Some Challenges in Forensics: Facial Sketch, Latent Prints & SMT

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

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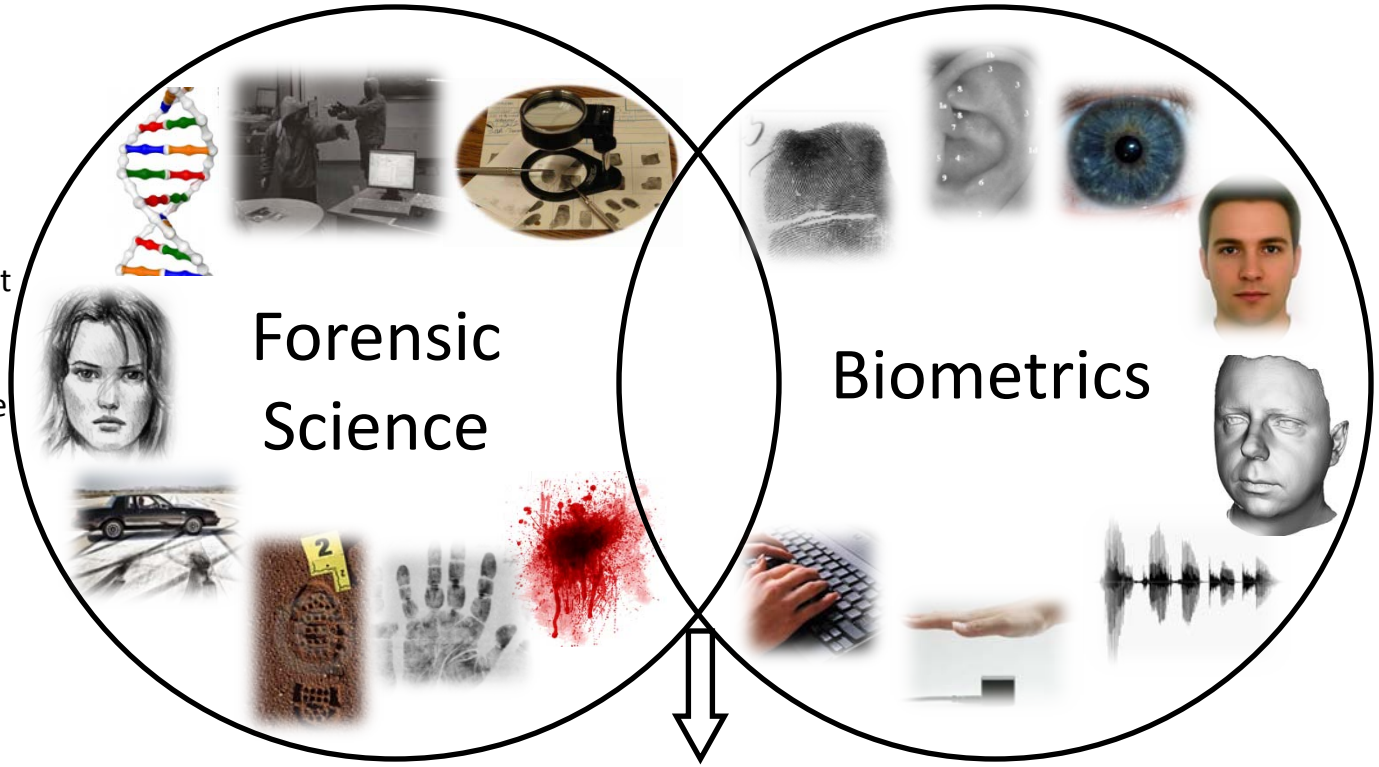
Forensics and Biometrics

- 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 or persons

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

Paradigm Shift in Forensic Science

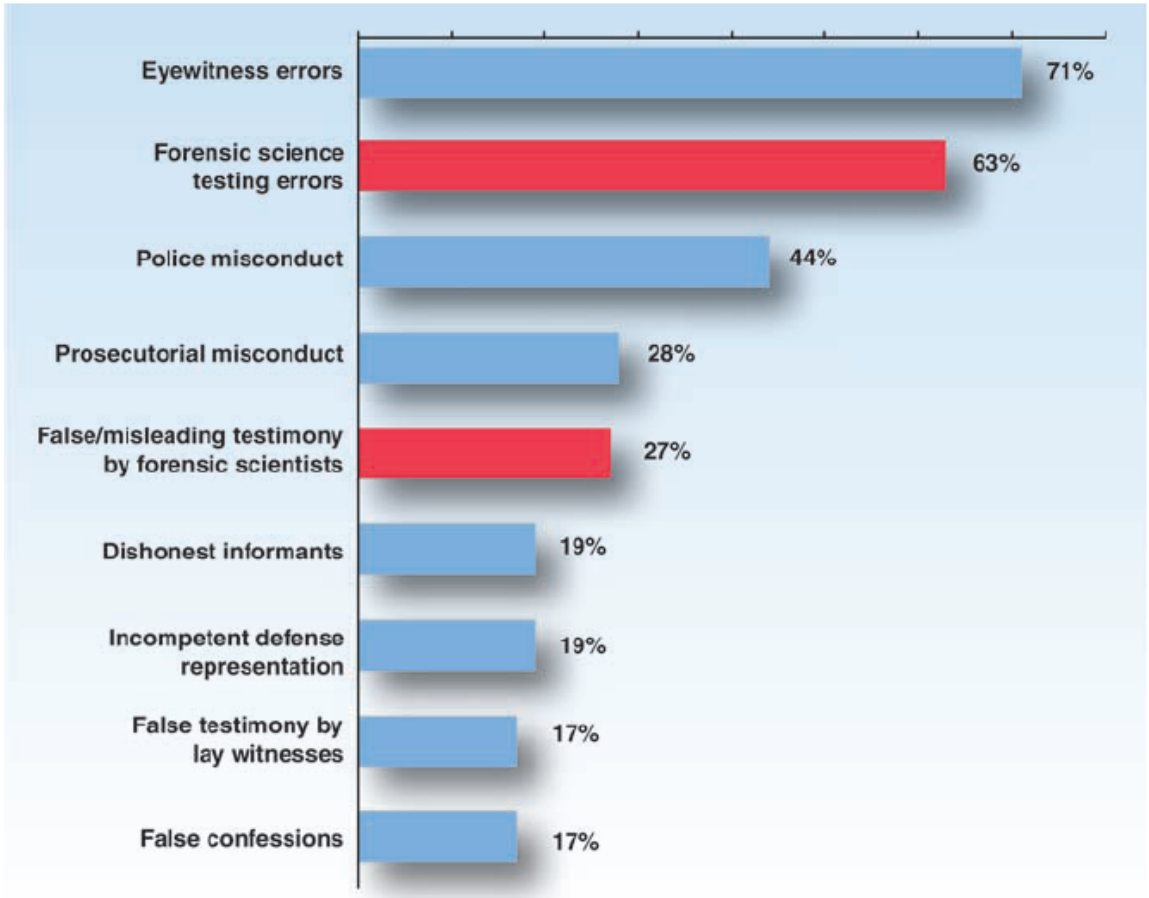


Fig. 1. Factors associated with wrongful conviction in 86 DNA exoneration cases, based on case analysis data provided by the Innocence Project, Cardozo School of Law (New York, NY), and computed by us. Percentages exceed 100% because more than one factor was found in many cases. Red bars indicate factors related to forensic science.

"The time is ripe for the traditional forensic sciences to replace antiquated assumptions of uniqueness and perfection with more defensible empirical and probabilistic foundation."

1. Saks and Koehler, The coming Paradigm Shift in Forensic Identification Science, Science, Aug 5, 2005
2. Strengthening Forensic Science in the United States: A Path Forward. National Academies Press, 2009

Outline

- Face Recognition
  - Sketch to photo matching
- Soft Biometrics
  - Scars, Marks & Tattoos (SMT)
- Fingerprint Matching
  - Latent fingerprint matching
  - Latent palmprint matching
- Summary

Meridian Township Police Release Sketch of Bank Robbery Suspect

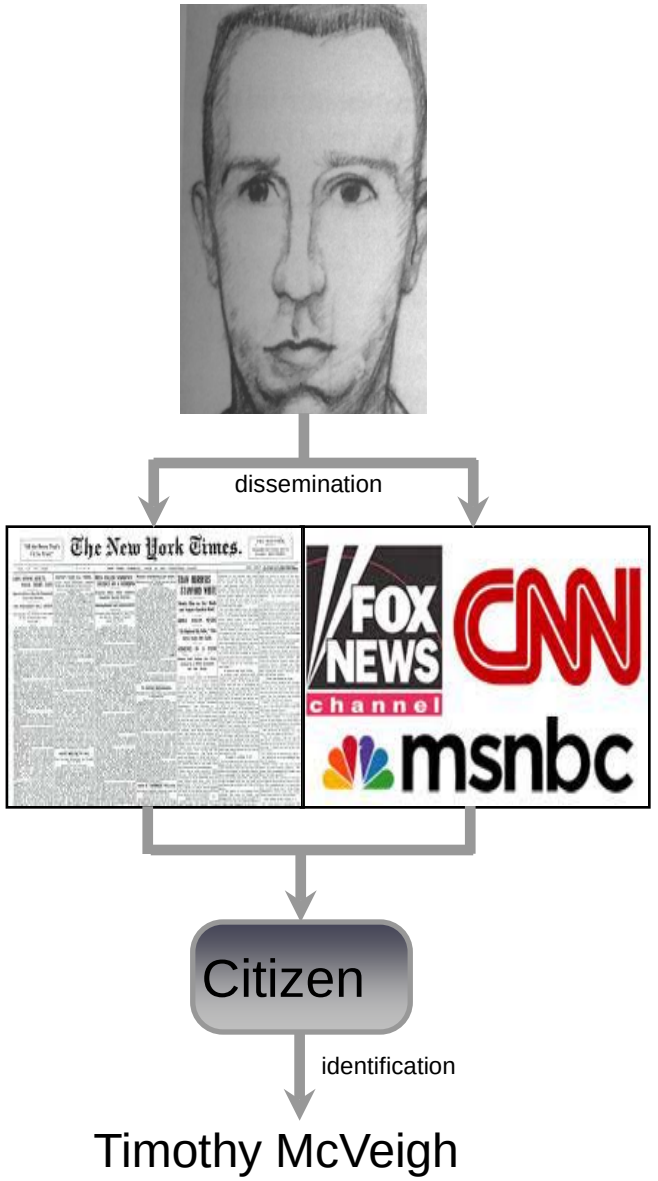
(Lansing State Journal, March 27, 2013)

- Police have released a composite sketch of a suspect in bank robbery
- The suspect is described as a white man in his mid-20s wearing a driver-type cap, mirrored sunglasses, Khaki pants and white Nike athletic shoes
- He had a thin build and was about 5 feet, 10 inches tall

http://www.lansingstatejournal.com/article/20130326/NEWS01/303260027/Meridian-Township-police-release-sketch-bank-robbery-suspect?nclick_check=1

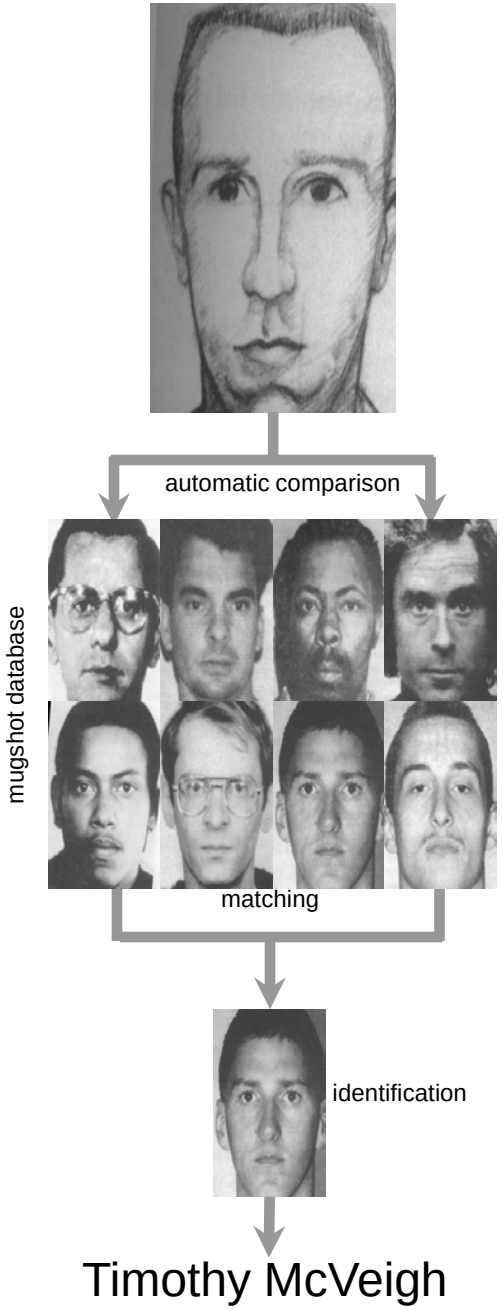
Current Approach

- Witness/victim provides a description of suspect to a police artist who generates a forensic sketch
- Law enforcement agencies disseminate a sketch to media
- Citizens provide tips about suspect's identity
- Slow and tedious process



