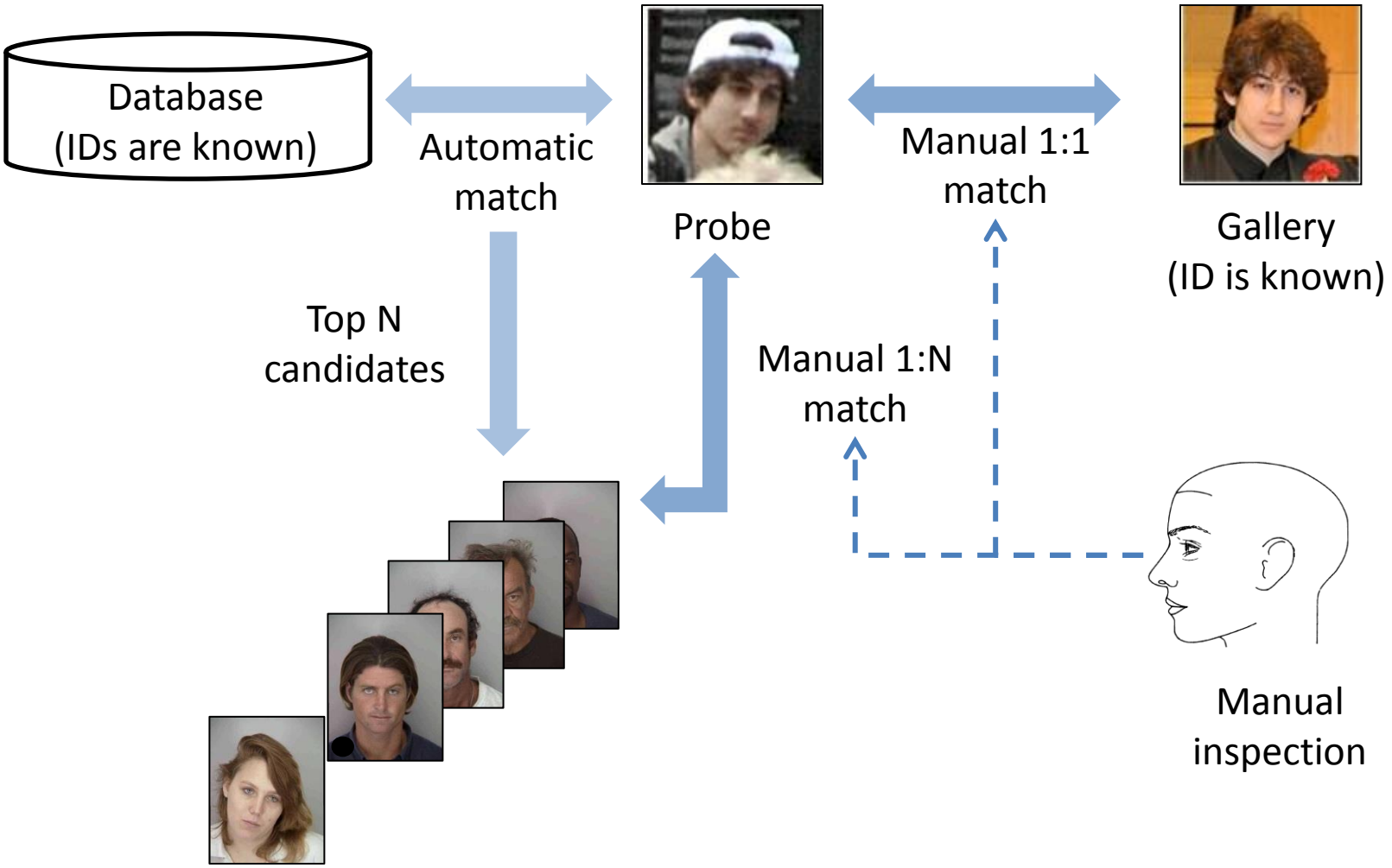


Enrolment vs. Recognition; False Accept vs. False Reject

State of the Art



Biometrics in Forensics



- A. K. Jain, B. Klare, and U. Park, "Face Matching and Retrieval in Forensics Applications", *IEEE Multimedia*, 2012
- J. C. Klontz and A. K. Jain, "A Case Study on Unconstrained Facial Recognition Using the Boston Marathon Bombings Suspects", MSU Technical Report, MSU-CSE-13-4, 2013

Top Retrieval Ranks for Tsarnaev Brothers

(100K gallery with demographic filtering)

116,342 **12,446** 87,501

1,869 **1** 12,622

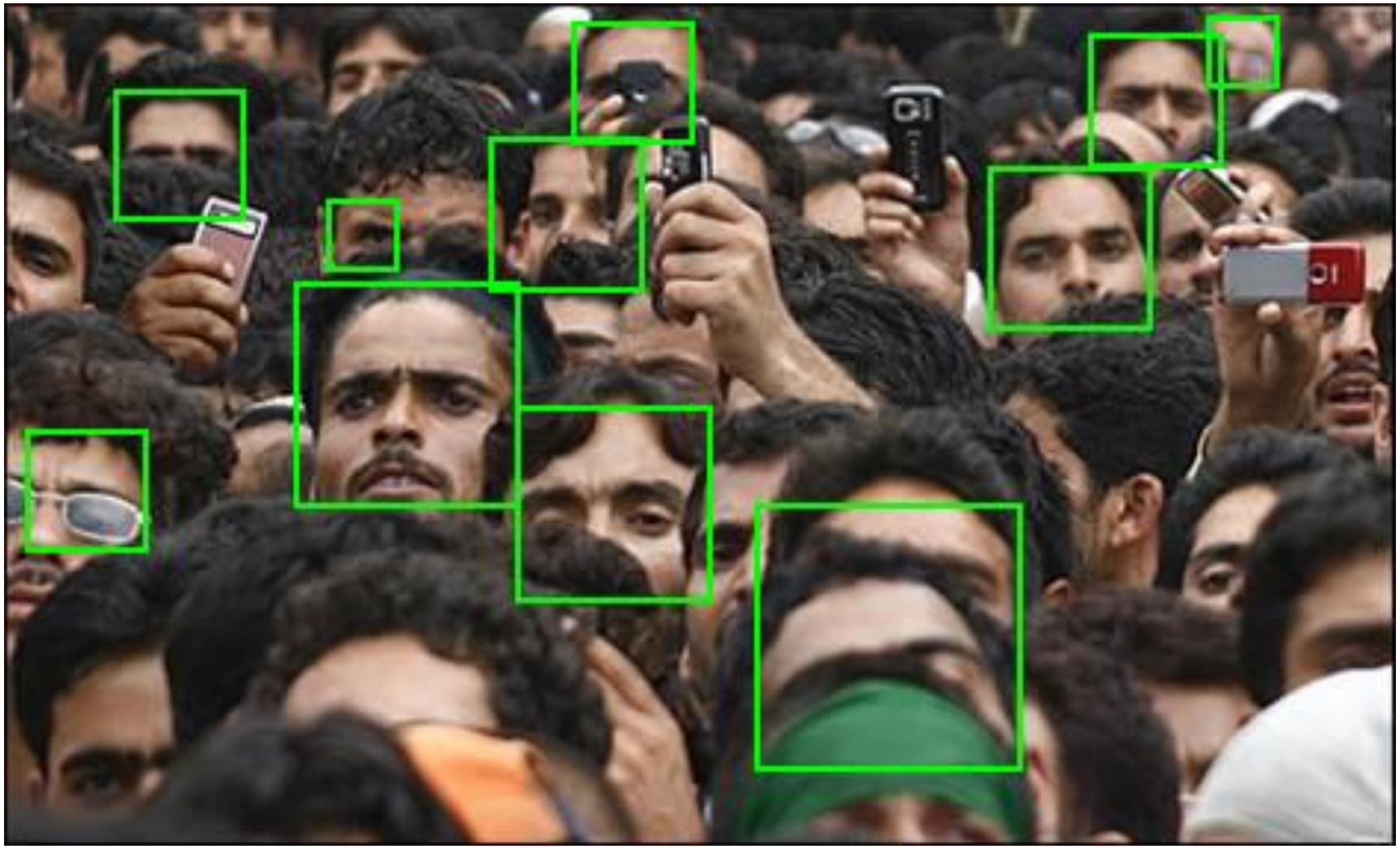
Challenges in Forensics

- Unconstrained face recognition
- Sketch (Composite) to mugshot matching
- Latent fingerprint matching
- Detecting Altered Fingerprints
- Matching Scars, Marks & Tattoos

Recognition systems with human in the loop

Unconstrained Face Recognition

- Face detection
- Alignment free matching



S. Liao, A. K. Jain, and S. Z. Li, "Partial Face Recognition: Alignment-Free Approach", *IEEE Trans. PAMI*, 2013

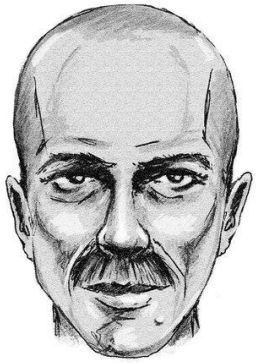
Fighting Crime With Pencil and Paper

Juan Perez, NYPD, creates sketches based on victims' descriptions

NYPD produced 273 sketches in 2012

Pleaded Guilty: Rene Otero arrested in the sexual abuse case of a 9-year-old girl

Charged With Murder: Erika Menendez arrested for shoving a man in front of a subway train



