High Resolution Fingerprint Matching Using Level 3 Features

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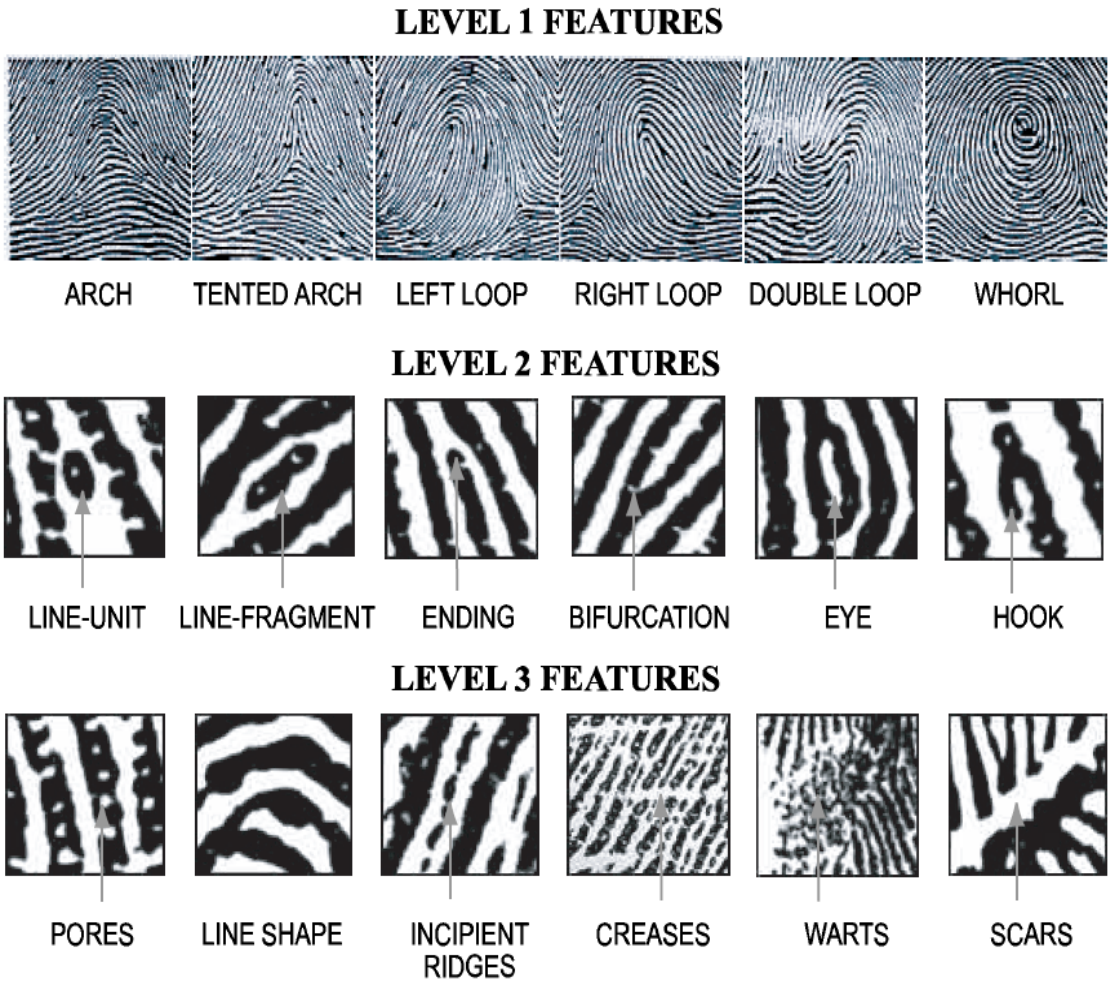
Fingerprint Features



"Latent print examiners use Level 3 all the time... We do not just count points... 'it is NOT the points, but what's in between the points that matters' ... all statistical models attempted in the past 100 years use only Level 1 and 2 details... AFIS too... "

-- German, Edward Raymond
latent print examiner
[*http://onin.com/fp/level123.html*]

Fingerprint Resolution

380 ppi (Identix DFR200)

500 ppi (CrossMatch ID1000)