Proposed Approach

- Match facial sketches against mugshot database automatically
  - Holistic approach (Klare & Jain[1])
  - Component approach (Han et al.[2])
- Training set:
  - 239 (facial sketch, mugshot) pairs

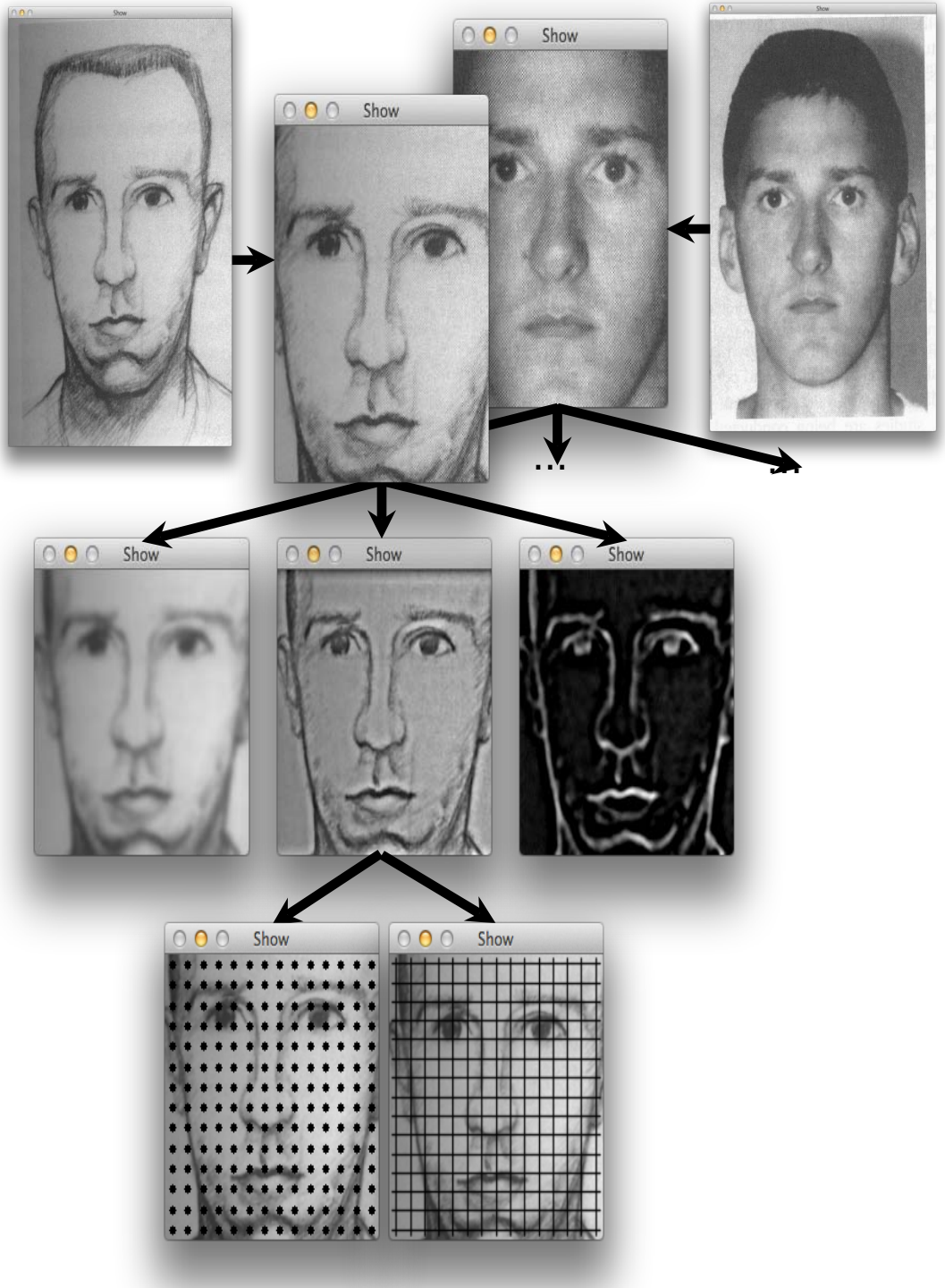


[1] B. Klare, Z. Li, and A. Jain, “Matching forensic sketches to mug shot photos,” IEEE Trans. PAMI, vol. 33, pp. 639–646, March 2011.

[2] H. Han, B. Klare, K. Bonnen, and A. Jain, “Matching composite sketches to face photos: A component based approach,” IEEE Trans. IFS, vol. 8, no. 1, 2013

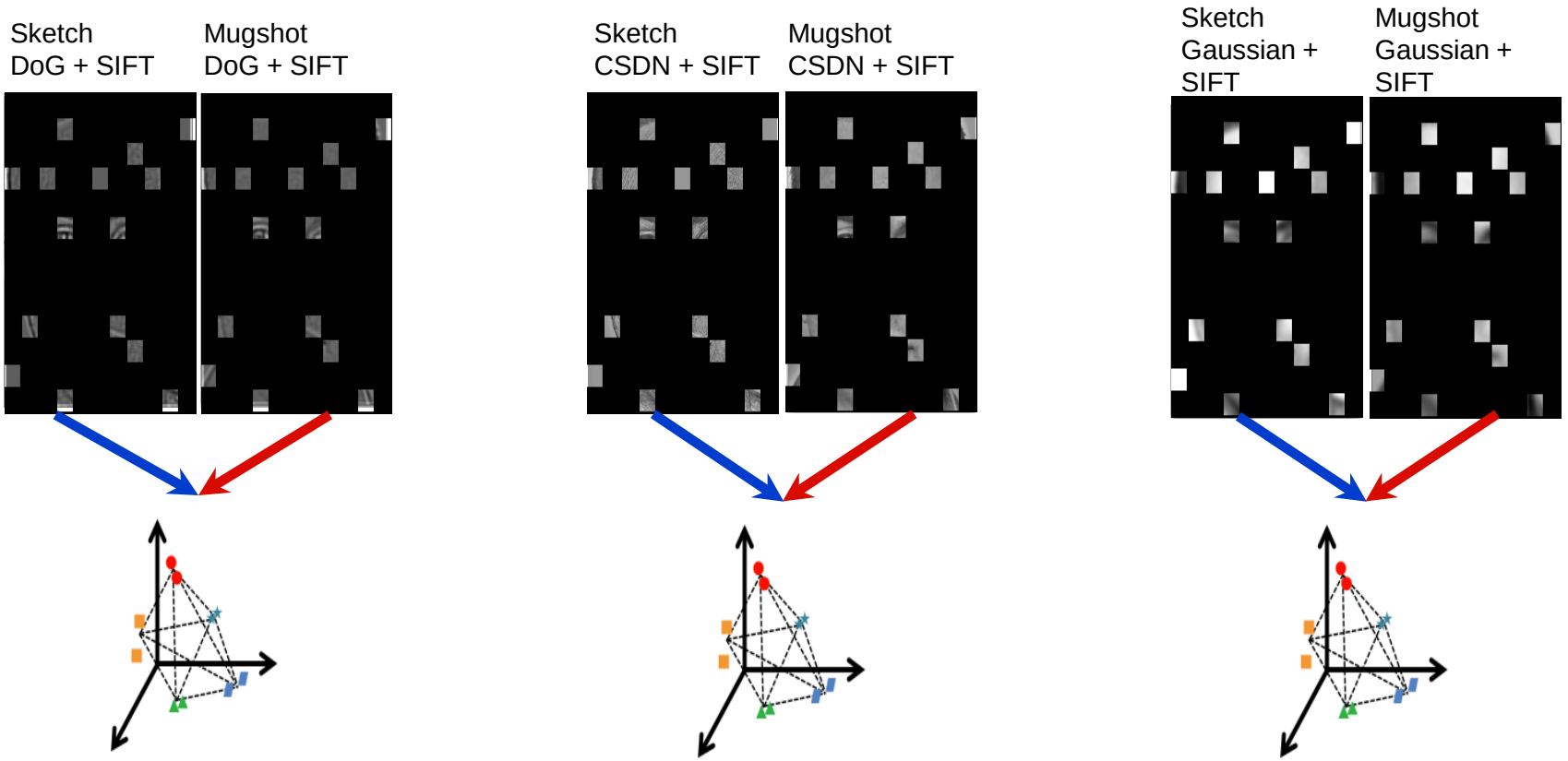
Holistic Matcher

- Scale and rotate image/sketch based on eye locations
- Convolve with 3 filters: DoG, CSDN, and Gaussian
- For each filter, use
  - Grid of key points to extract SIFT features
  - Rectangular blocks to extract MLBP features



Random Sample Linear Discriminant Analysis

Holistic Matcher

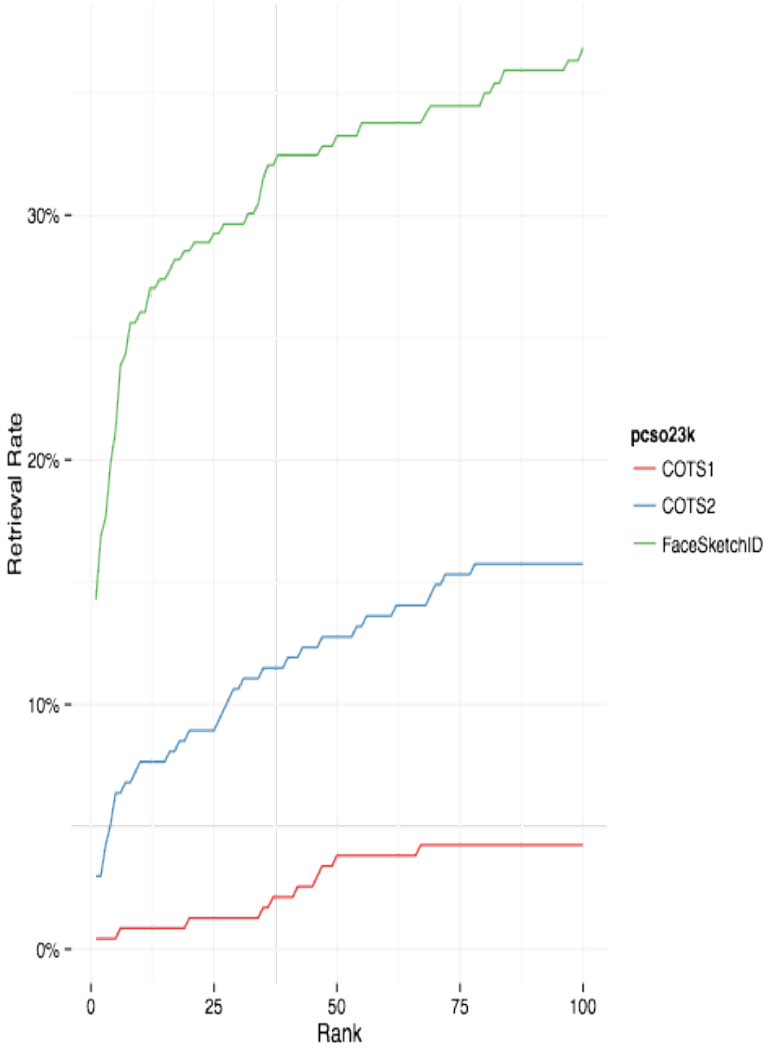


A subspace projection is learnt for each bag of patches. Final representation is a concatenation of all learnt representations. An analogous process is used for all MLBP filter/descriptor combinations.