Now in Prison: Steven Pappa serving time for kidnapping and sexual assault

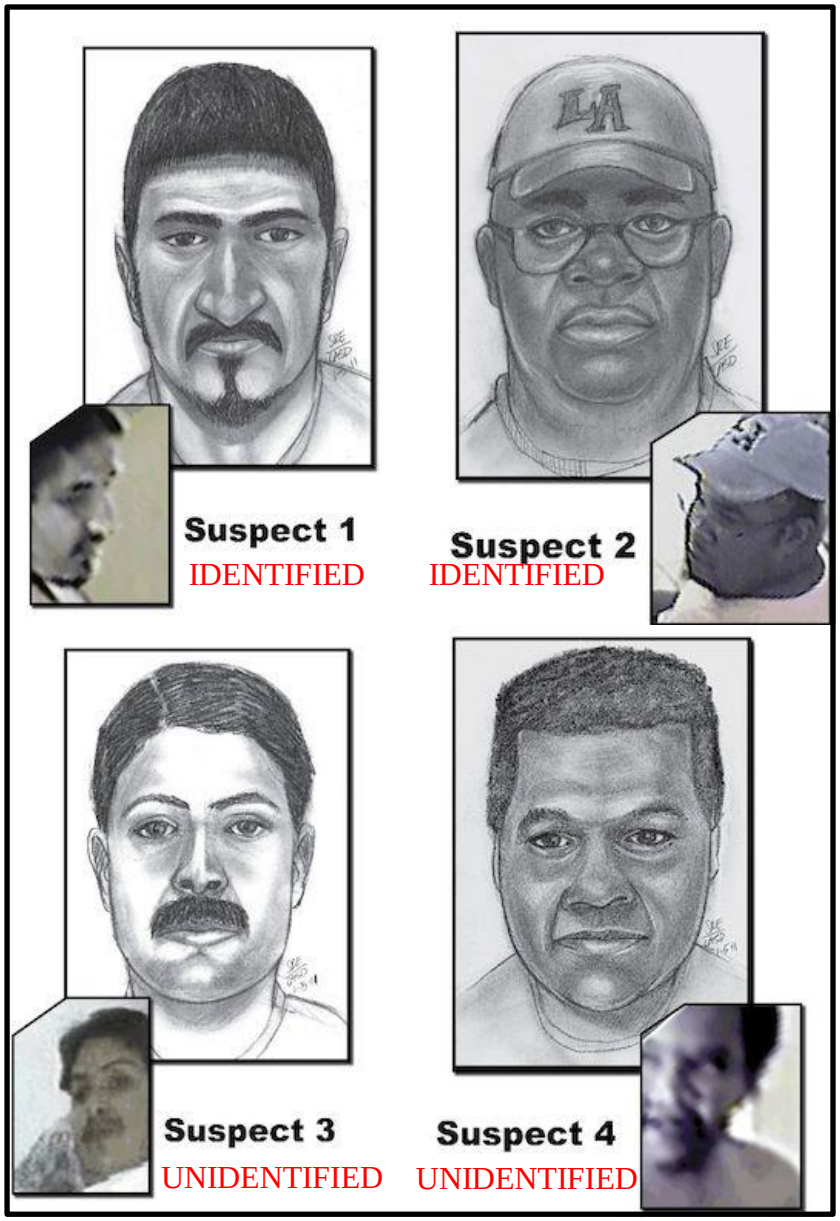
http://www.nytimes.com/2013/08/19/nyregion/still-finding-value-in-the-vanishing-art-of-police-sketches.html?pagewanted=all&_r=1&

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"



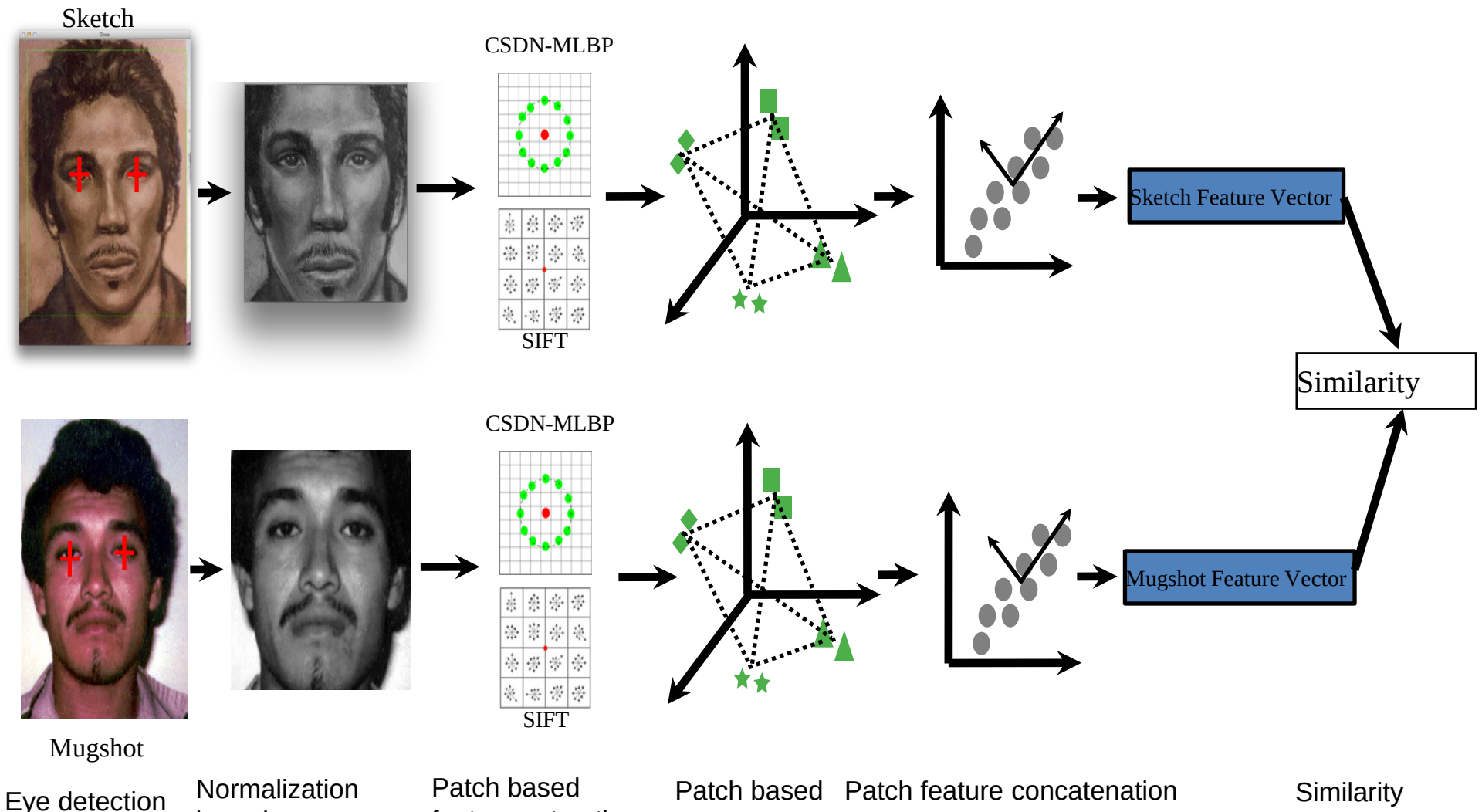
http://www.nytimes.com/2011/01/08/us/08disabled.html

