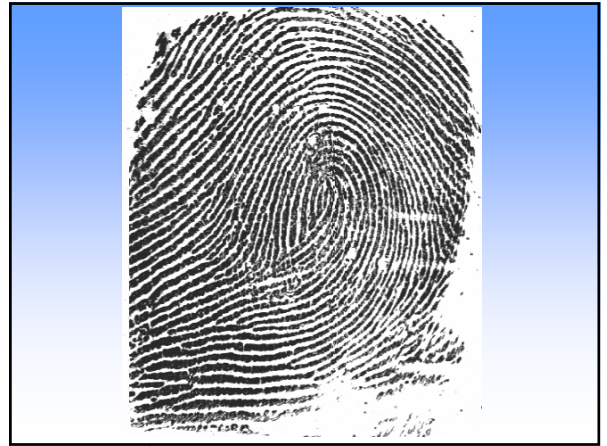


# Fingerprints: Proving Ground for Pattern Recognition

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Michigan State University



## Fingerprints

“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

## Proving Ground

A number of **societal problems** now need a highly accurate, scalable, real-time, low cost, user-friendly fingerprint recognition system

## Fingerprints in Forensics

- Repeat Offenders: Compare **rolled (ten print)** inked impressions
- Crime Scenes: Compare **latent** prints with forensic database

FBI AFIS: **~50M 10 prints**; 50,000 searches per day; 2 hour response time; only 15% matches are in “lights out mode”

## Inked Prints & Latents

Latent

FBI card

## Fingerprints: New Era

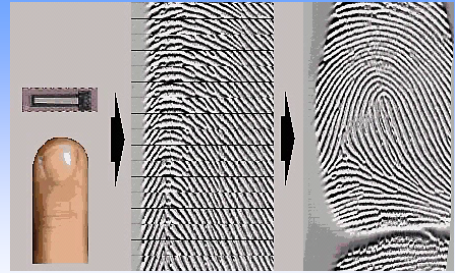
- Border security
- Financial fraud
- User convenience

New deployments need

- Cheap & compact sensors
- Fully automated matching



## Live Scan Capture



Sensors based on **optical, ultrasound, thermal, solid-state, multispectral** technologies

## Disney World, Orlando



Throughput: 100K/day, 365 days/ year

## Outline

- Dermatoglyphics
- Characteristics of fingerprints
- Applications
- Representation
- Matching
- Performance
- Research Directions

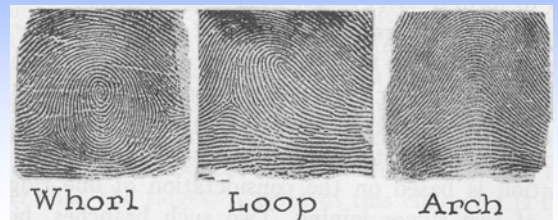
## Dermatoglyphics

- Ridged (**friction**) skin on fingers, palms & soles
- Derma (**skin**) + glyphē (**carve**): study of ridged patterns



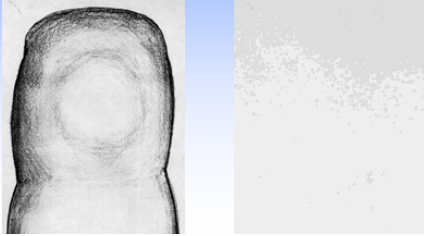
## Fingerprints

- Patterns of **epidermal ridges** on fingers
- Ridges prevent slipping while grasping
- Main types of pattern: **whorl, loop, arch**



## Fingerprint Formation

- Ridge formation starts at 1 or 2 focal points and spreads over the fingertip
- Localized ridge units merge to form ridges at ~10.5 weeks estimated gestational age



## Biological Principles

- Uniqueness (**individuality**)
- Permanence (**persistence**)
- Classifiability (**indexing**)
- **Genotype** & **phenotype** characteristics



Identical twins have different prints



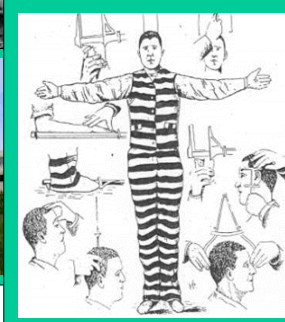
Fingerprint = "uniqueness"