FaceSketch ID System

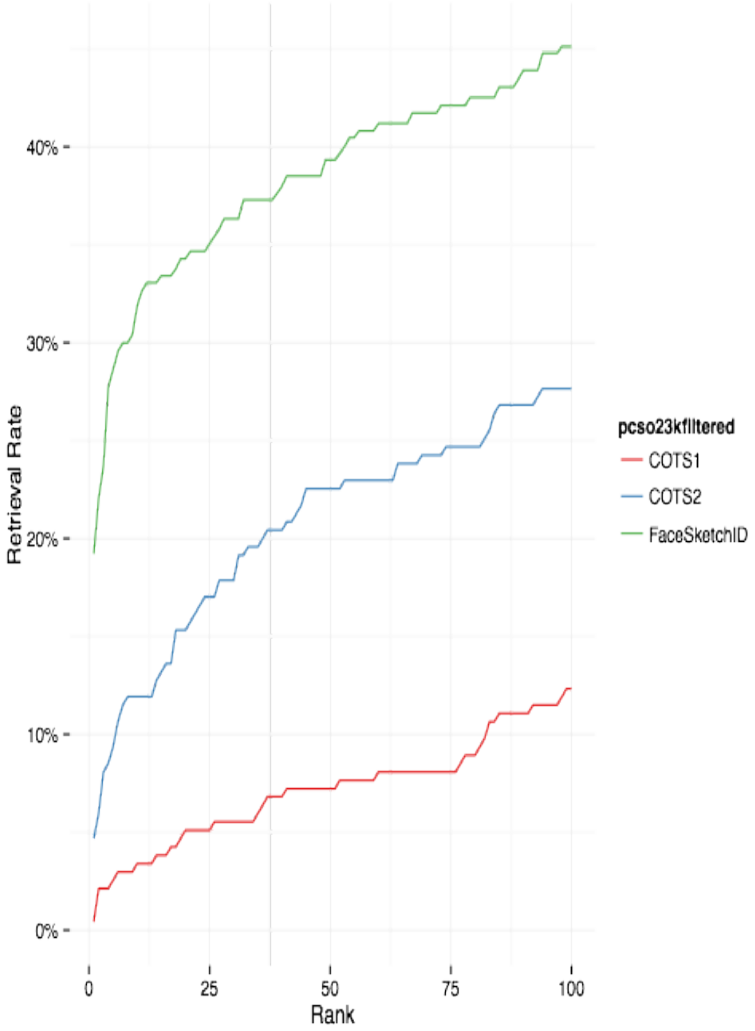
Forensic Sketch to Photo Matching

- 239 (sketch, mugshot) pairs based on prior arrests;10-fold cross validation results
- 23K additional face images added to the gallery from a mugshot database
- Baseline matchers: Two COTS systems

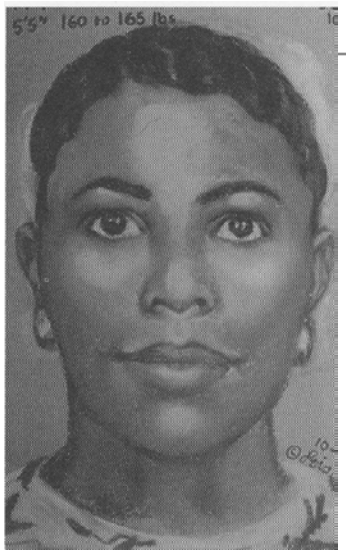


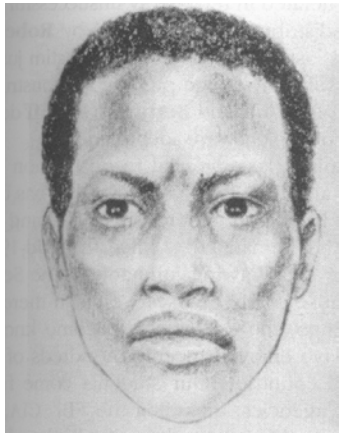
Filtering Using Demographics

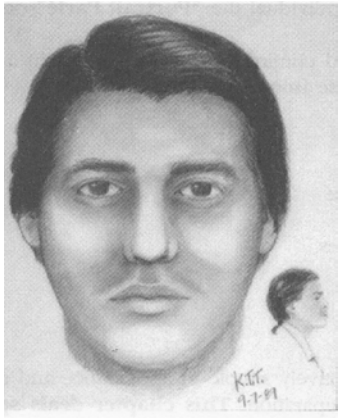
- Age
  - Witness estimates range of suspect (e.g. 20-30), true age is assigned to be mean of the range
- Race
  - White, Black, Hispanic, Asian, other
- Gender

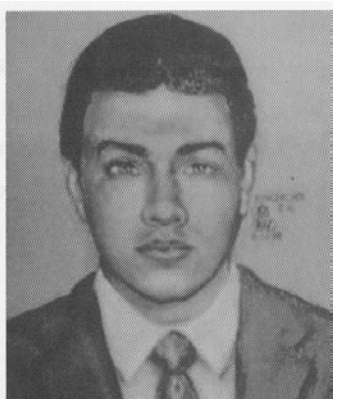


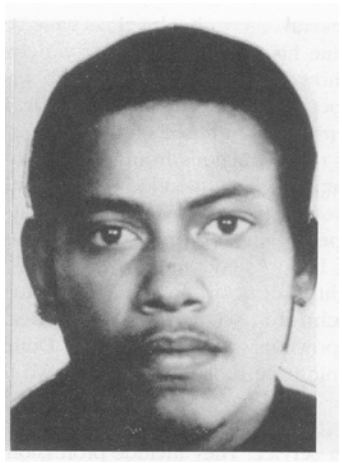
Successful Matches at Rank 1

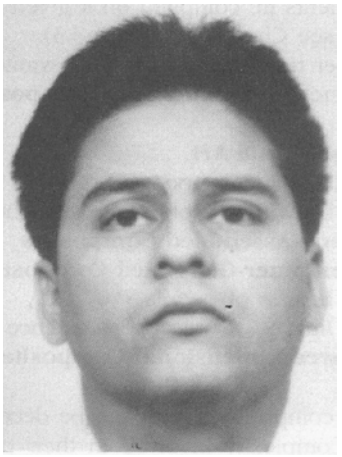


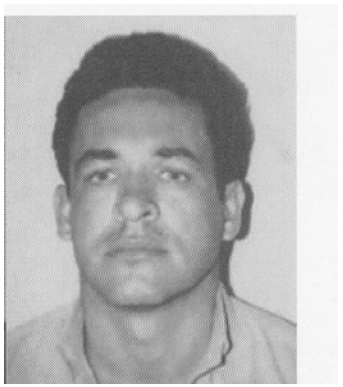






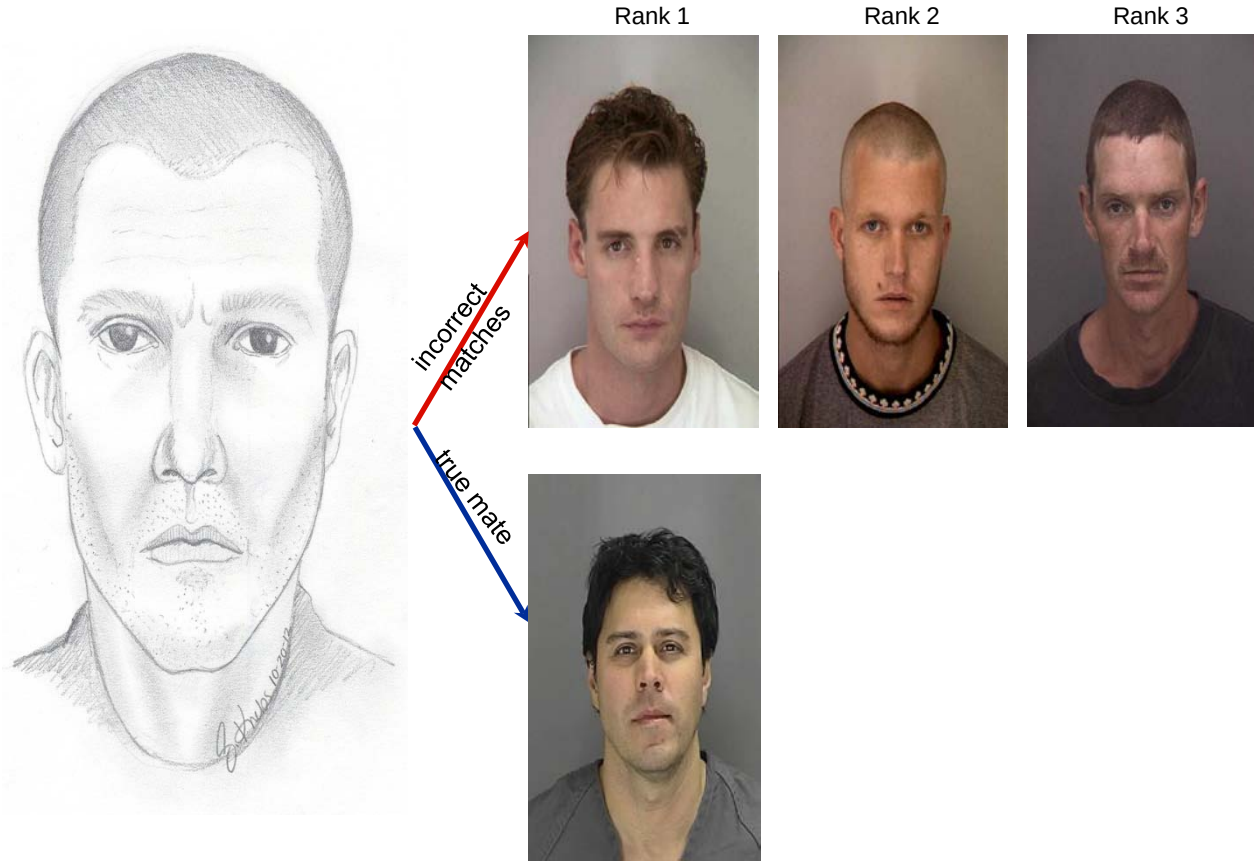






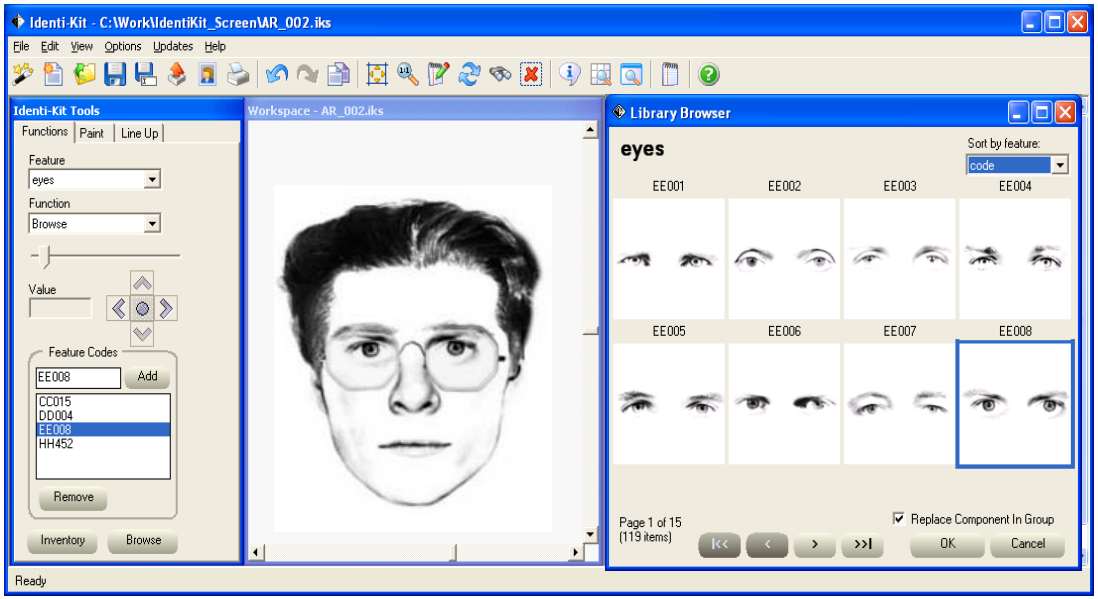
Unsuccessful Matches

- Mugshots retrieved at a low rank often look more like the sketch than the true mate



Composite Sketches

- Composite sketches are created using a facial composite software; not by a sketch artist



The figure and software are from Identi-Kit Solutions.