http://www.lacrimestoppers.org/wanteds.aspx

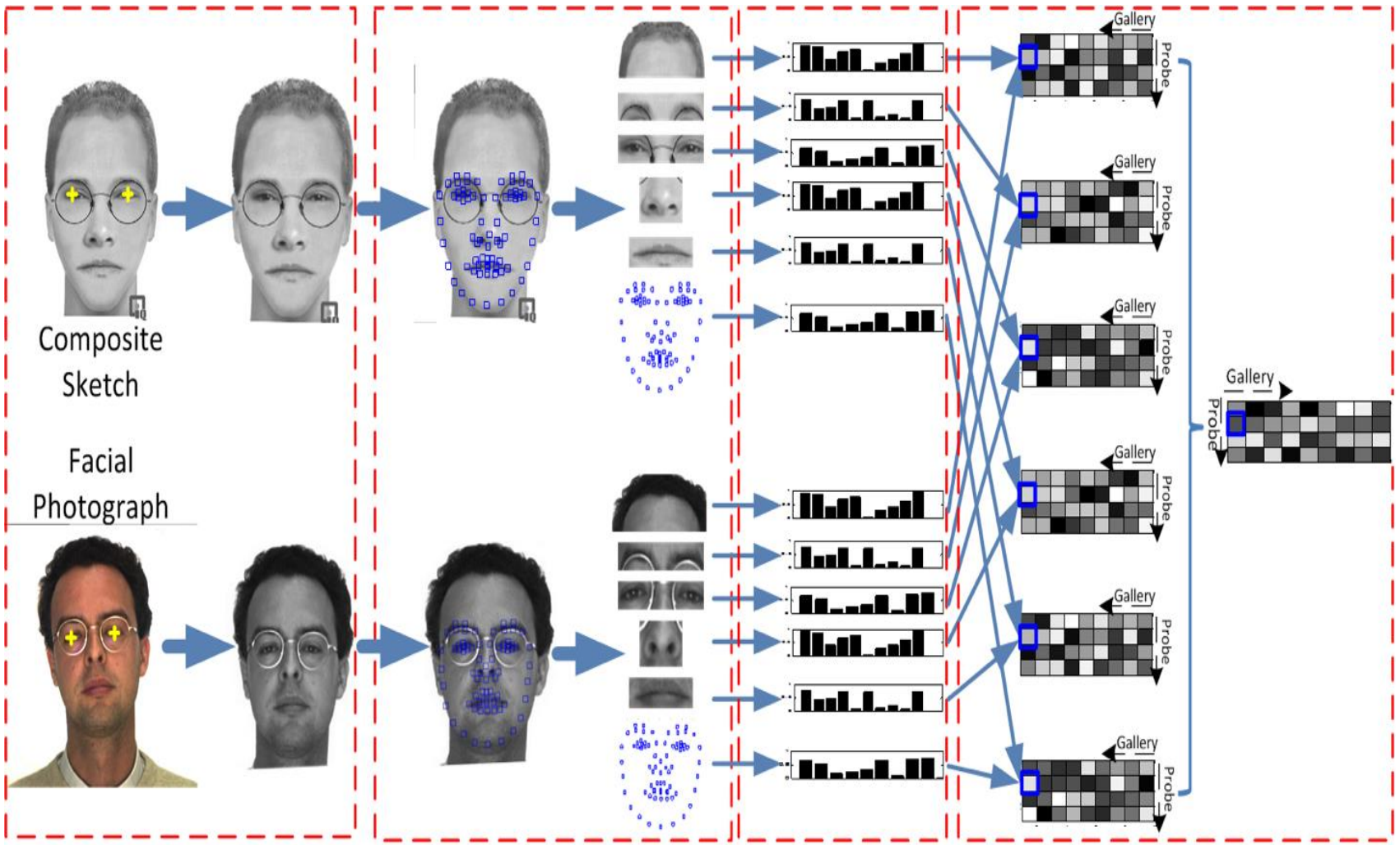
Sketch and Mugshot Mates

Challenges: Witness description, expertise of artist, time gap, modality gap

Holistic Representation & Matching



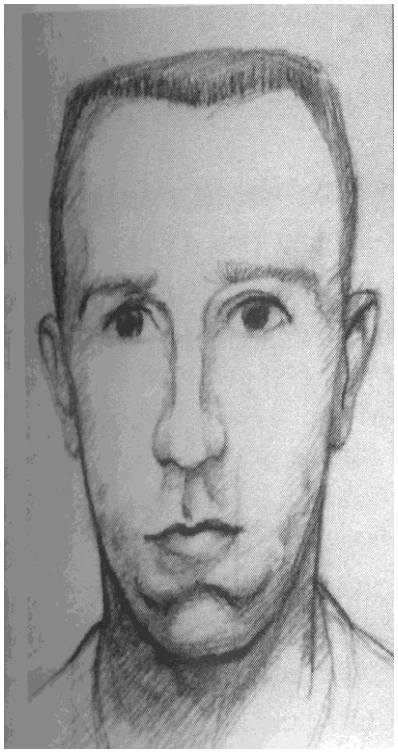
Component Based Representation

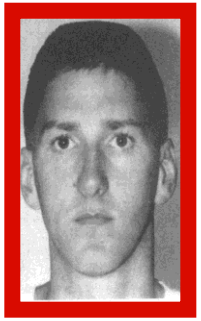
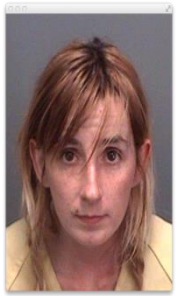
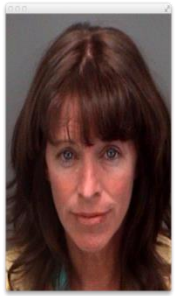


FaceSketchID System

Retrievals by FaceSketchID and COTS Matchers

Forensic sketch



	Rank 1	Rank 2	Rank 3	Rank 4	Rank 5
FaceSketchID					
COTS-1					
COTS-2					
COTS-3					

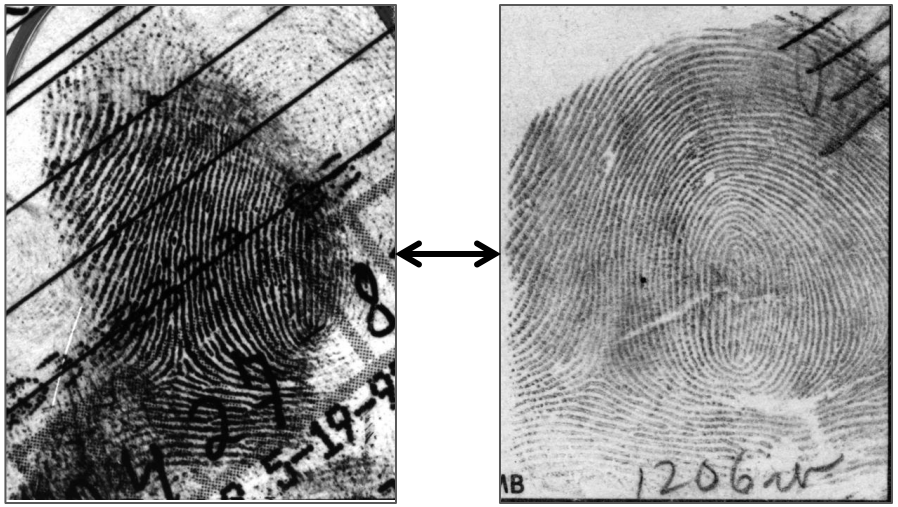
Fingerprint Matching

Rolled-to-Rolled matching

TAR of 99.4% @ FAR = 0.01%

Latent-to-Rolled matching

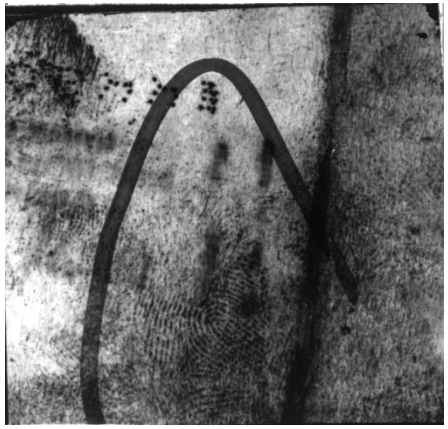
Rank-1 identification rate = 68%



C. Wilson *et al*., Fingerprint Vendor Technology Evaluation 2003: Summary of Results and Analysis Report, NIST IR-7123, 2004
M. Indovina, R. A. Hicklin, and G. I. Kiebuzinski. Evaluation of latent fingerprint technologies: Extended feature sets. NIST IR-7775, 2011

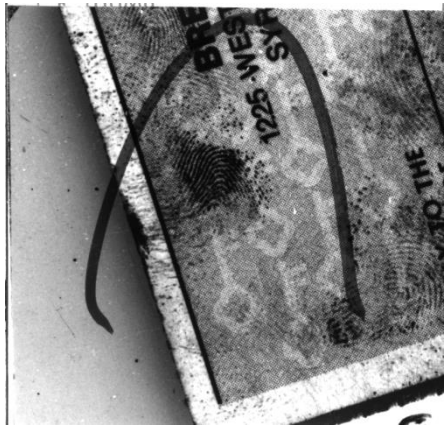
Challenges in Latent Matching

Reliable feature extraction

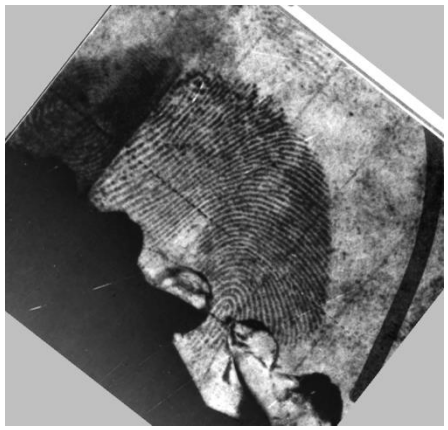


Unclear ridges

Complex background



Partial fingerprint

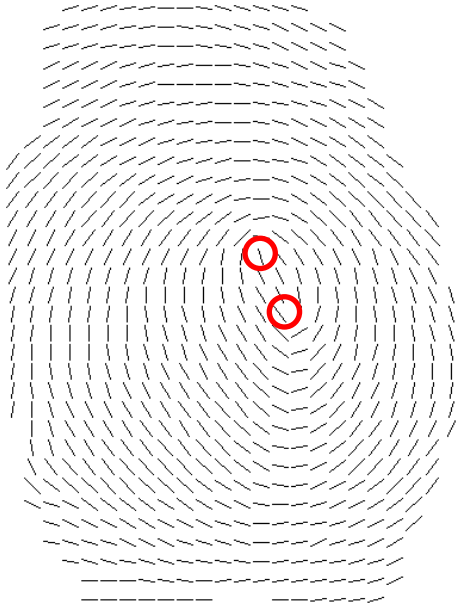


Large distortion

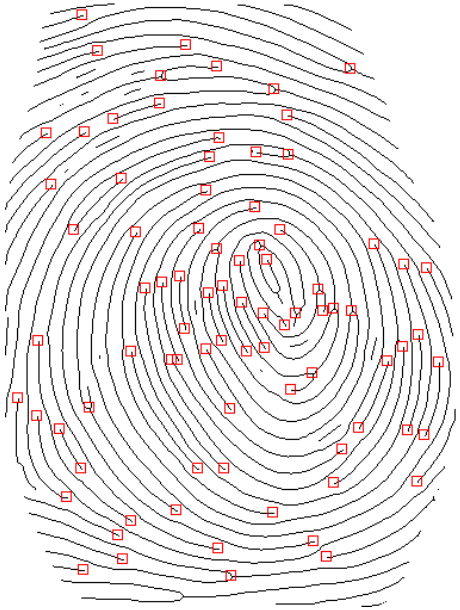
Robust feature matching

Fingerprint Features

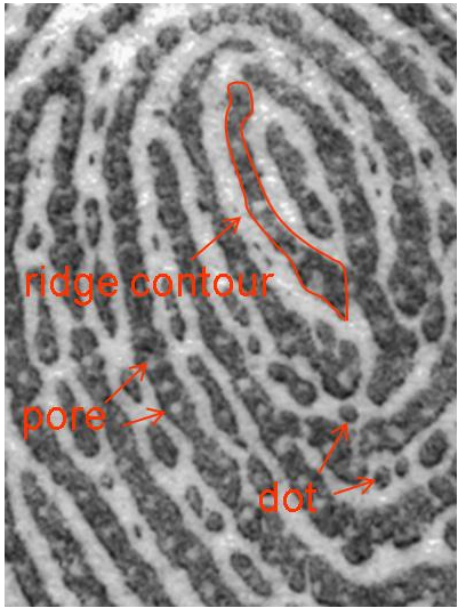
Fingerprint image
(ridges, valleys)