## Fingerprint Milestones

Henry Faulds publishes article



Bertillonage of sale w invented fingerprint



的 "patterns" in Nature

Courtesy: John D. Woodward, RAND Corporation

## Fake Documents

The **nineteen** 9/11 terrorists had a total of **63 valid driver licenses**



## US-VISIT



~ 60 million visitors have been processed through US-VISIT; 1,100 criminals denied entry

## Hong Kong Smart Identity Card



## HK Smart ID Card

- Security: Prevent misuse of stolen cards
- Convenience: e-Certificate
- Service: electronic government services
- Travel: Passenger Clearance System



## Identity Theft

Credit card fraud amounts to **billions in losses for millions of customers**



Customer pay by fingerprints; no need for cards/cash

## Who is Moving the Mouse?

**Personalization**: Understand customer interests



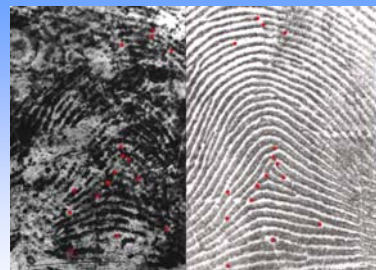
Comm. ACM, August 2006

## Fingerprint Matching

Find the **similarity** between two fingerprints

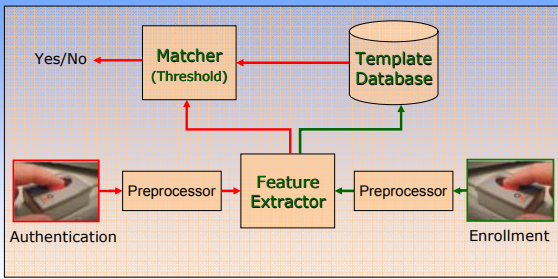


## Latent Matching



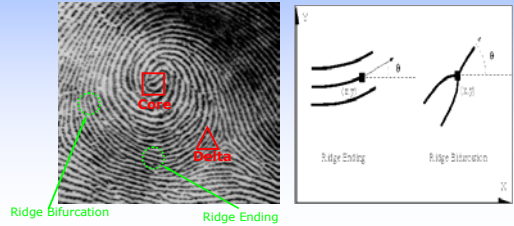
Latents **at the Madrid bombing site were matched to those** of Mayfield by FBI. He was arrested but later released after Spanish officials found the real culprit

# Fingerprint Matching System



# Features

- Local ridge characteristics (**minutiae**): ridge endings and bifurcations
- Singular points (**core and delta**): discontinuity in ridge orientations



# Matching

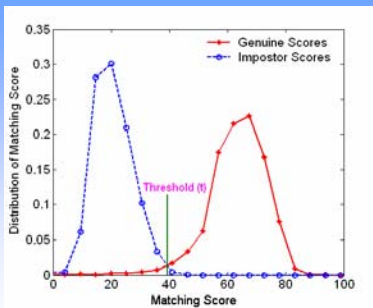
- Register query and template images
  - Estimate rotation, translation & distortion
- Compute the similarity
  - Find the **number of corresponding minutiae**



# Minutiae-based Matchers



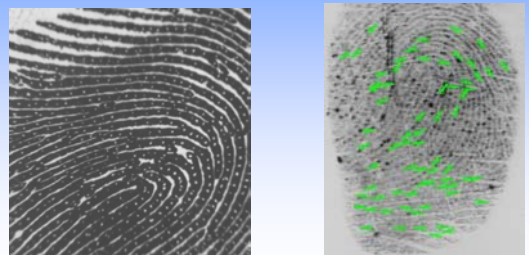
# Match Score Distributions



False Accept Rate vs. False Reject Rate

# Matching Errors

Large intra-class variation (distortion & noise)