1000 ppi (CrossMatch ID1000)

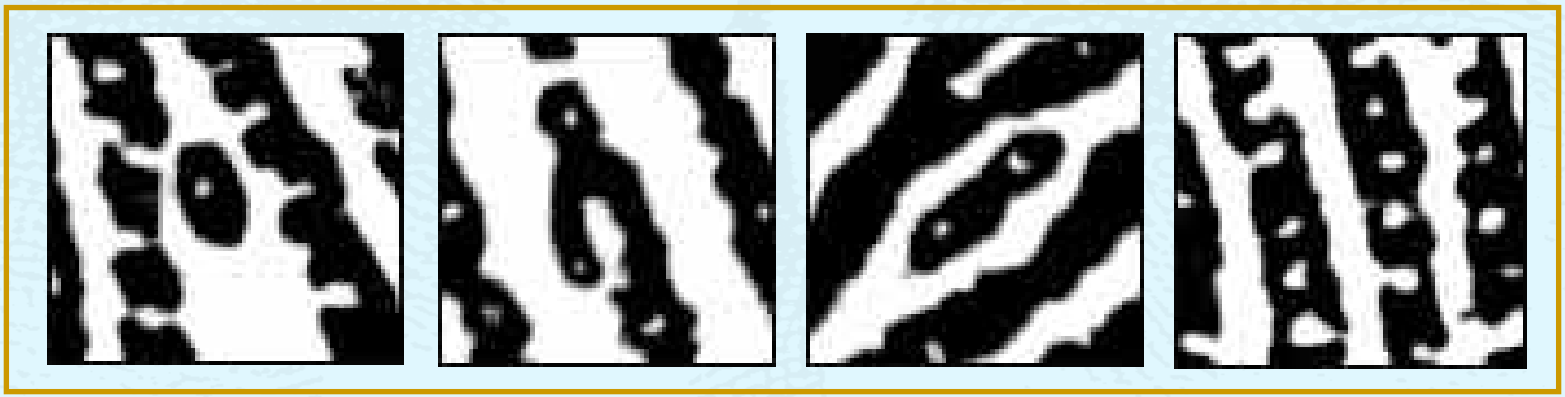
- **250 ~ 300 ppi**: the minimum resolution for Level 1 & 2 feature extraction
- **500 ppi**: (50 micra): FBI standard for AFIS
- **1000 ppi**: the minimum resolution for Level 3 feature extraction, e.g., pores (~60 micra)

"(merely) increasing scan resolution will not improve results acquired from the AFIS matching."

[*NIST Fingerprint Data Interchange Workshop, 1998*]

Fingerprint Formation

- Friction ridges are constructed of ridge units with various shape, size and alignment
- No. of ridge units in a ridge is established at random
- Location of the ridge unit where a branching develops is established at random
- Location of the pore opening on a ridge unit is established by random forces



Ashbaugh, D., *Quantitative-Qualitative Friction Ridge Analysis*, 1999, CRC Press