Level 1
(OF, core, delta)

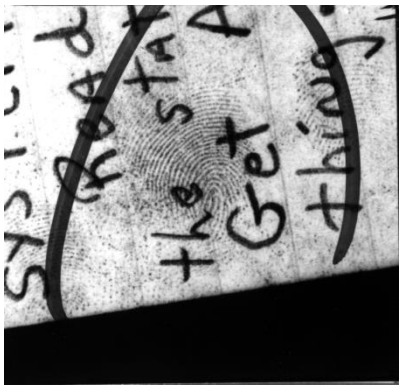


Level 2
(minutiae)

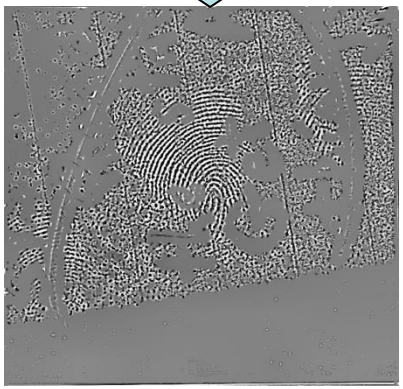


Level 3
(pores, dots)

Segmentation & Enhancement



Latent fingerprint

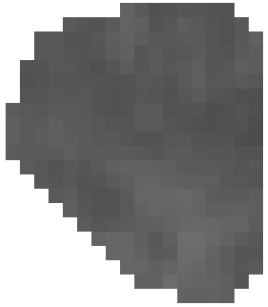


Texture part

Segmented fingerprint

Orientation field

Gabor filter



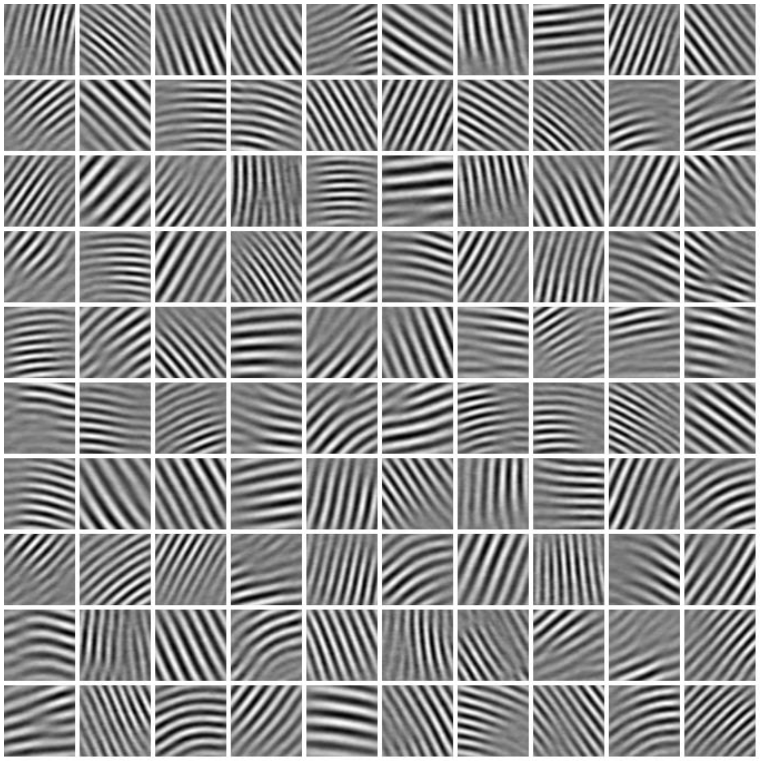
Frequency field

Segmented & enhanced fingerprint

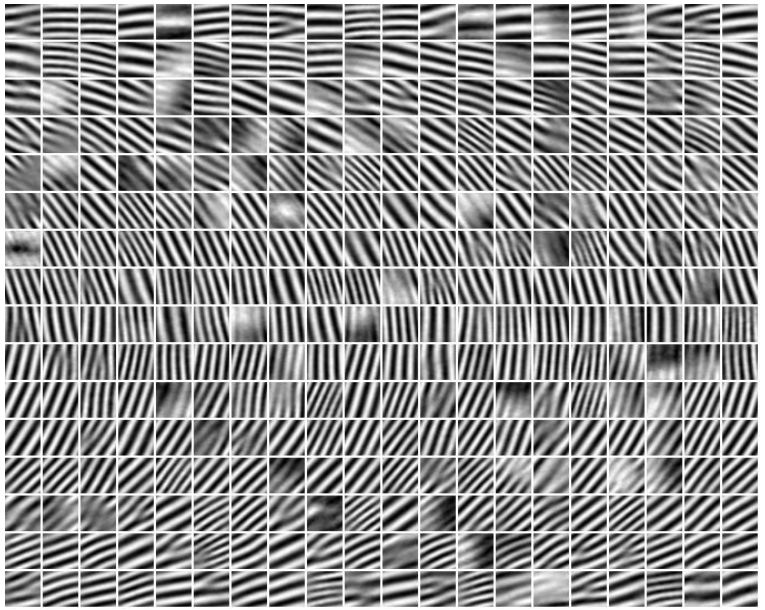
Cao, Liu and Jain, Segmentation and Enhancement of Latent Fingerprints: A Coarse to Fine Ridge Structure Dictionary, PAMI, 2014

Ridge Structure Dictionary

Dictionary used to learn ridge orientation & ridge frequency fields



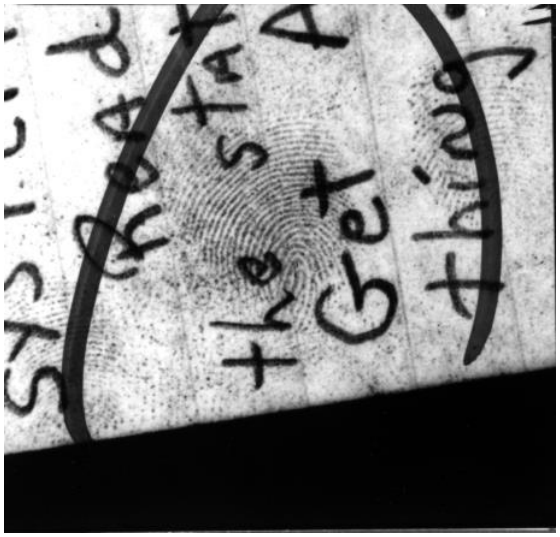
Coarse-level dictionary (patch size: 64×64).
Total number of dictionary element is 1,024



16 orientation specific fine-level dictionaries (patch size: 32×32). Total no. of elements in each orientation specific dictionary is 64.

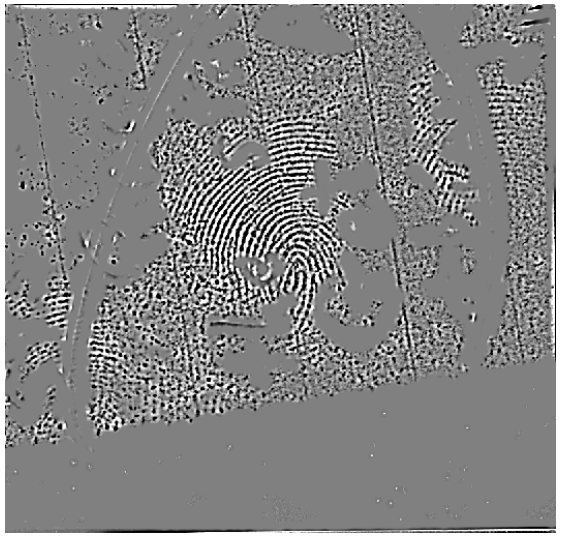
Image Decomposition

Features: Local total variation
Method: Nonlinear decomposition



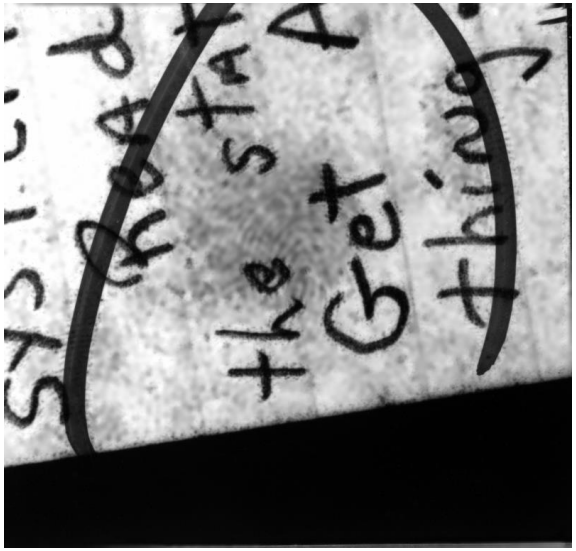
Gray image
(768 x 800)