Forensic vs. Composite Sketches

(a)

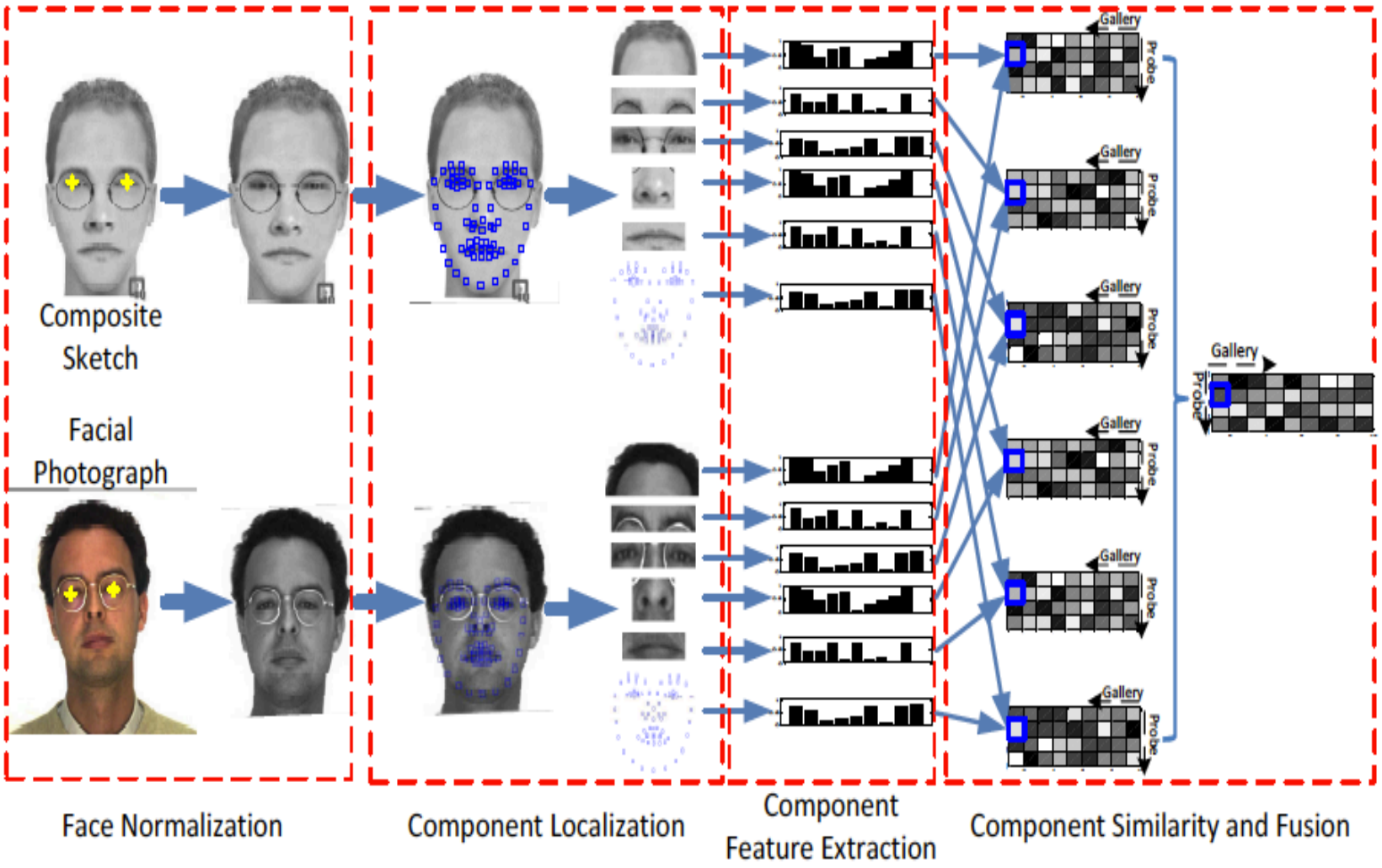
(b)

(c)

We have created a (forensic sketch, composite sketch, mugshot) database for 75 subjects[3]

[3] S. Klum, H. Han, and A. Jain, “Sketch Based Face Recognition: Forensic vs. Composite Sketches ,” International Conference on Biometrics, 2013 (to appear).

Component Representation & Matching




TEXAS
LONGHORNS
Texas
Tattoo-ID

Soft Biometrics

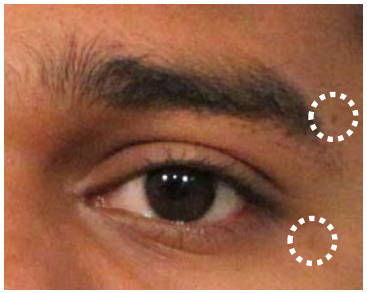
Provide some discriminatory information; can be used alone or in conjunction with primary traits

Ethnicity, Gender, Skin & Hair color
(Sub-Saharan African, Indian, Southern European, and Northwest European)

Height

Eye color

Scars, Marks, and Tattoos (SMT)



Periocular

Weight

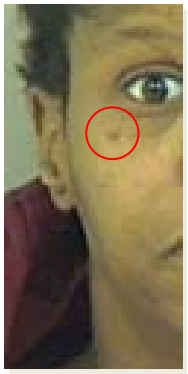
‘Adults Only' Vending Machine

iSample machine distributes new dessert (**Temptations)** but will refuse to serve children

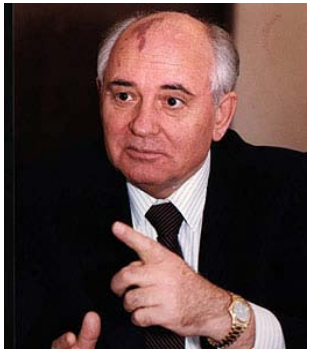
Machine 'looks' at consumers via a webcam, and reads details (age, gender and time in front of the machine)

http://www.dailymail.co.uk/sciencetech/article-2079048/Kraft-unveils-adults-vending-machine-scans-faces-ensure-children-free-pudding.html

Facial Marks



Partial face



Large birth mark

Non-frontal video frame

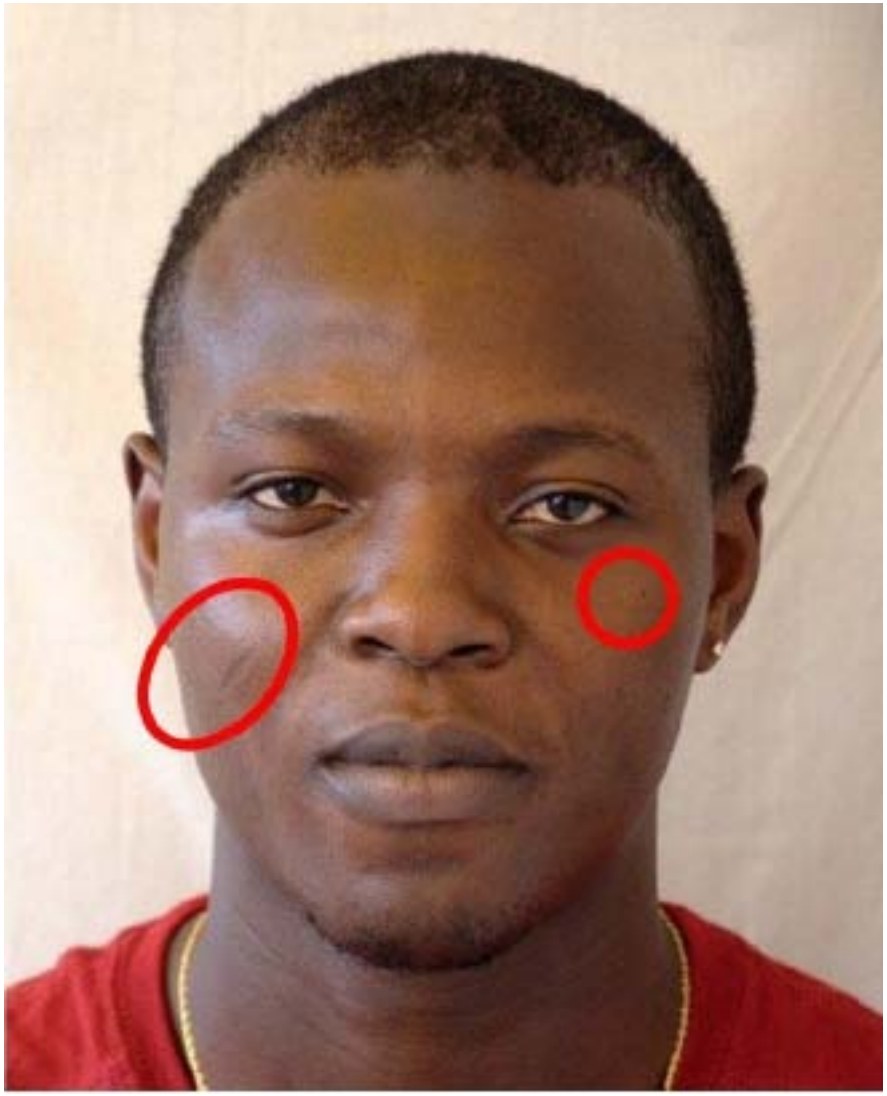
Tattoo

Identical Quadruplets

Haircuts help to avoid confusion among the four six-year-old twins

http://www.cbsnews.com/8301-503543_162-57508537-503543/chinese-mom-shaves-numbers-on-quadruplets-heads/

Face Marks



A pair of identical twins that could only be distinguished by face marks

Tattoo Parlors

Tattoo Culture in Los Angeles Perseveres Through Rough Economy

http://www.neontommy.com/news/2011/09/tattoo-industry-remains-strong-los-angeles-1

One in Five U.S. Adults Now Has a Tattoo

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

(a)

(b)

(c)

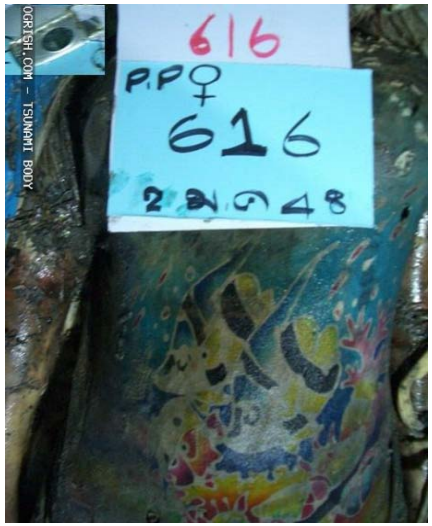
(d)

(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 Identification

- Tattoo may be the only clue to identify victims



(a)

(b)

(c)

(d)

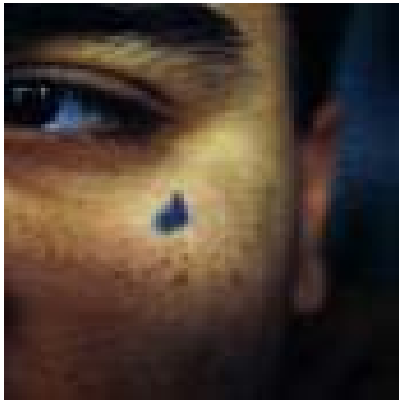
Tattoo on (a) Asian tsunami (2004) victim, (b) victim of 9/11 terrorist attack, (c) body of an unidentified murdered woman, and (d) body part found in a Florida state park

Suspect Identification

- Tattoos often imply gang membership and previous convictions

(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)

Gang Tattoos

Skull, Russia

Black Power, New Zealand

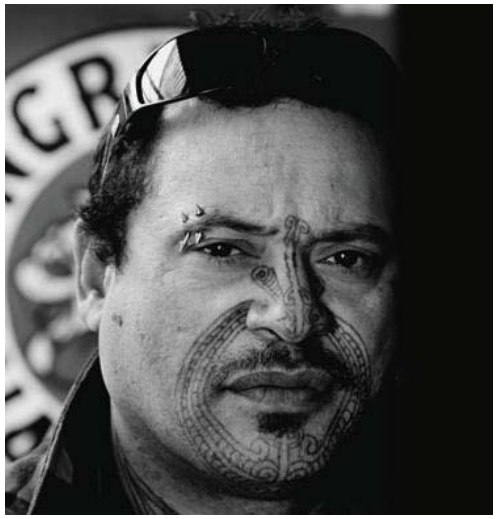
Asian Boyz, China

Norteno Killer, Mexico

A juvenile gang, Bag-snatchers, Thailand

Mafia, Italy

Gang Tattoos



Mongrel Mob, New Zealand

Yakuza, Japan

ACAB, The United Kingdom

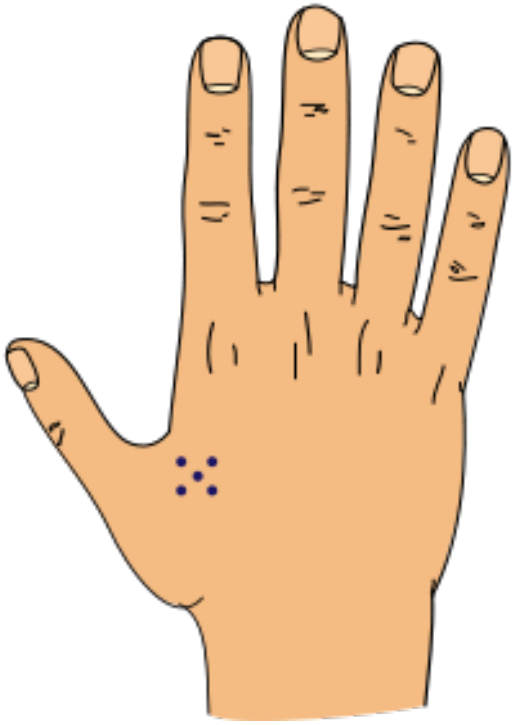
Chinese Triads, China

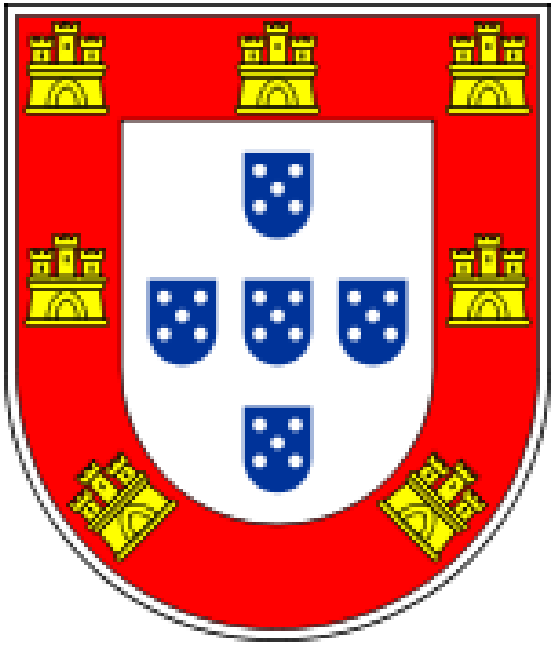
The Nazi Bike Gangs, Germany

The Numbers, South Africa

Five Dots Tattoo

The five dot pattern occurs on the five shields (themselves arranged in a quincunx) on the flag of Portugal, which represent the five Holy Wounds inflicted upon Jesus during his crucifixion. In American and Canadian prisons the tattoo is worn by many Portuguese-North American inmates. This tattoo was also sometimes formerly worn by members of the Portuguese army on the hand or shoulder. It is also prevalent as a Portuguese-American and Portuguese-Canadian street tattoo.