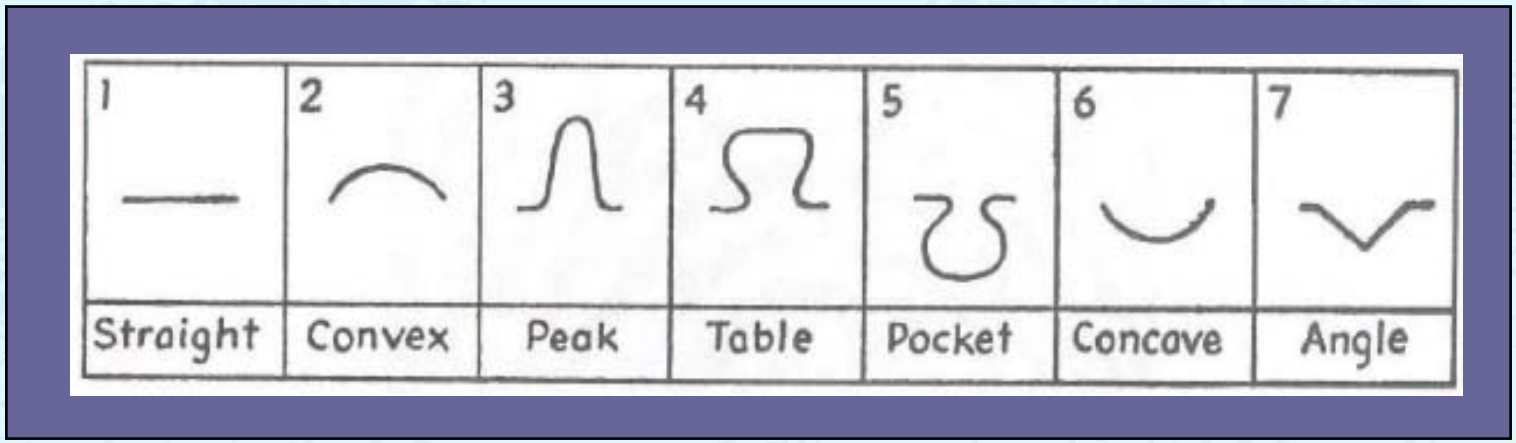
Ridge Width

- A typical fingerprint has as many as 150 ridges; a ridge 5 mm long would contain approximately 10 ridge units
- Ridge width depends on location and person; narrower in females (0.427 mm) than in males (0.483 mm)

Ashbaugh, D., *Quantitative-Qualitative Friction Ridge Analysis*, 1999, CRC Press

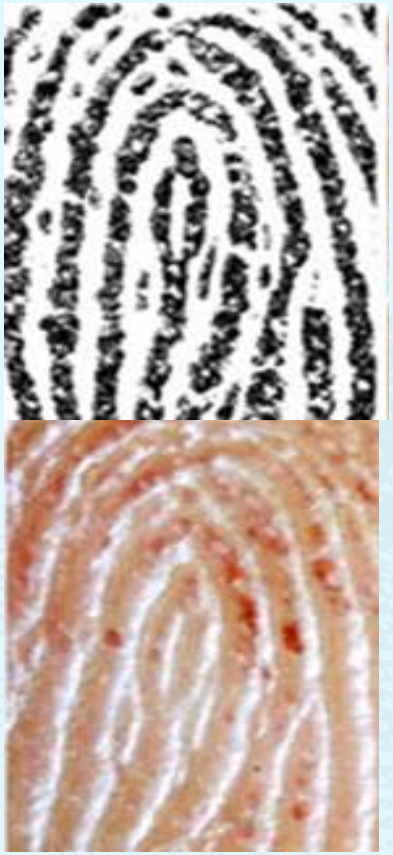
Ridge Contours

- Shape of the ridge edge
- Caused by (i) differential growth of the ridge units (ii) pores near the edge of the ridge
- Can be classified using Chatterjee's scheme



Ashbaugh, D., *Quantitative-Qualitative Friction Ridge Analysis*, 1999, CRC Press