=



Texture part

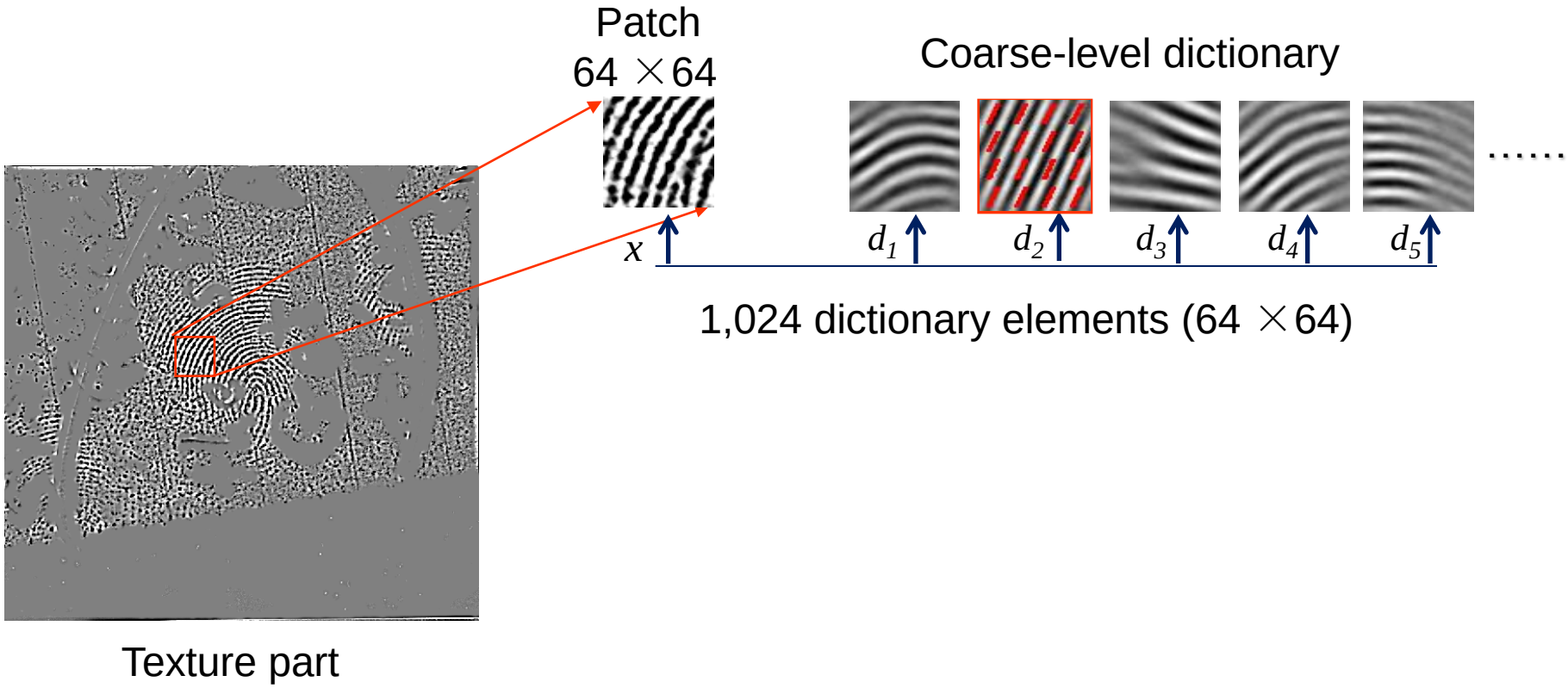
+

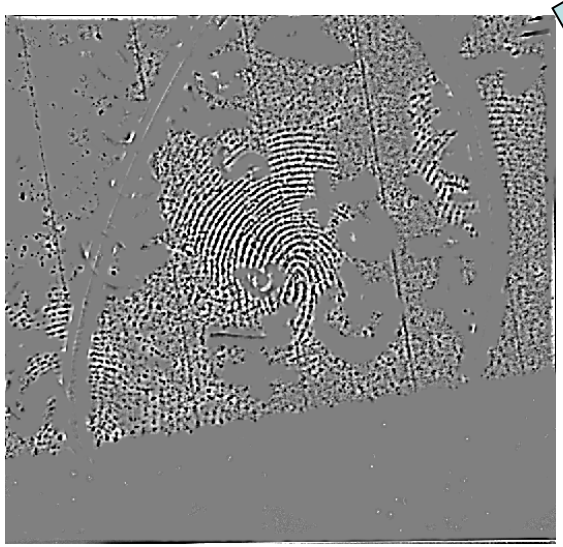


Cartoon part

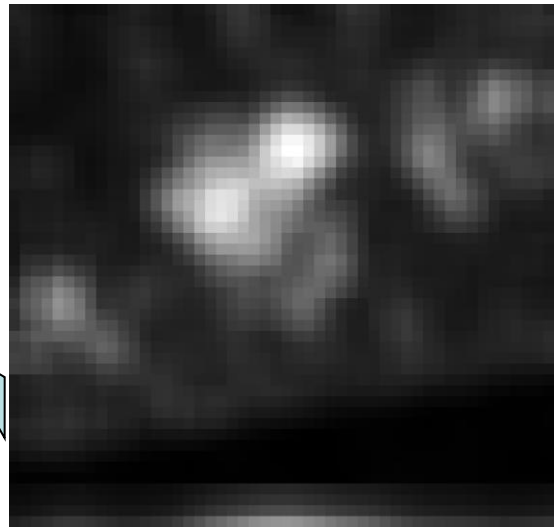
Buades et al, Fast cartoon+texture image filters, IEEE TIP, 2010

Ridge Structure Dictionary

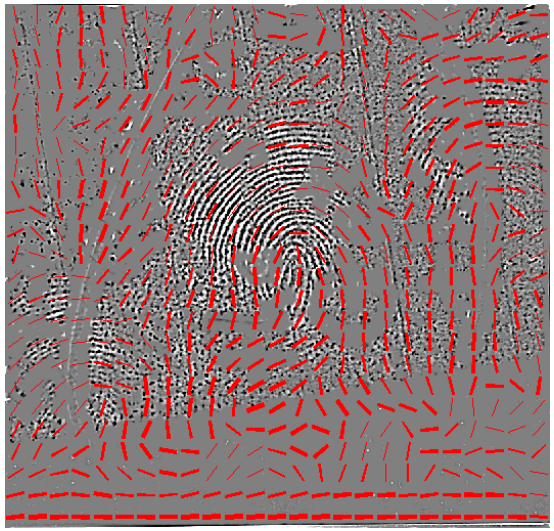




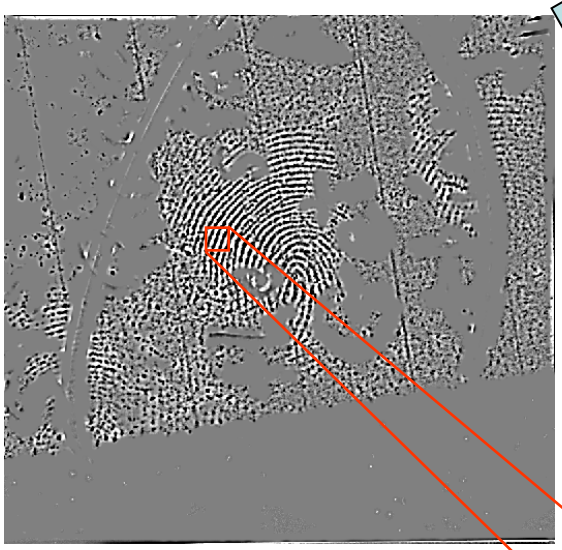
Texture part



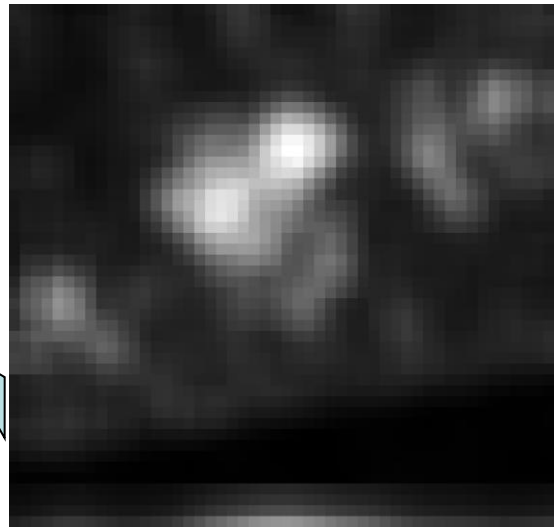
Coarse quality map
(Similarity between image patch and the most similar dictionary element)