## "State-of-the-art" Error Rates

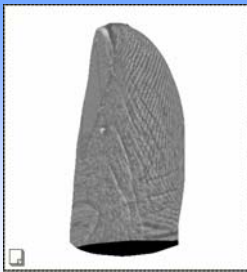
Test	Database Characteristics	False Reject Rate	False Accept Rate
FVC [2002]	100 fingers, 8 impressions/finger	0.2%	0.2%
FVC [2004]	Same as FVC 2002 with <b>distortion</b>	2%	2%
FpVTE [2003]	US govt. data (10,000 fingers)	0.1%	1%

~100,000 passengers/day at HK airport; using the top FpVTE system, 100 "good" passengers will be stopped

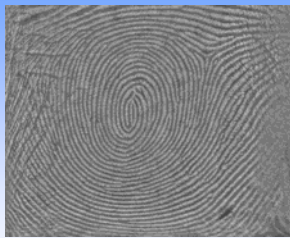
## Research Directions

- Sensing
- Spoof Detection
- Extended feature set (Level 3)
- Uniqueness of fingerprints
- Multibiometrics
- Template security
- Fingerprint fuzzy vault

## Touchless Fingerprint Imaging



Touchless 3D image

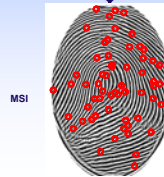
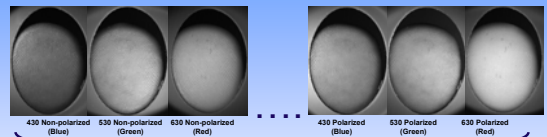


Touchless "rolled" image

Courtesy: TBS North America (NIJ Fast Capture Program)

## Multispectral Imaging

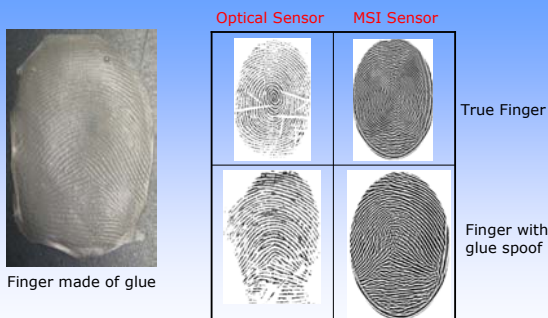
Captures both **surface** and **subsurface** ridges



VS.

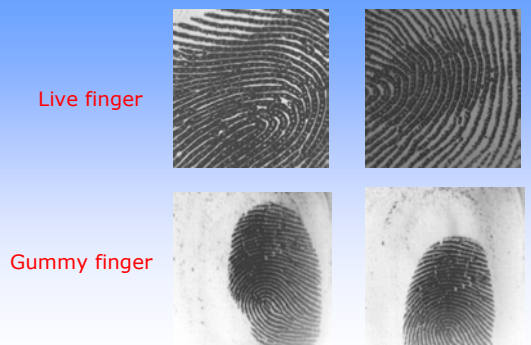
Courtesy: Lumidigm

## Spoof Detection



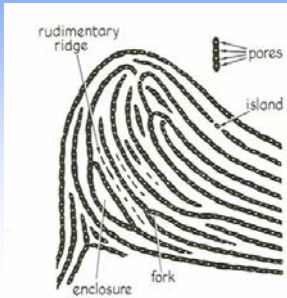
MSI sensor can see through the spoof

## Deformation-Based Spoof Detection

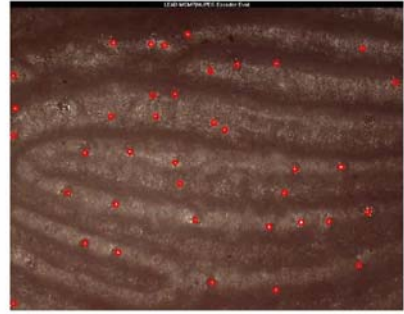


## Extended Feature Set

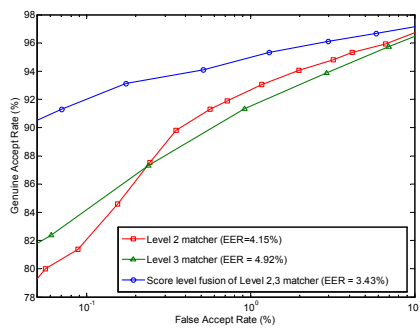
'It is NOT the points, but what's in between the points that matters' Edward German, *latent print examiner*