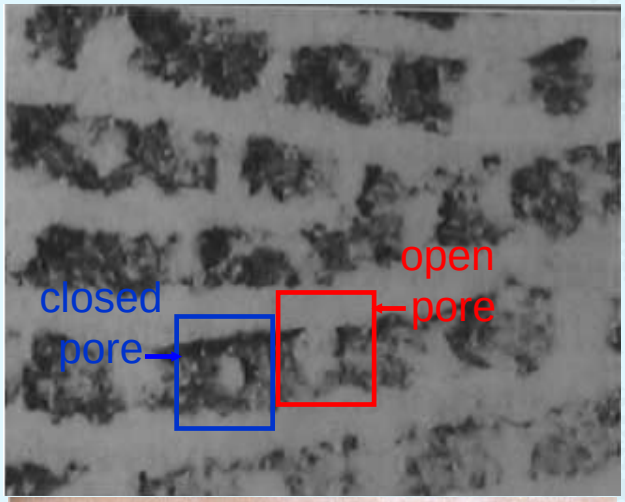
Incipient Ridges

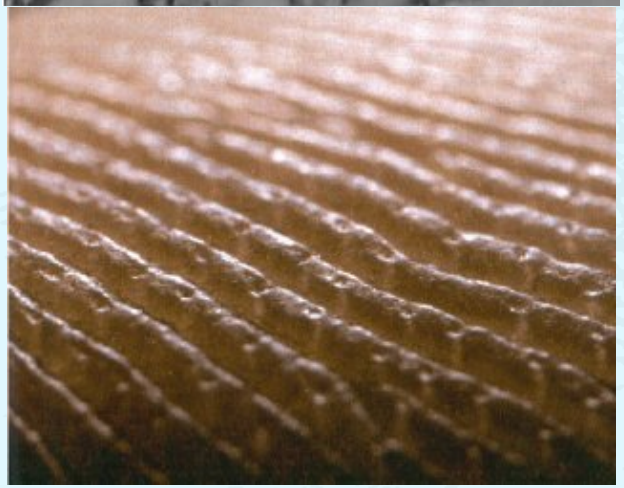


- Immature ridges between papillary lines
- Thinner & shorter than papillary lines
- Rarely bifurcates and rarely has pores
- May appear as a series of dots
- Occurs in ~45% of the people and in 3 fingers/person, on average. Incipient ridges are in ~13.5% of all fingers
  (http://www.xs4all.nl/~dacty/incipien.htm)

Ashbaugh, D. R., *Incipient ridges and the clarity spectrum,* Journal of Forensic Identification, vol. 42, pp. 106, 1992

Pores





- Perpetual, immutable and unique
- Avg. no. of pores is 9 ~ 18/cm of a ridge
- Various sizes (88-220 micra in diameter)
- Various shapes (round, elliptical, oval, square, rhomboid, or triangular)
- Various positions (mostly in the middle, but occasionally open on the side)

Locard, *Les pores et l'identification des criminals,* Biologica, vol.2, pp. 357-365, 1912

"One must not expect to find two separate prints of the same pore to be exactly alike, as the pore may be open in one and closed in the other in accordance with the amount of pressure applied" -- Ashbaugh

Pore extraction and matching

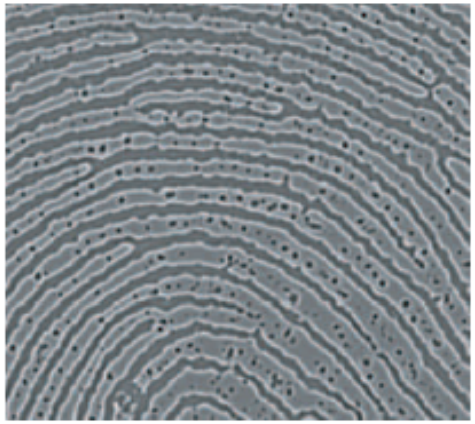
- Lee et al., *Association of Finger Pores and Macrofeatures for Identification of Individuals, US Patent 20020154795A1, 2002*
- Stosz et al. *Automated system for fingerprint authentication using pores and ridge structure. Proceedings of the SPIE, Automatic Systems for the Identification and Inspection of Humans, Volume 2277, pp. 210-223, 1994.*
- Kryszczuk et al., *Study of the Distinctiveness of Level 2 and Level 3 in Fragmentary Fingerprint Comparison. ECCV Workshop BioAW, 2004, pp. 124-133*

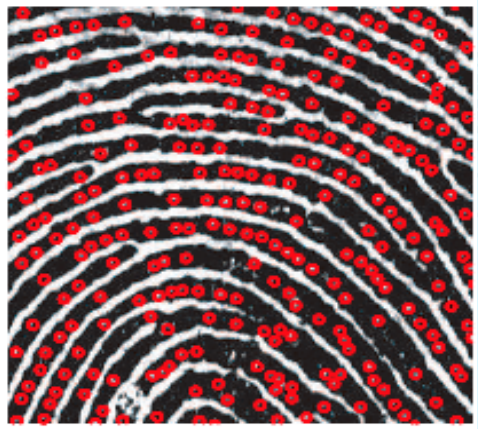
- Skeletonization for pore extraction
- Open pores and closed pores are detected separately
- Regions of interest were predefined or manually selected
- 500 ppi or ~2000 ppi scan resolution
- EER = 12% to 15% for pore matching
- Database: 60 ~ 258 prints

Proposed Level 3 Feature Extraction

Pore Extraction

(a) Input image (1000 ppi) (b) Gabor enhanced image





(c) Wavelet Transform (d) [(b) + (c)] (e) Pores

Ridge Contours

Ridge contours are edges of ridges. Unlike Chatterjee's classification scheme, we utilize ridge contours as an attribute of the ridge; matching is based on the distance between points on the ridge contours

Why ridge contours?