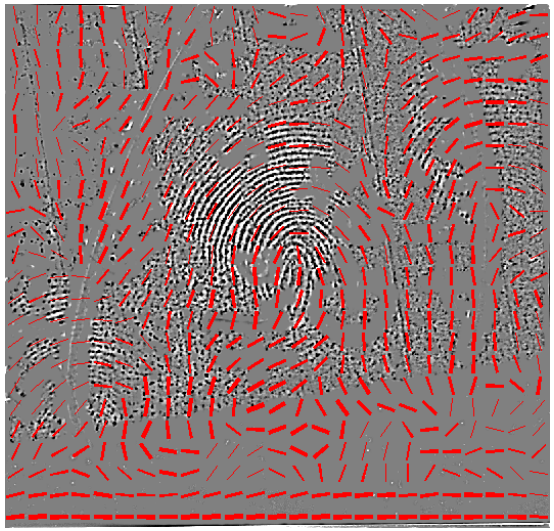
Coarse orientation and frequency fields



Texture part



Coarse quality map

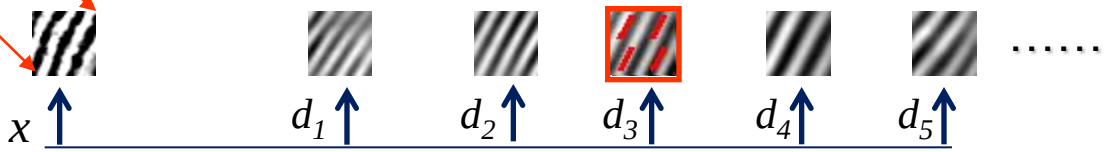


Coarse orientation and frequency fields

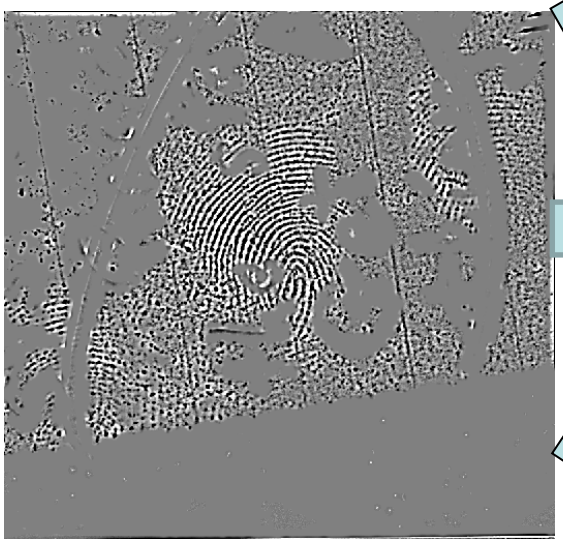
Fine-level dictionary selection

Patch 32 × 32

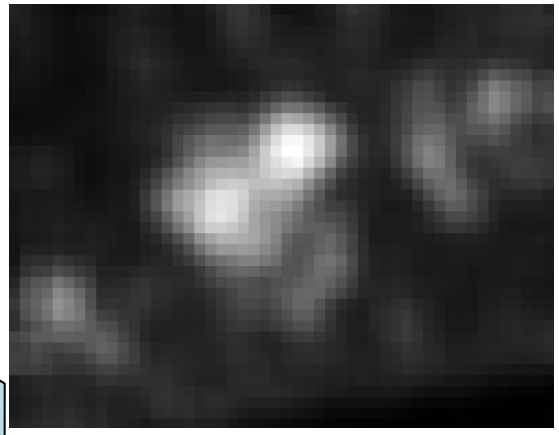
Specific fine-level dictionary

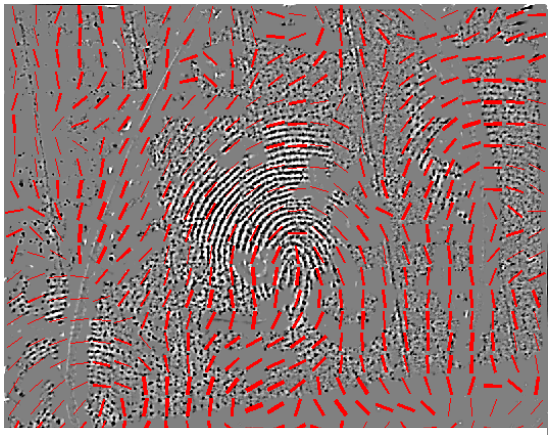


64 dictionary elements for each of 16 orientations



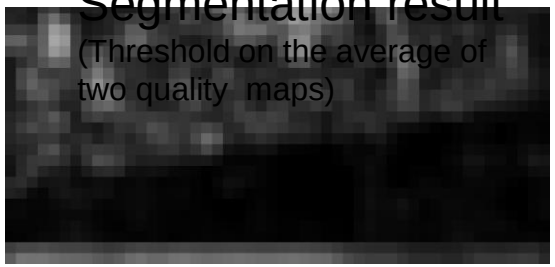
Texture part





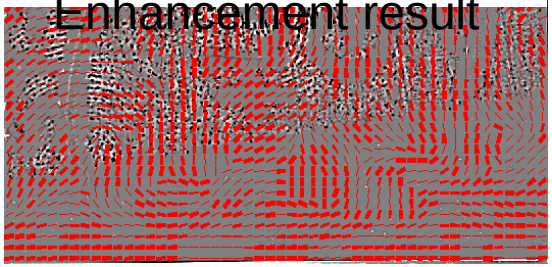
Segmentation result

(Threshold on the average of two quality maps)



Fine quality map

Enhancement result



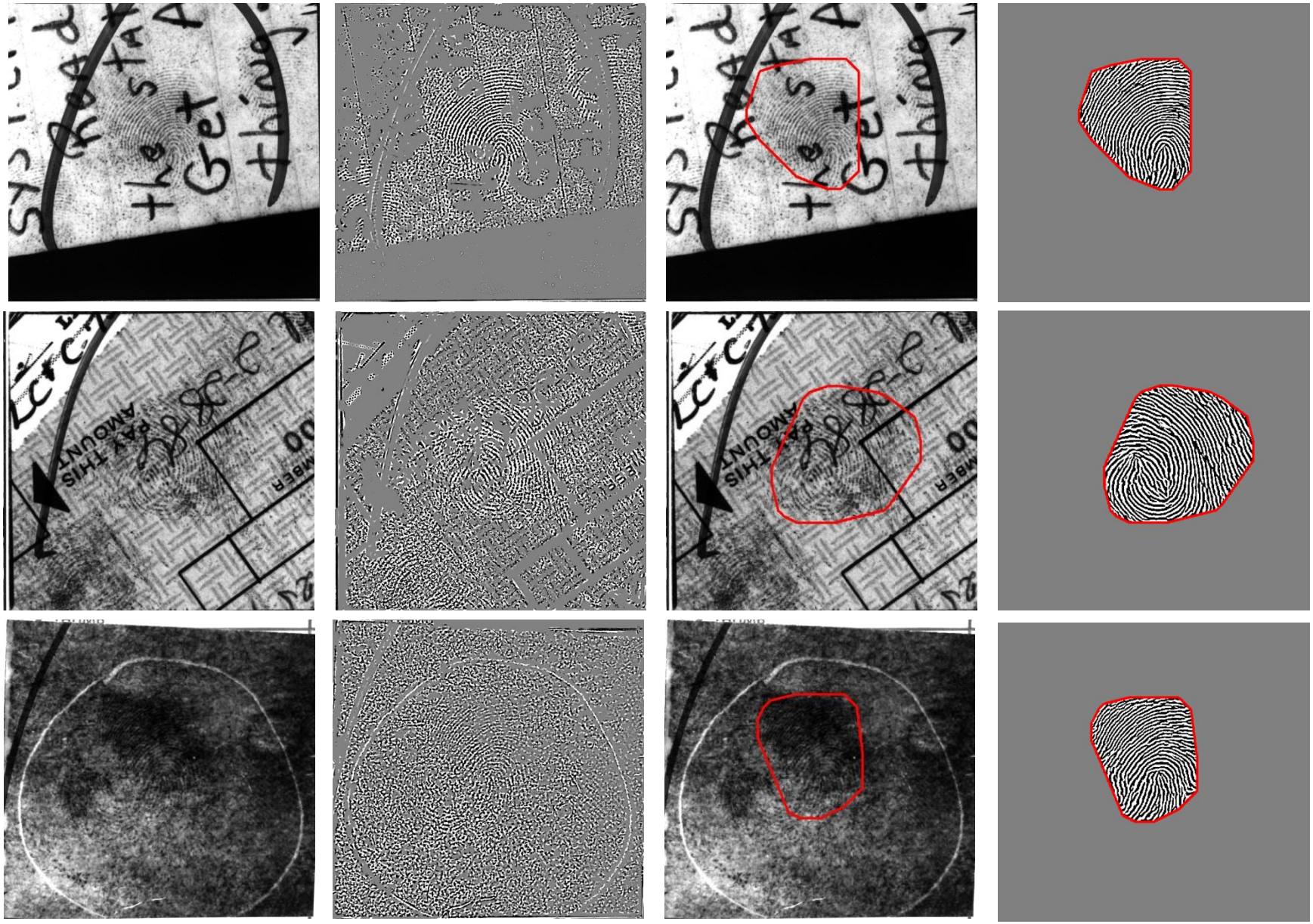
Fine orientation and frequency fields

Results on NIST SD27

Good latent

Bad latent

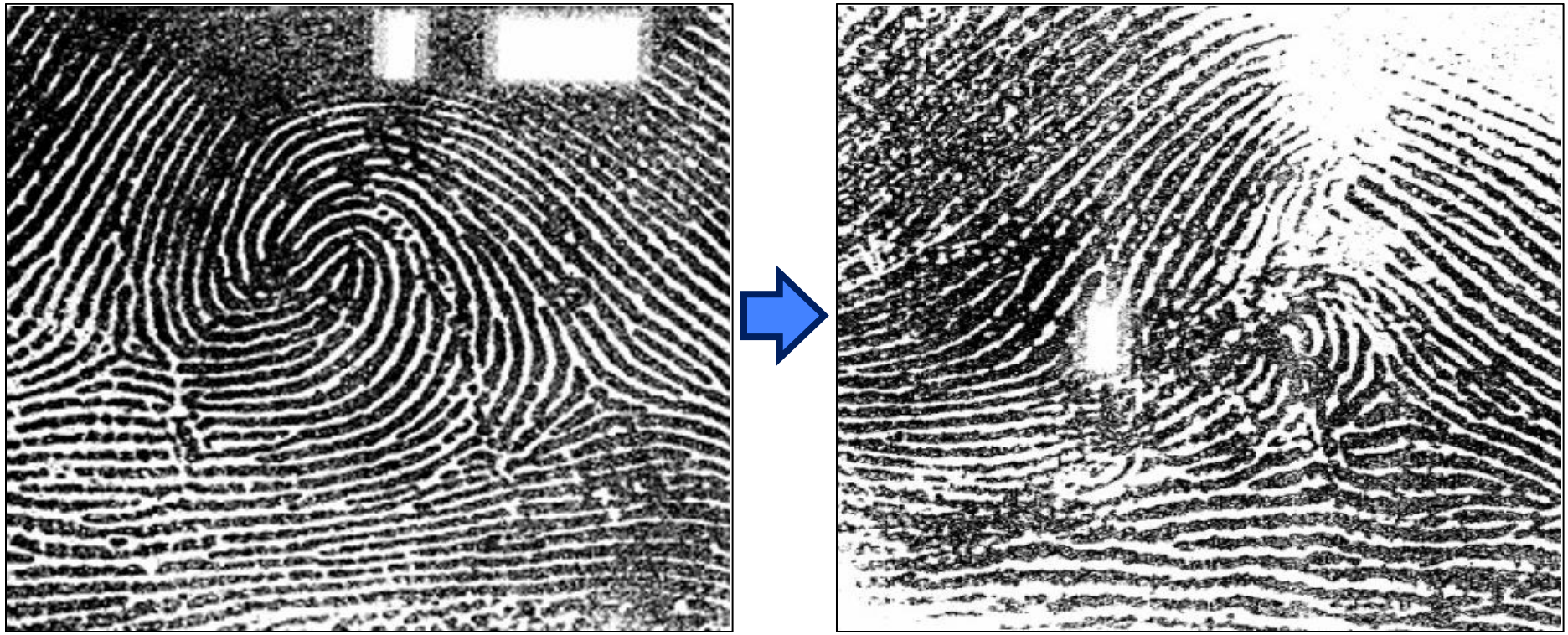
Ugly latent



(a) Gray image (b) Texture image (c) Segmentation (d) Segmentation and enhancement