## High Resolution Sensors



## Levels 2 & 3 Feature Fusion



## Are Fingerprints Unique?

"Only Once during the Existence of Our Solar System Will two Human Beings Be Born with Similar Finger Markings" *Harper's headline, 1910*

"Two Like Fingerprints Would be Found Only Once Every 10<sup>48</sup> Years" *Scientific American, 1911*

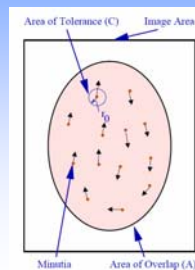
The **uniqueness** of fingerprints has been accepted over time because of relentless repetition and lack of contradiction

## Challenges to Uniqueness

- *Daubert vs. Merrell Dow, 1993*
  - Test of hypothesis
  - Known or potential error rate
  - Peer reviewed and published
  - General acceptance
- Challenges (*USA v. Byron Mitchell, 1999*)
  - **Error rate** is not known
  - **Uniqueness** has not been tested

## Probability of Random Correspondence

- Given two fingerprints with  $m$  &  $n$  minutiae, what is the probability they will share  $q$  minutiae?



1.  $m=n=52, q=12$   
 $PRC = 4.4 \times 10^{-3}$   
 (Observed value =  $3.5 \times 10^{-3}$ )
  2.  $m=n=52, q=26$   
 $PRC = 3.4 \times 10^{-14}$
- $M = A/C=413$  (NIST-4 database)

## Template Security

Can fingerprint be reconstructed from minutiae?



Reconstructed images matched true fingerprints **23%** of the time

## Match on Card

Complete system (sensor, feature extractor, matcher, template) resides on card; **template is never transmitted or released from card**



IEEE Spectrum, July 2006

## Match on Card



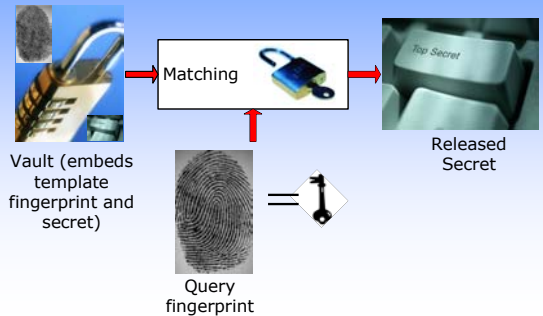
Biometric Smart Card  
(UPEK Inc.)



Biometric Key Chain  
(Privaris, Inc.)

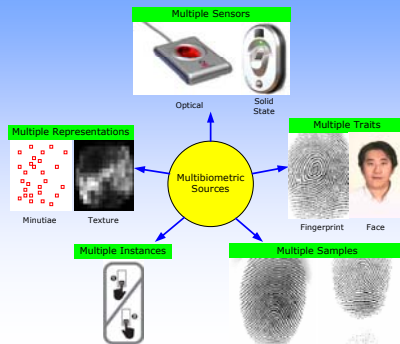
## Fingerprint Fuzzy Vault

Secure an encryption key with fingerprint so **only the authorized user can access the secret**

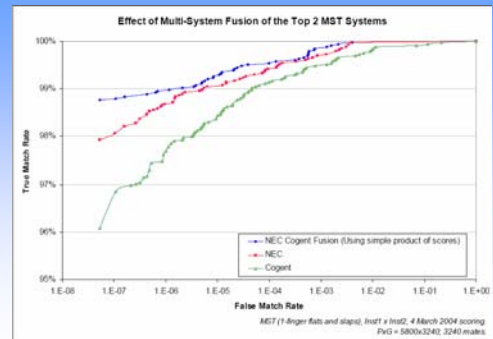


## Multibiometrics

Failure to enroll, spoof attacks, error rate



## Fusion of Matchers



## Summary

- Fingerprint recognition is the earliest & largest deployment of pattern recognition
- Fingerprints are believed to be fail proof, but commercial systems have **finite error rates**
- Many **societal needs** (identity theft, financial fraud, security) require robust, accurate & cost-effective fingerprint matchers
- **It is a proving ground for pattern recognition**