http://en.wikipedia.org/wiki/Five_dots_tattoo

Tattoo Reveals True Identity

The suspect gave his name as “Darnell Lewis”, but his real name, “Frazier” was tattoed on his neck! He was arrested on four misdemeanor warrants (Dec. 2008, St. Paul)

Tattoo Caught in Surveillance 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/

Tattoo Matching

ANSI/NIST ITL 1-2000 Tattoo Classes

Class description	Class code
Human Forms and Features	HUMAN
Animals and Animal Features	ANIMAL
Plants	PLANT
Flags	FLAG
Objects	OBJECT
Abstractions	ABSTRACT
Insignias & Symbols	SYMBOL
Other Images	OTHER

ANSI/NIST ITL 1-2000 Animal Tattoo Subclasses

Subclass	Subclass code
Cats & Cat Heads	CAT
Dogs & Dog Heads	DOG
Other Domestic Animals	DOMESTIC
Vicious Animals (Lions, Tigers, etc.)	VICIOUS
Horses (Donkeys, Mules, etc.)	HORSE
Other Wild Animals	WILD
Snakes	SNAKE
Dragons	DRAGON
Birds (Cardinal, Hawk, etc.)	BIRD
Spiders, Bugs, and Insects	INSECT
Abstract Animals	ABSTRACT
Animal Parts	PARTS
Miscellaneous Animal Forms	MANIMAL

Retrieval based on 8 major classes; 70 subclasses


Human


Animal


Plant

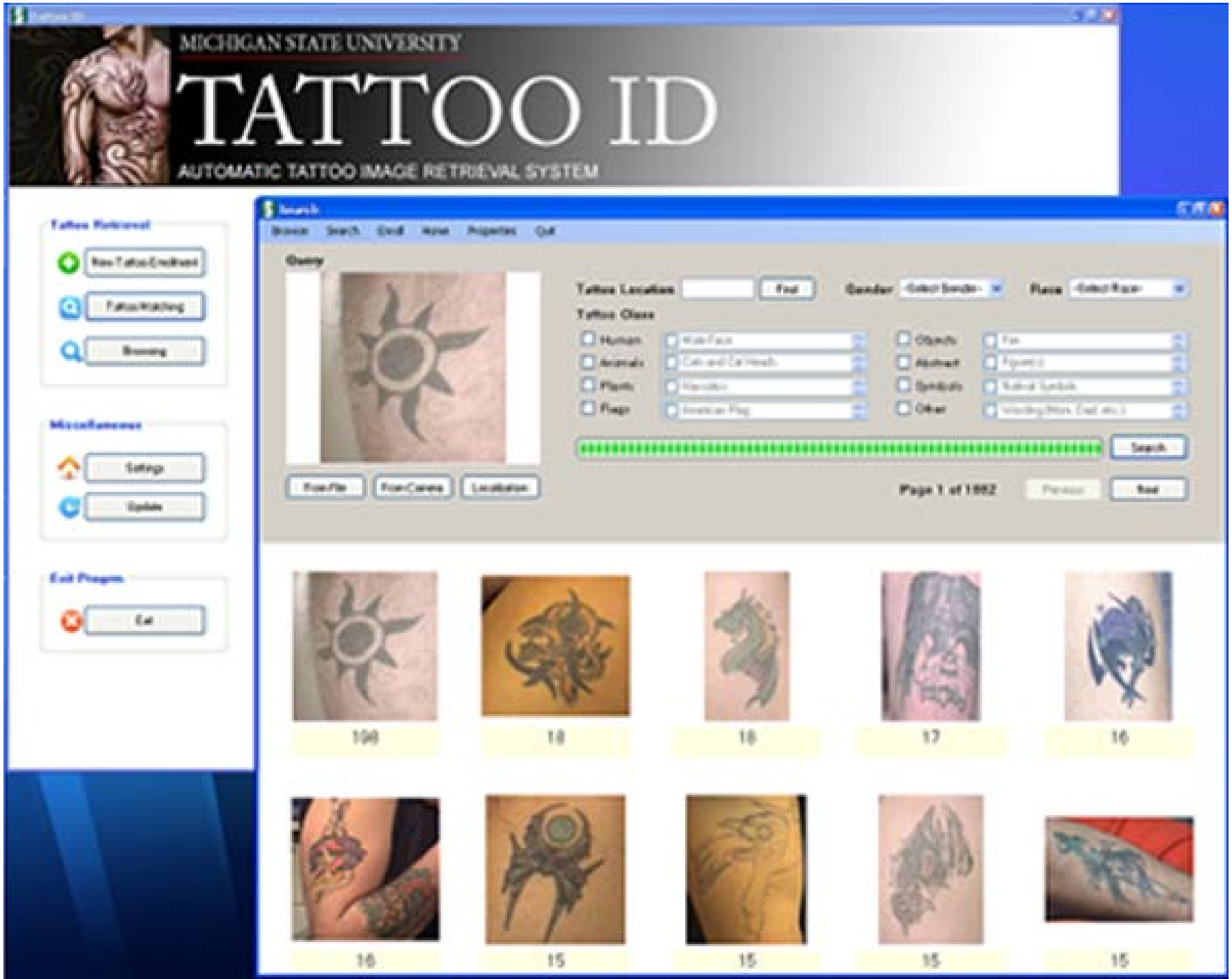

Flag


Object


Abstract


Symbol

Other


MICHIGAN STATE UNIVERSITY
TATTOO ID
AUTOMATIC TATTOO IMAGE RETRIEVAL SYSTEM
Tattoo Retrieval
Miscellaneous
Exit Program
Exit
Query
Tattoo Location
Find
Gender
Race
Tattoo Class
Human
Animals
Plants
Flags
Objects
Abstract
Symbols
Other
Search
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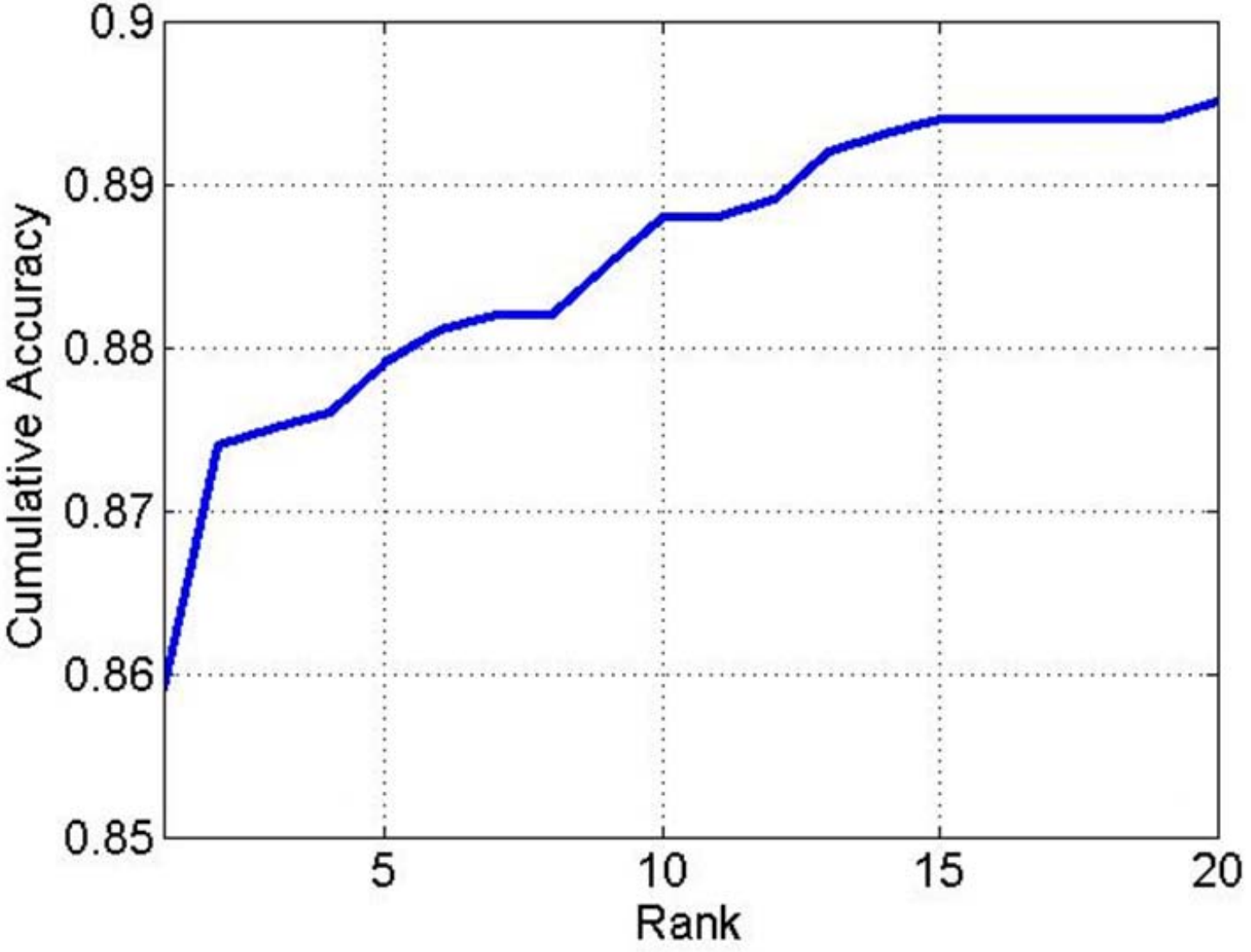
Feature Extraction & Matching