Fingerprint Alteration: Gus Winkler (1933)

Double-loop changed to left loop



Fingerprint Alteration

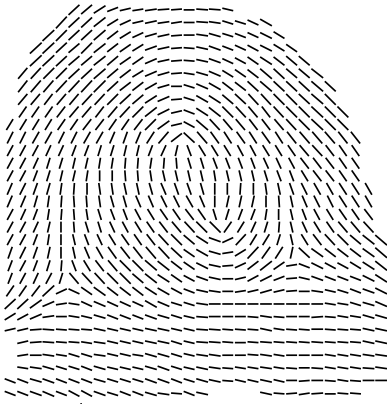
Transplanted from foot[1]

Bitten[2]

- http://www.clpex.com/images/FeetMutilation/L4.JPG
- K. Singh, Altered Fingerprints, 2008.
- "Criminals go to extremes to hide identities," *USA TODAY*, Nov. 6, 2007.
- "Criminals cutting off fingertips to hide IDs," *TheBostonChannel.com*, Mar. 3, 2008.

Altered Fingerprint Detection

- Large orientation field discontinuity
- Non-uniform minutiae distribution



Orientation Field Representation

$$\dot{x} = f(x,y) \qquad \dot{y} = g(x,y)$$

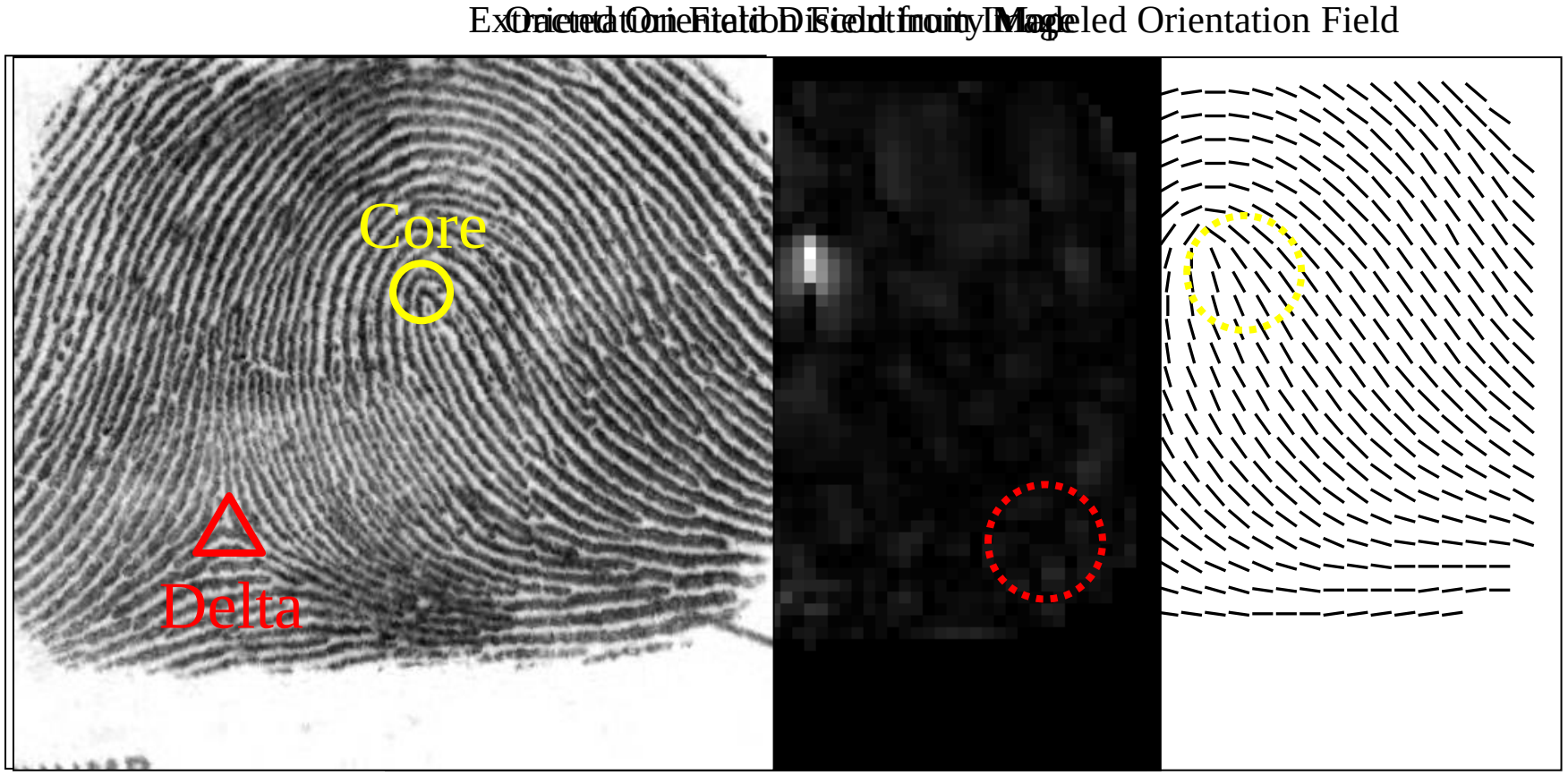
$$\theta(x,y) = \frac{1}{2}\tan^{-1}\left(\frac{\dot{y}}{\dot{x}}\right) = \frac{1}{2}\tan^{-1}\left(\frac{g(x,y)}{f(x,y)}\right)$$

Polynomial Model

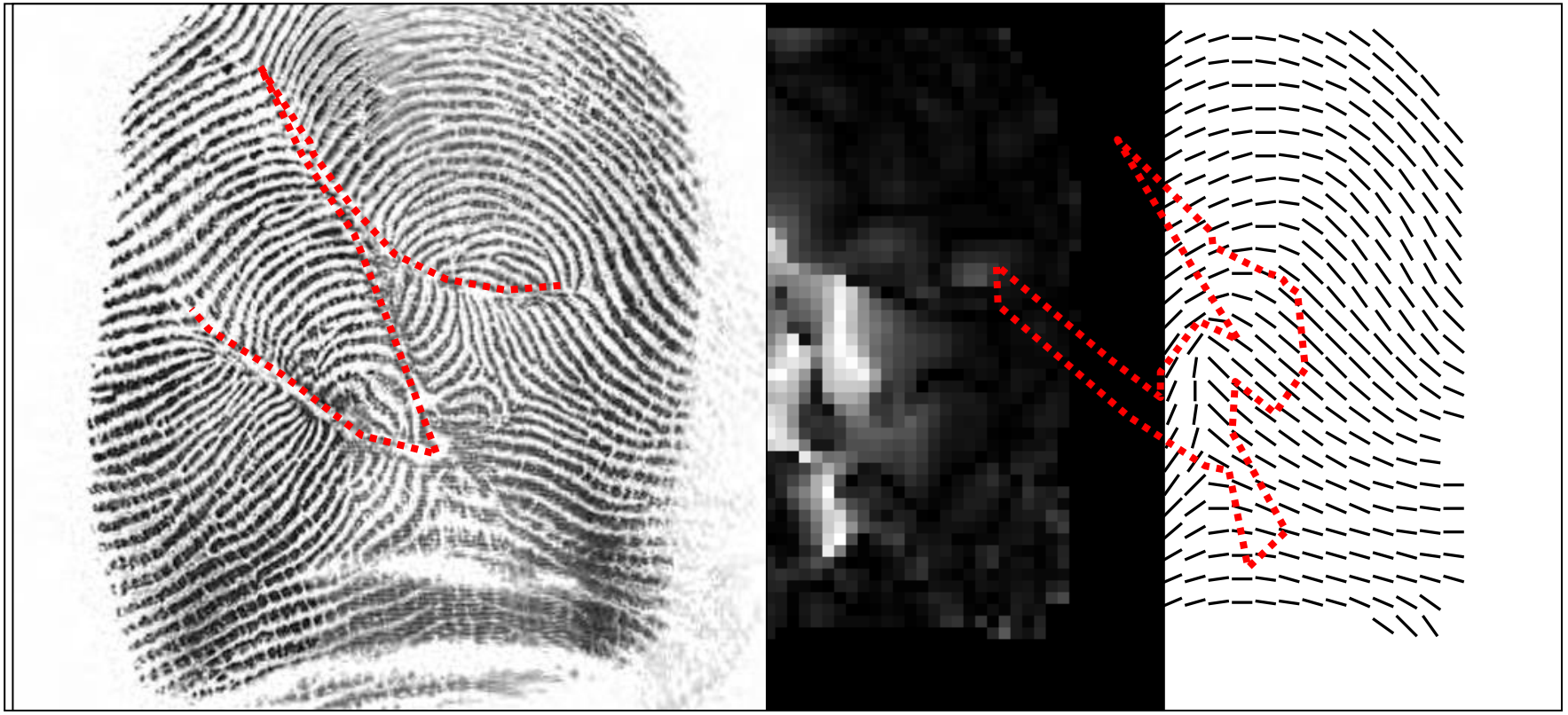
$$f(x,y) = \sum_{k=0}^{n}\sum_{l=0}^{k} a_{kl} x^{k-l} y^{l}$$