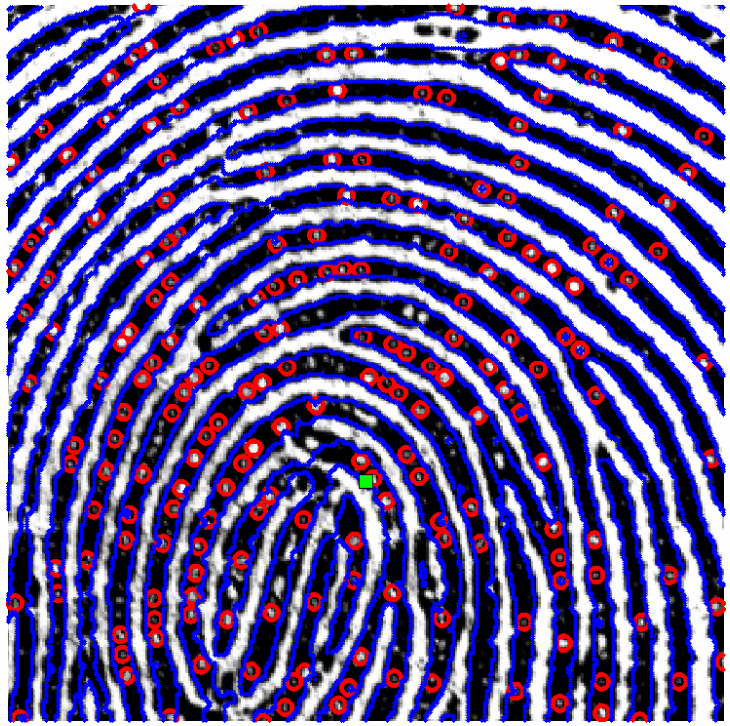
1. Matching using pore locations alone is not reliable
2. Pores are not consistently presented

Ridge Contour Extraction

(a) Input image (1000 ppi) (b) Gabor enhanced image

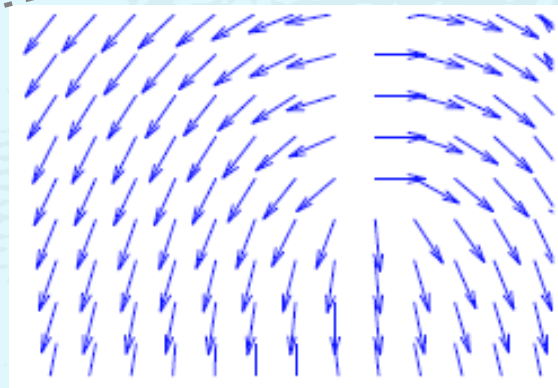
(c) Wavelet Transform (d) [(b) - (c)] (e) Ridge contours

Demo
(Level 3 Feature Extraction)