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

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


FTW
AMI EVIL

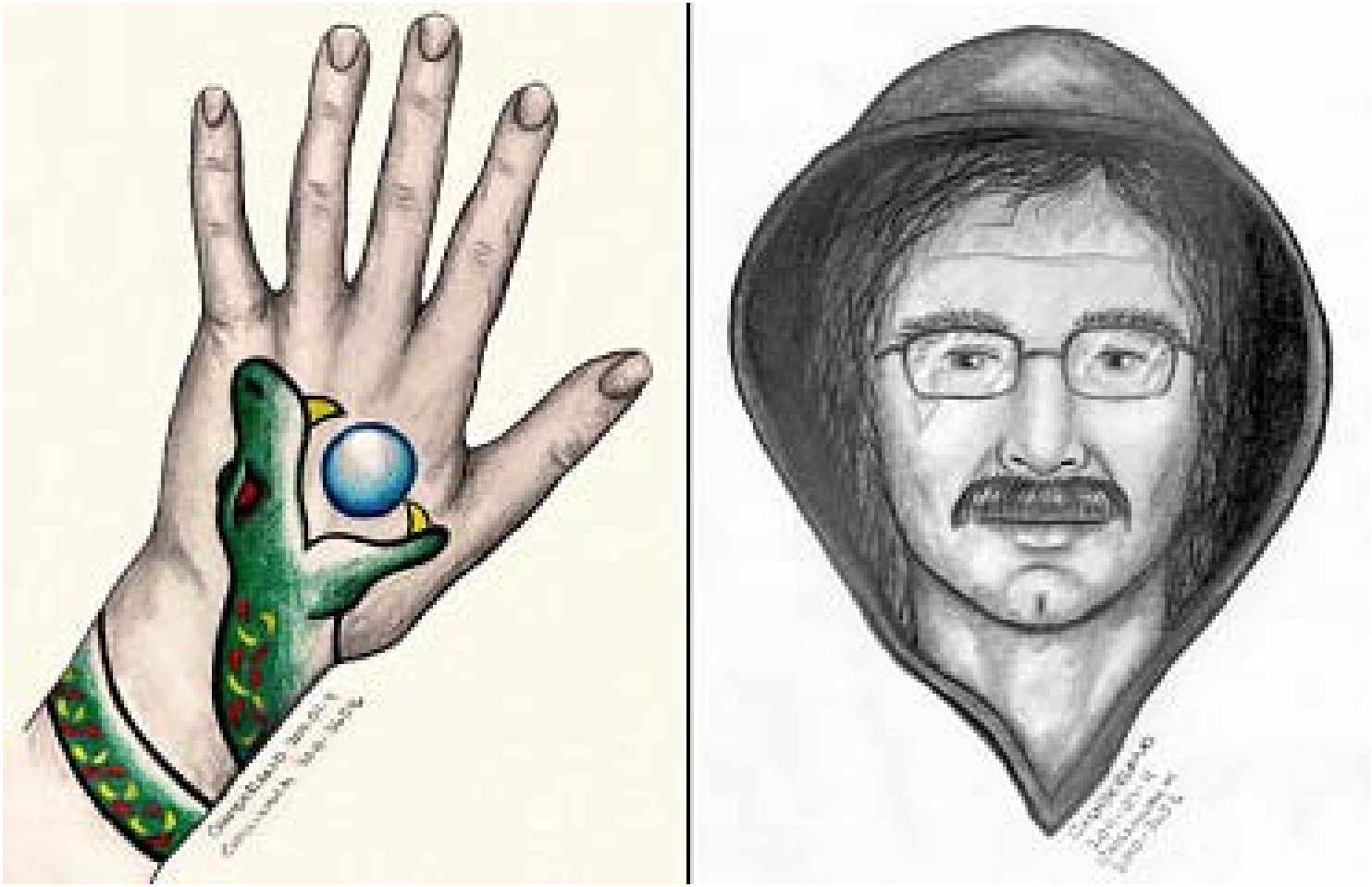
Near-Duplicate Tattoo Retrieval



100K gallery; 1K probe images

Successful Retrievals

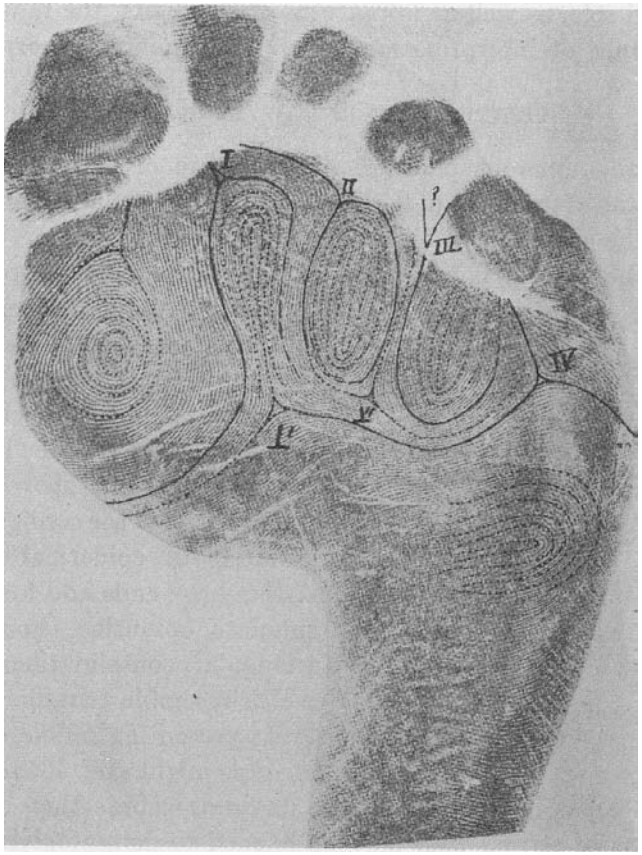
Tattoo Sketch



Justice for Caylee (www.justice4caylee.org) Sketch released of suspect and his tattoo in attempted Chilliwack child abduction, Jan. 26. 2011 (http://www.justice4caylee.org/t8931p45-canada-cases)

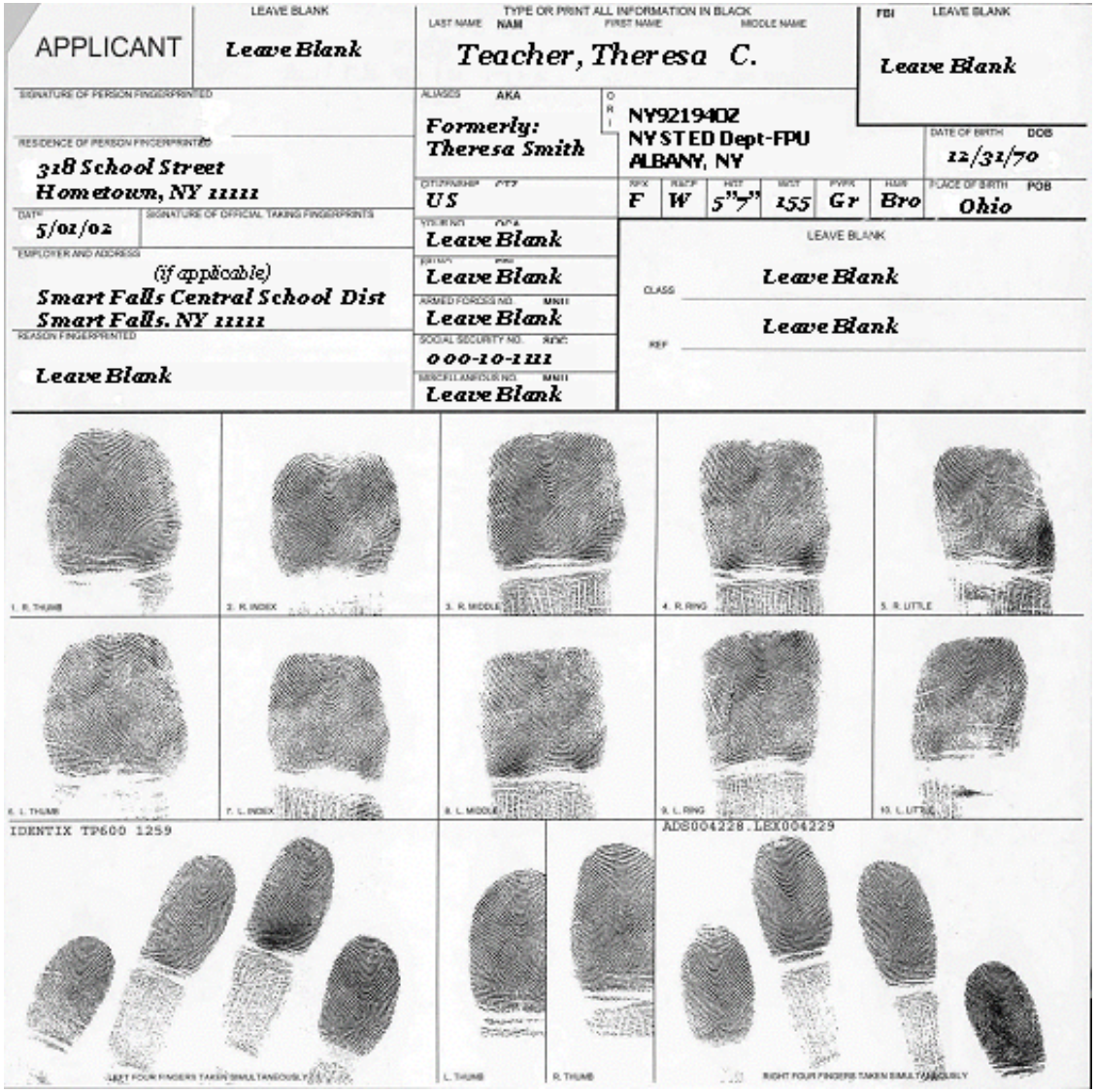
Dermatoglyphics

- Ridged or friction skin occurs on the fingers, palms and soles of all primates, including man
- Derma (skin) + glyphē (carve): study of ridged patterns

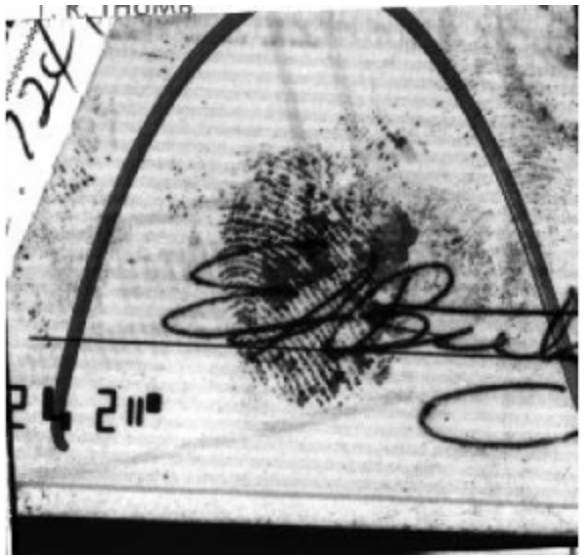


Types of Fingerprints

FBI Tenptint Card



Latent



Rolled fingerprints
("nail-to-nail")

Slap/Plain fingerprints

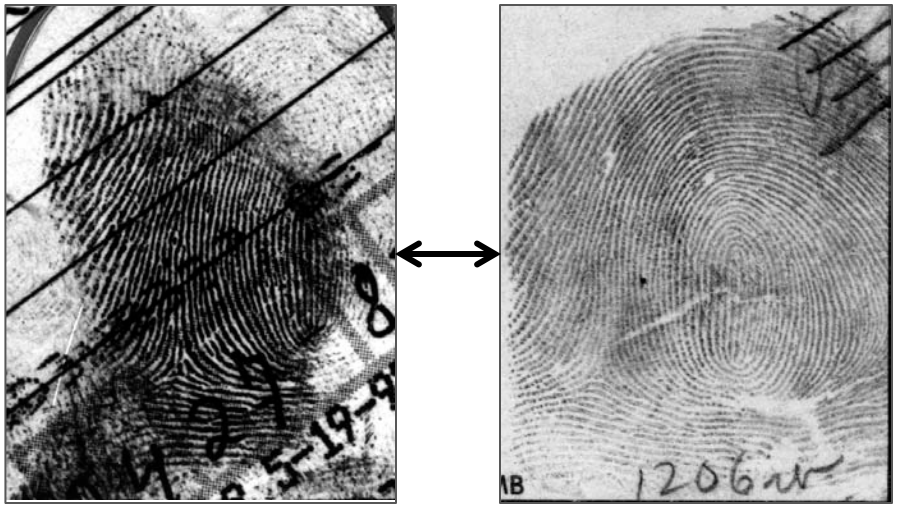
State of the Art

Rolled-to-Rolled matching

TAR of 99.4% at FAR of 0.01%

Latent-to-Rolled matching

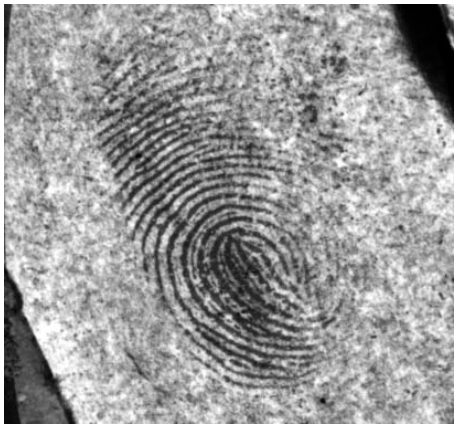
Rank-1 identification rate of 68%



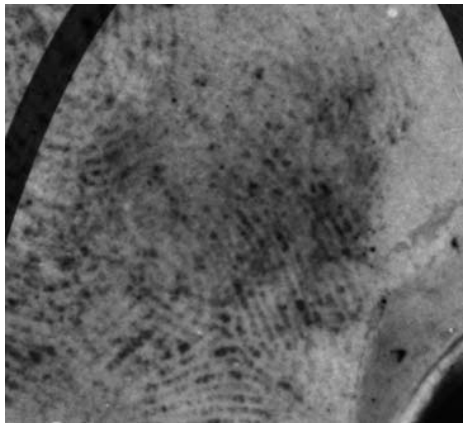
C. Wilson *et al*., Fingerprint Vendor Technology Evaluation 2003: Summary of Results and Analysis Report, NIST IR-7123, 2004
M. Indovina, R. A. Hicklin, and G. I. Kiebuzinski. Evaluation of latent fingerprint technologies: Extended feature sets. NIST IR-7775, 2011