$$g(x,y) = \sum_{k=0}^{n}\sum_{l=0}^{k} b_{kl} x^{k-l} y^{l}$$

Natural Fingerprint



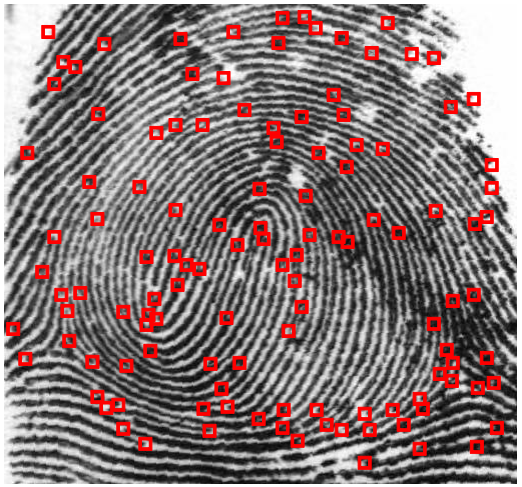
Altered Fingerprint



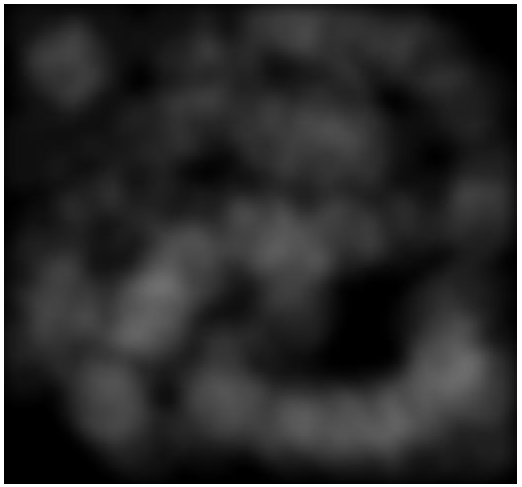
Minutiae Density Map

Natural Fingerprint

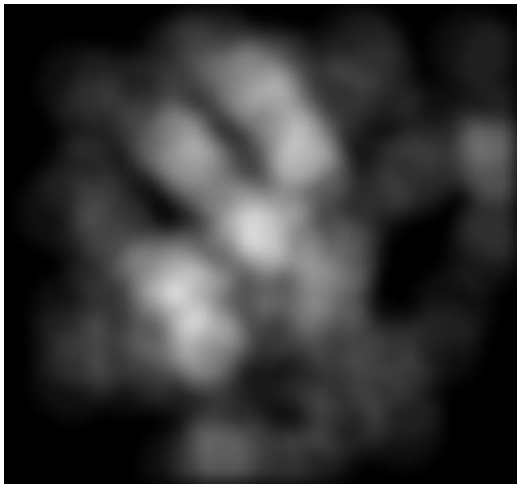
Minutiae



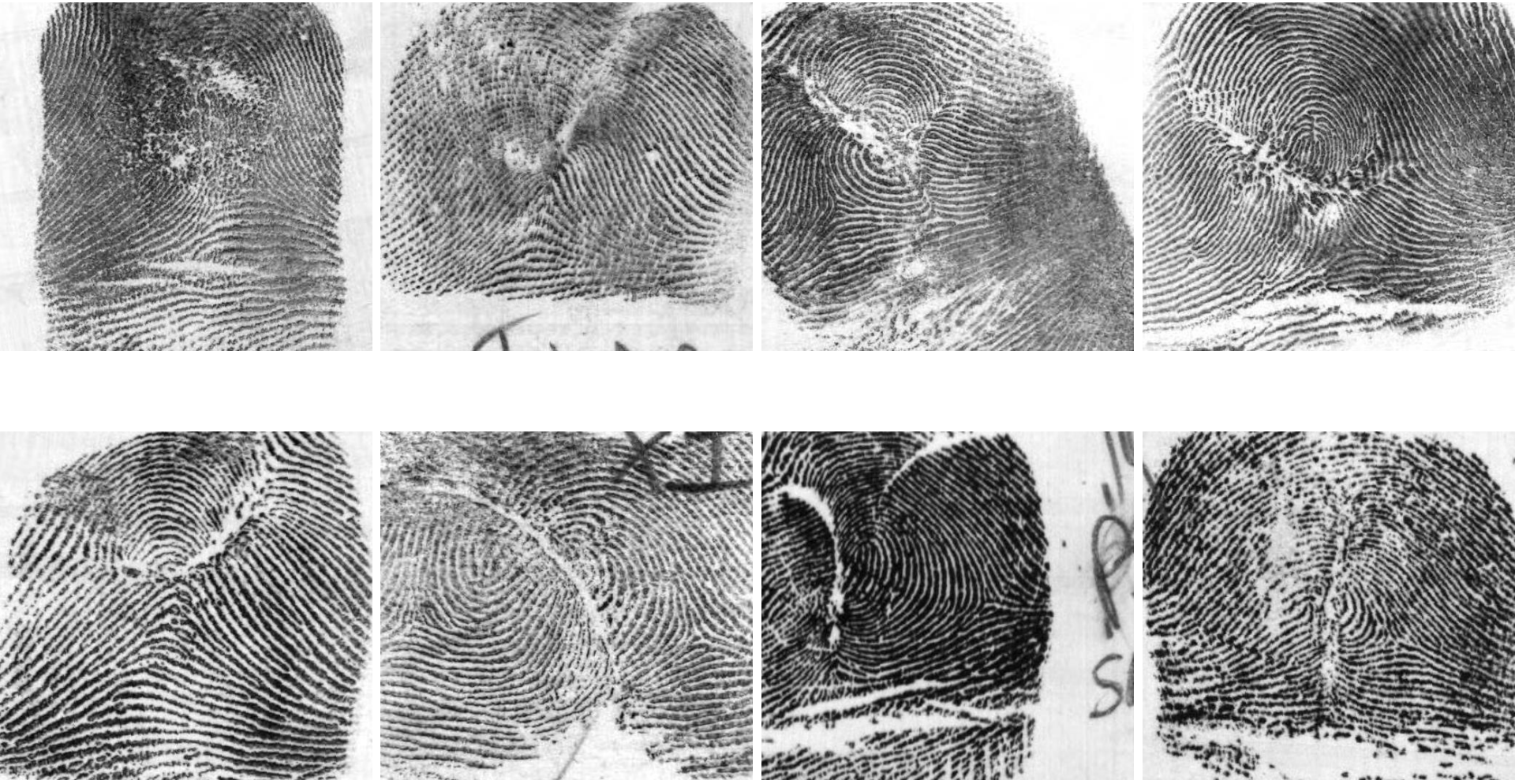
Minutiae Density Map



Altered Fingerprint



Successful Detections



S. Yoon, J. Feng, and A. K. Jain, "Altered Fingerprints: Analysis and Detection", *IEEE Trans.PAMI* Vol. 34, No. 3, pp. 451-464, March 2012.

Tattoos

- 20% of adults have a tattoo (Harris Poll of 2,016 adults, Jan, 2012)
- Adults aged 30-39 are most likely to have a tattoo (38%)

(a)

(b)

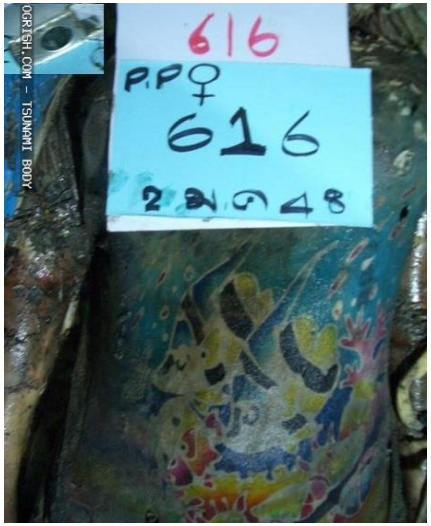
(c)

(d)

(a) Tattoo used by sailors in the British navy, (b) 18th street gang tattoo, (c) religious tattoo, (d) tattoo related to 9/11 terrorist attack

http://www.harrisinteractive.com/NewsRoom/HarrisPolls/tabid/447/mid/1508/articleId/970/ctl/ReadCustom%20Default/Default.aspx

Victim & Suspect Identification



(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

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)

MICHIGAN STATE UNIVERSITY
TATTOO ID
AUTOMATIC TATTOO IMAGE RETRIEVAL SYSTEM
Tattoo Retrieval
Tattoo Matching
Browsing
Miscellaneous
Settings
Update
Exit Program
Exit
Search
Browse
Search
Email
Move
Properties
Quit
Query
Tattoo Location
Find
Gender
Race
Tattoo Class
Human
Animals
Plants
Flags
Objects
Abstract
Symbols
Other
Search
From File
From Camera
Localization
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16
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15
15
15

Feature Extraction & Matching

- Extract and match keypoints
- *Similarity* based on no. of matched keypoints

Lee, Tong, Jin, and Jain, "Image Retrieval in Forensics: Tattoo Image Database Application", *IEEE Multimedia*, Vol. 19, No. 1, pp. 40-49, 2012.

FTW
AMI EVIL

Successful Retrievals

Summary

- Biometrics Recognition is becoming a necessary component of any identification technology
- Biometrics is the only way to ensure that the same person does not have multiple documents (e.g., driver license, passport)
- System requirements (application dependent): error rate, template size, usability, resistance to attacks, exception handling, throughput, seamless integration, return on investment,…

Dan Wasserman

The Bostom Globe, Jan 22, 2014