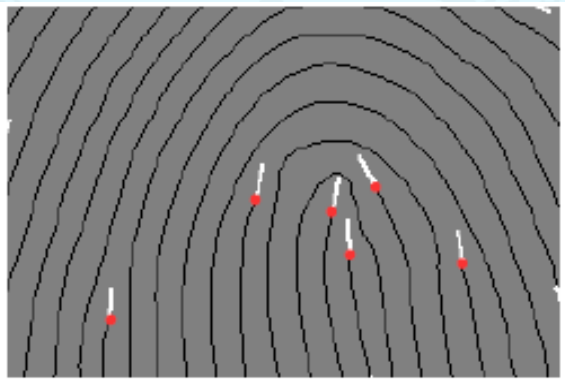


Automatic Feature Extraction at All Levels

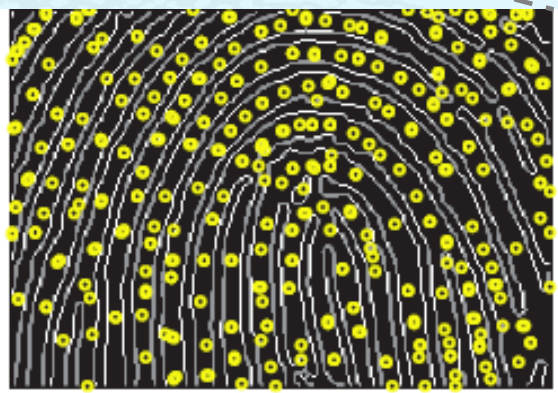
1000 ppi
(CrossMatch ID1000)



Orientation field
(Level 1)



Minutiae points
(Level 2)



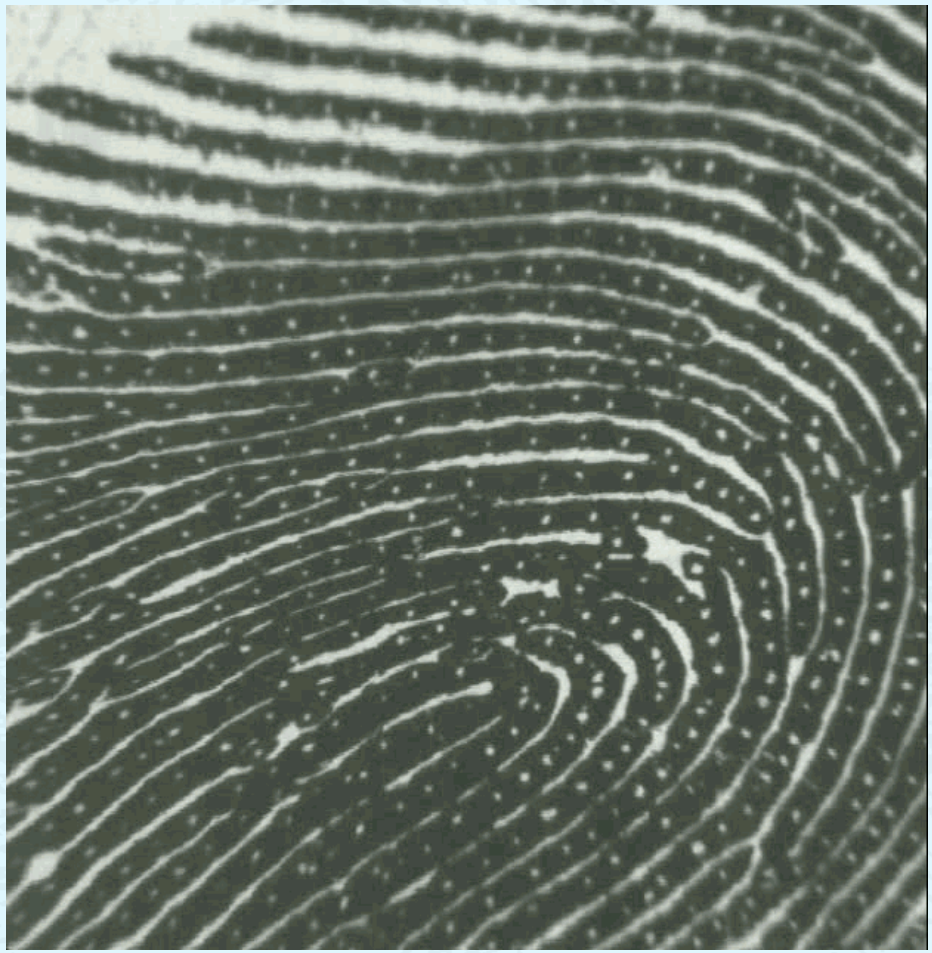
Pores + Ridge contours
(Level 3)