Latent Fingerprint Matching

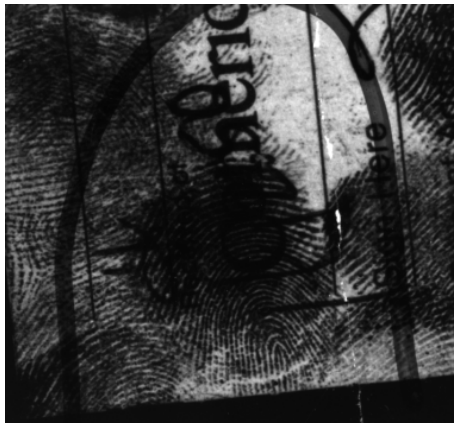
- Challenges:
  - Poor quality, partial prints and complex background
- Goals:
  - Eliminate or minimize human intervention
  - Improve latent matching accuracy in “Lights-Out” mode



Partial prints



Unclear ridges

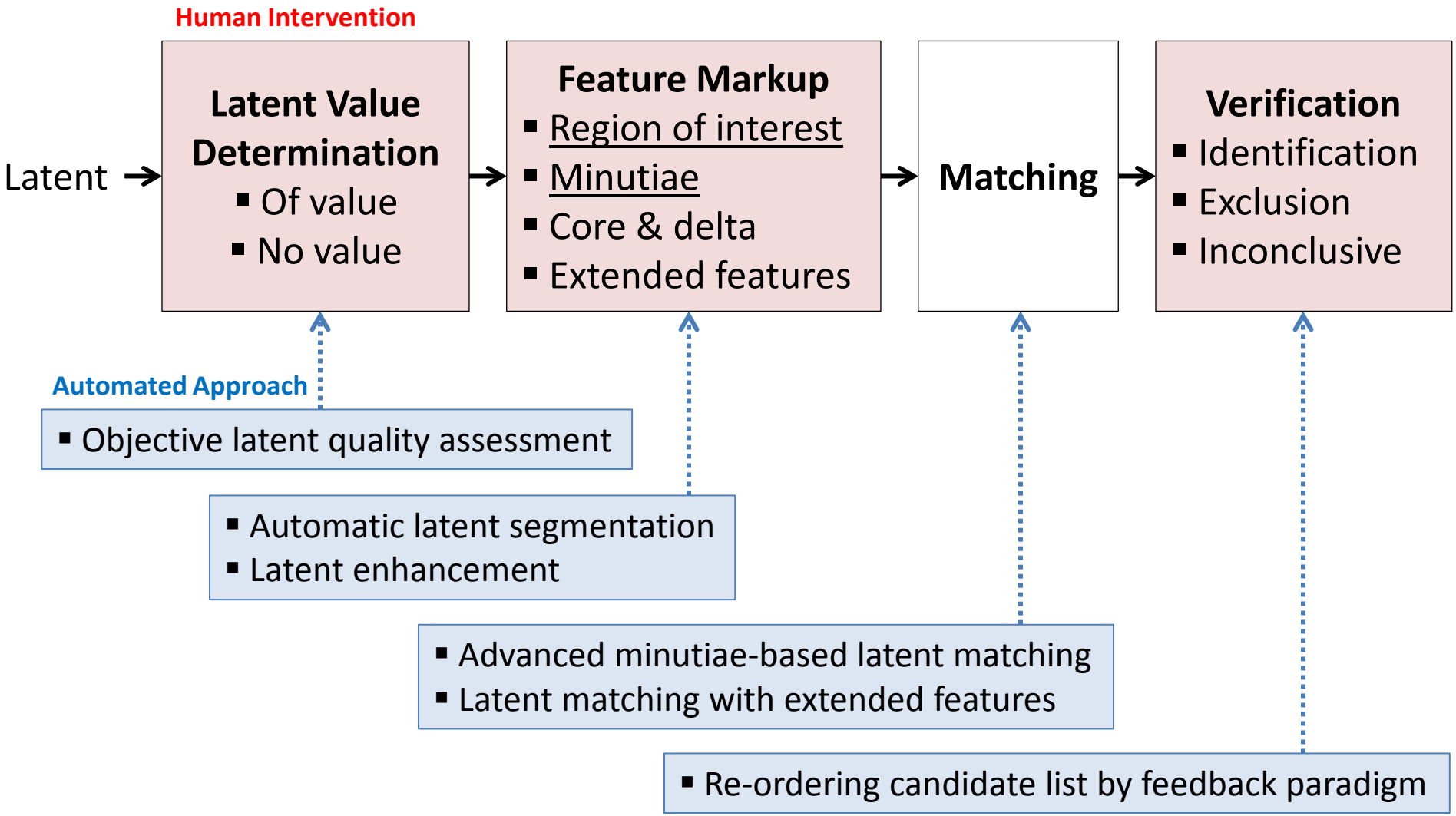


Overlap with other prints

Complex background

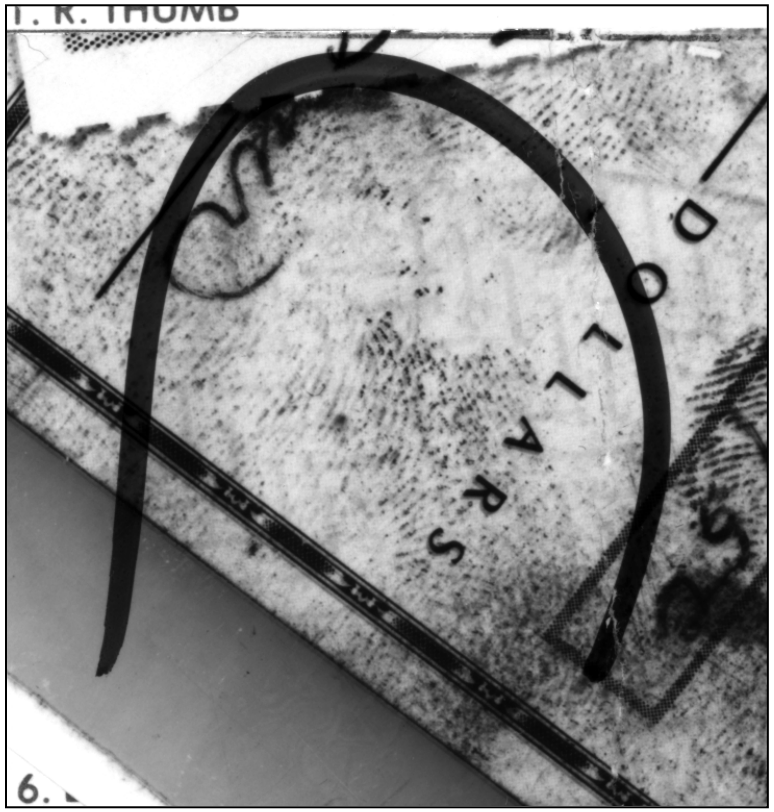
A. K. Jain and J. Feng, "Latent Fingerprint Matching", *IEEE Trans. Pattern Analysis and Machine Intelligence*, Vol. 33, No. 1, pp. 88-100, 2011

Research in Latent Matching



Latent Quality

In the ACE-V methodology (Analysis, Comparison, Evaluation and Verification), an examiner assigns one of three value to a latent: "No Value", "Value for Exclusion Only " and "Value for Individualization"



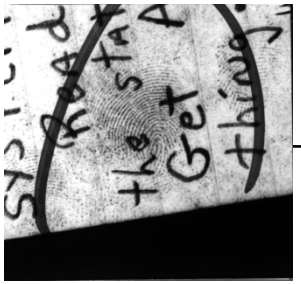
Latents marked "No Value", but whose mates are retrieved at rank 1 by an AFIS

Latent Segmentation & Enhancement

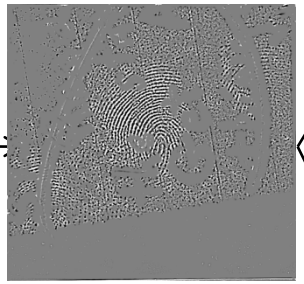
Dictionary learning

1,024 64x64 patches

Coarse estimation



Input latent image



Texture extraction

Quality map

Frequency field

Orientation field

Quality map

Frequency field

Orientation field

Confidence level (CL) estimation

$0 \leq CL \leq 1$

CL > TH

Segmentation and enhancement result

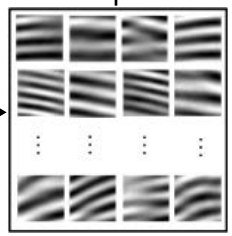
CL ≤ TH

Reject

Fine estimation

Dictionary learning

1,024 32 32 patches

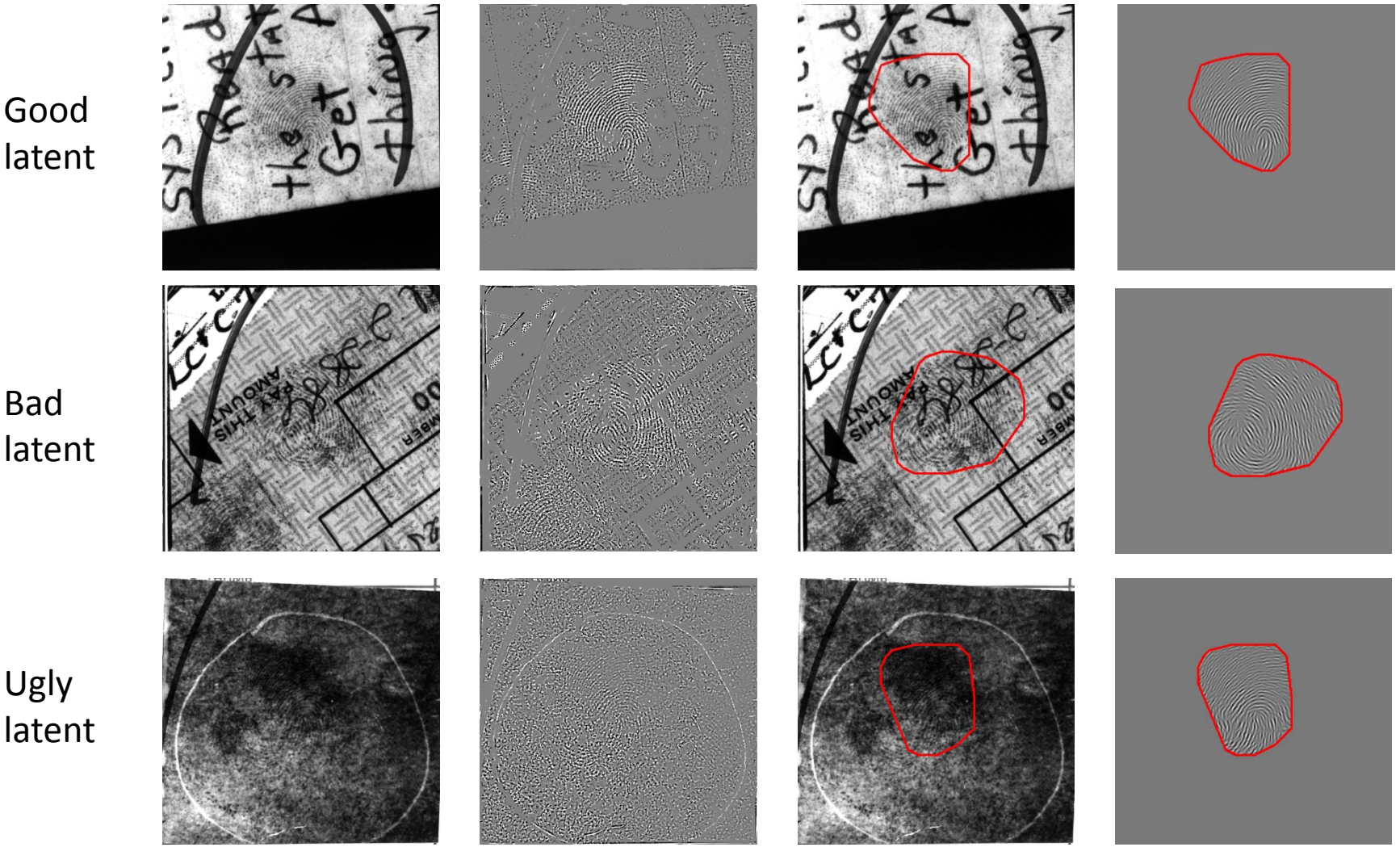


$(0, \pi/16]$

$(\pi/16, 2\pi/16]$

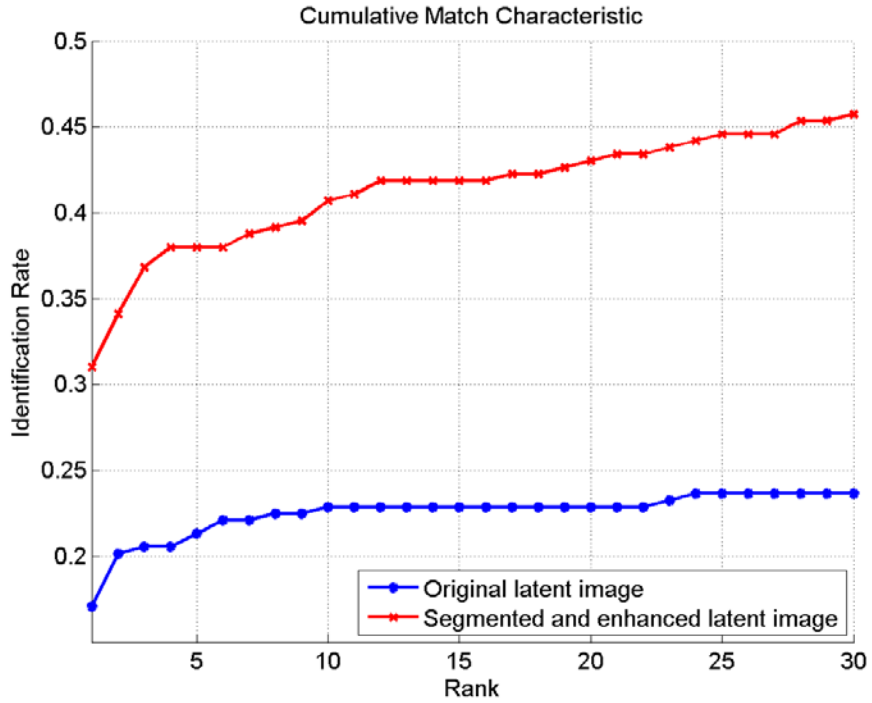
$(15\pi/16, \pi]$

Some Results on NIST SD27



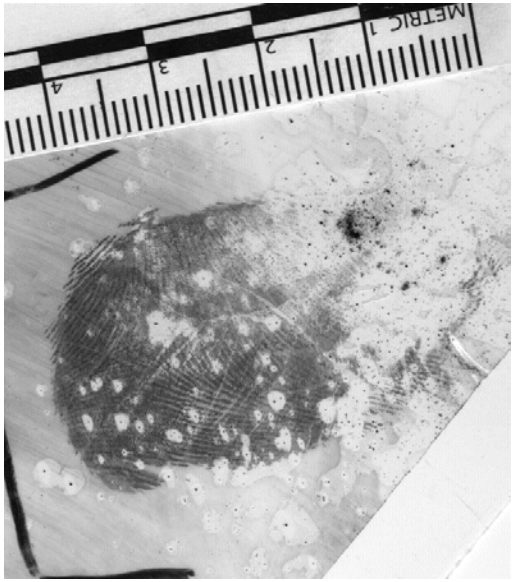
Matching Performance

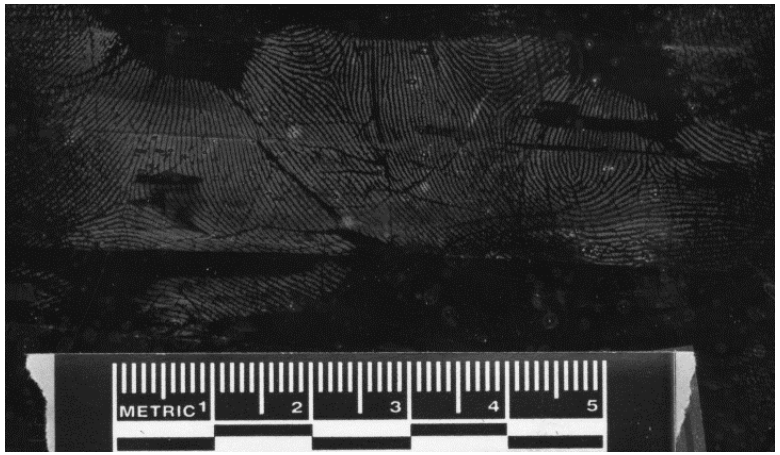
- Latent Database
  - 258 images in NIST SD27
- Background Database
  - ~30K rolled prints
- Matcher: COTS Matcher

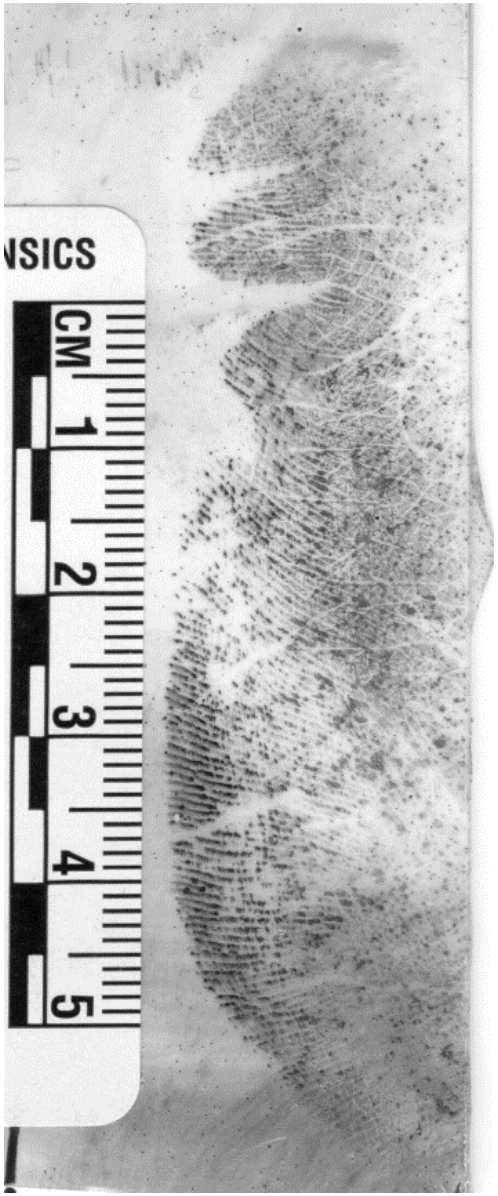


Latent Palmprints

- Among the friction ridge evidence found at crime scenes, ~30% are from palms (~25% of crimes scenes contains only palmprints)

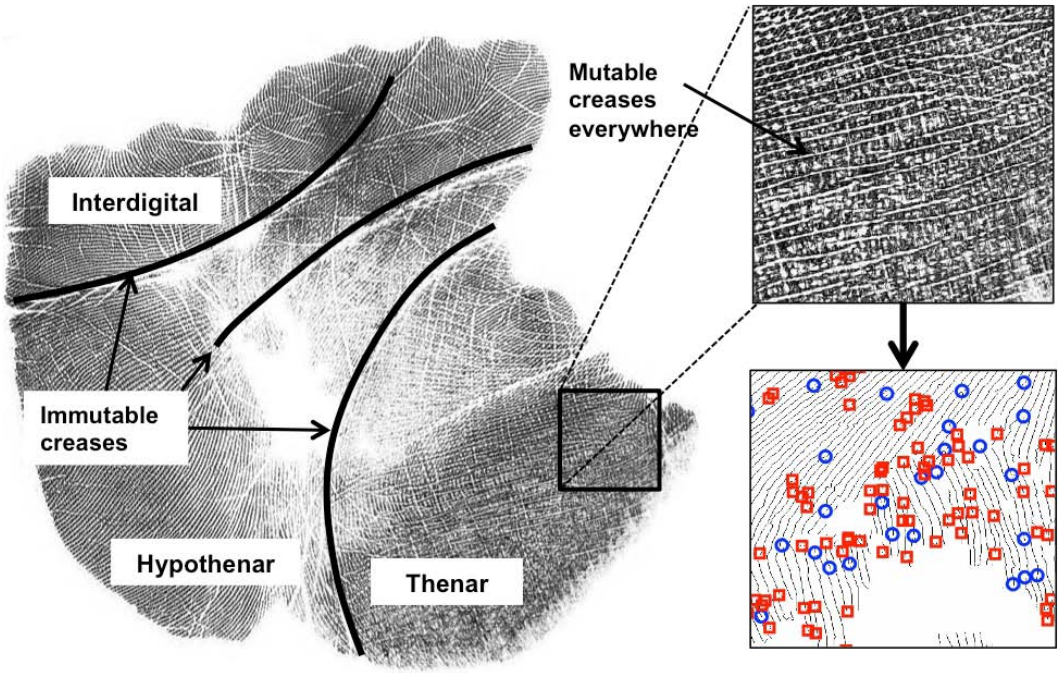




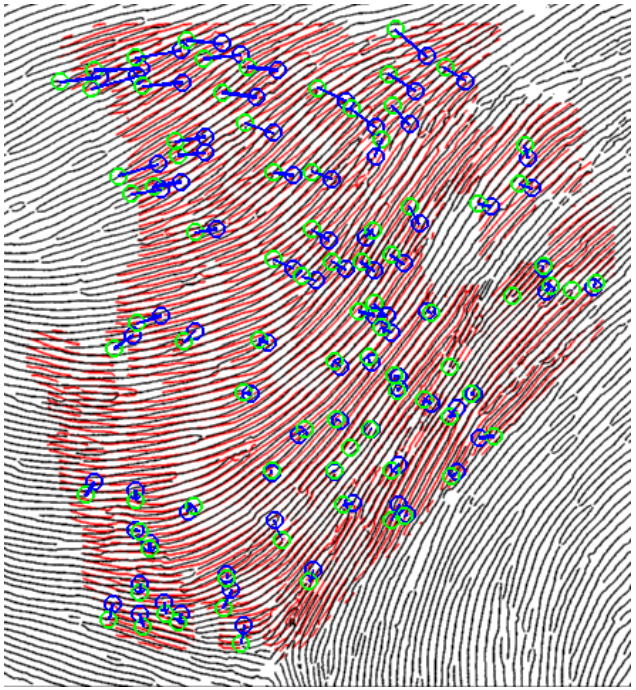


Challenges

- Large no. of minutiae in palmprints (~1,000)
- Many spurious minutiae detected because of creases
- Nonlinear distortion due to hand skin elasticity

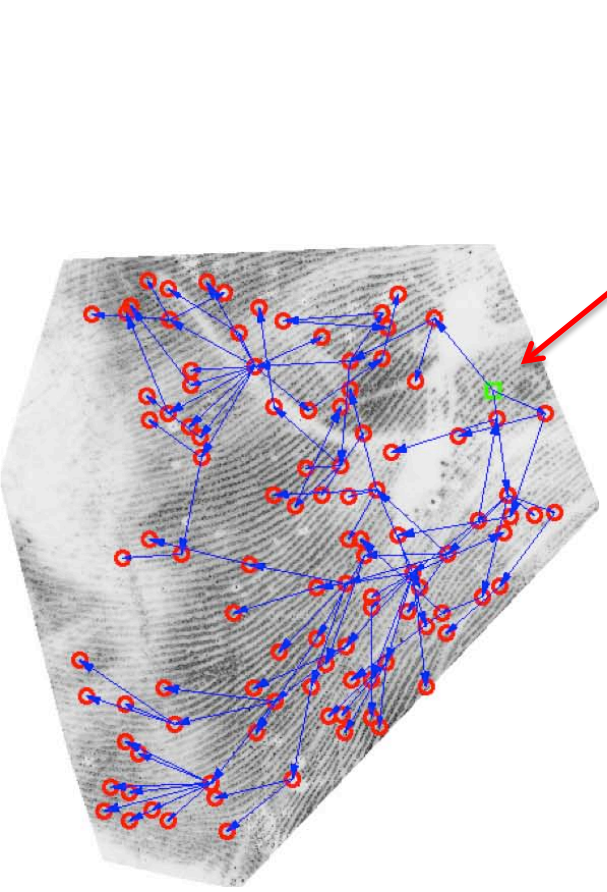


Creases and spurious minutiae



Non-linear distortion

Latent Palmprint Matching



Latent palmprint

Corresponding area of mated palmprint

Mated palmprint

E. Liu, A. K. Jain, and J. Tien, "A Coarse to Fine Minutiae-Based Latent Palmprint Matching", *IEEE Trans. Pattern Analysis and Machine Intelligence*, 2013

Summary

- We have come long ways since fingerprints were first used for person recognition over 100 years back
- Biometric recognition is indispensable in forensic, law enforcement, border crossing, de-duplication of documents, access control,….
- Challenge is to recognize individuals in non-cooperative scenarios using multiple attributes and contextual information
- Forensics offers many such challenges to biometrics researchers