Proposed Level 3 Feature Matching

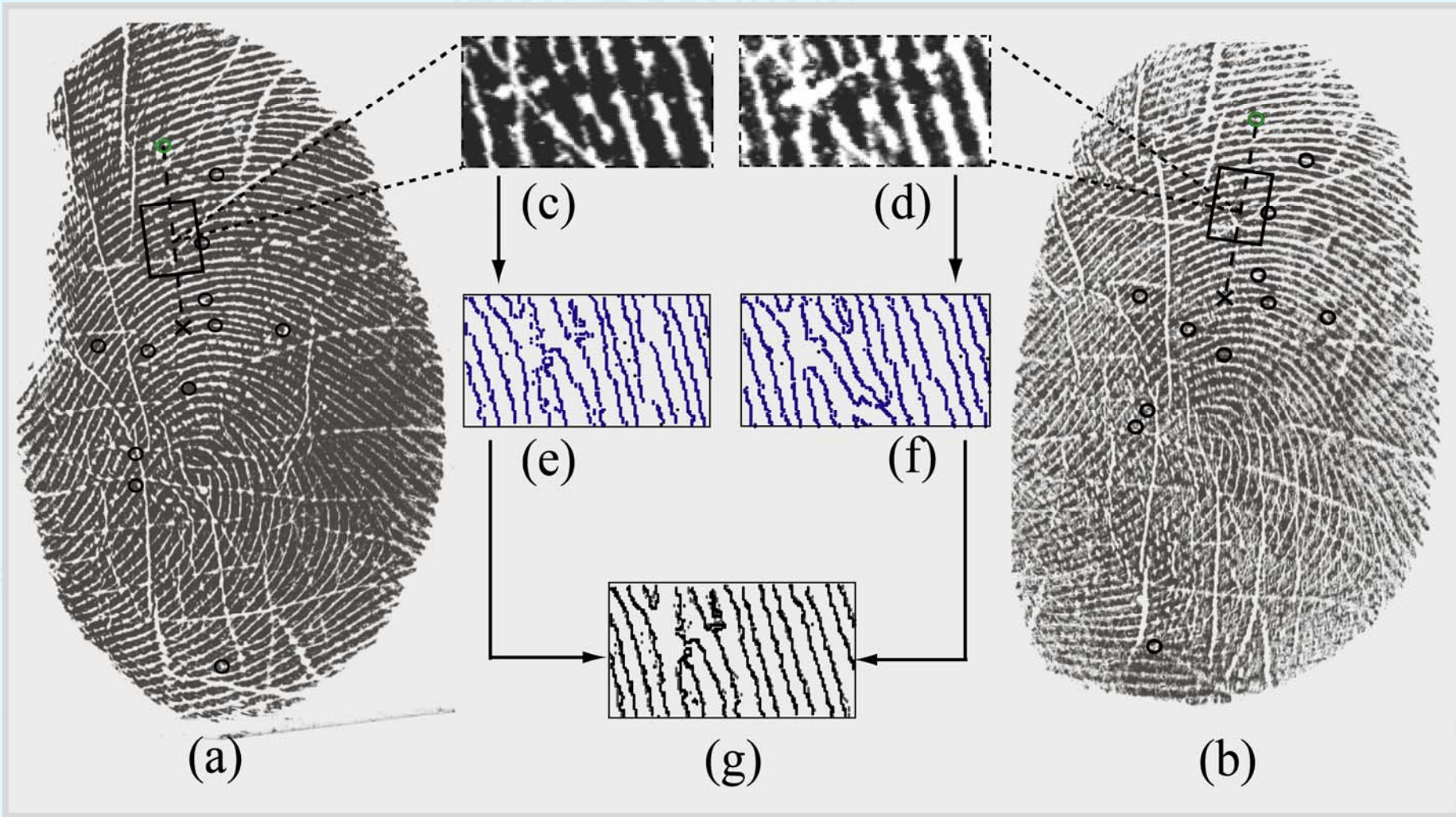
Localized Matching

- Extract Level 3 features in regions of interest (ROI)
- ROI are 60x120 (in pixels) windows associated with Level 2 features (i.e. minutiae)
- No. of detected Level 3 features in the corresponding template and query ROI are often different
- Local non-linear distortion is approximated by rigid transformation
- Local rigid transformation is estimated using Iterative Closest Point (ICP) Algorithm

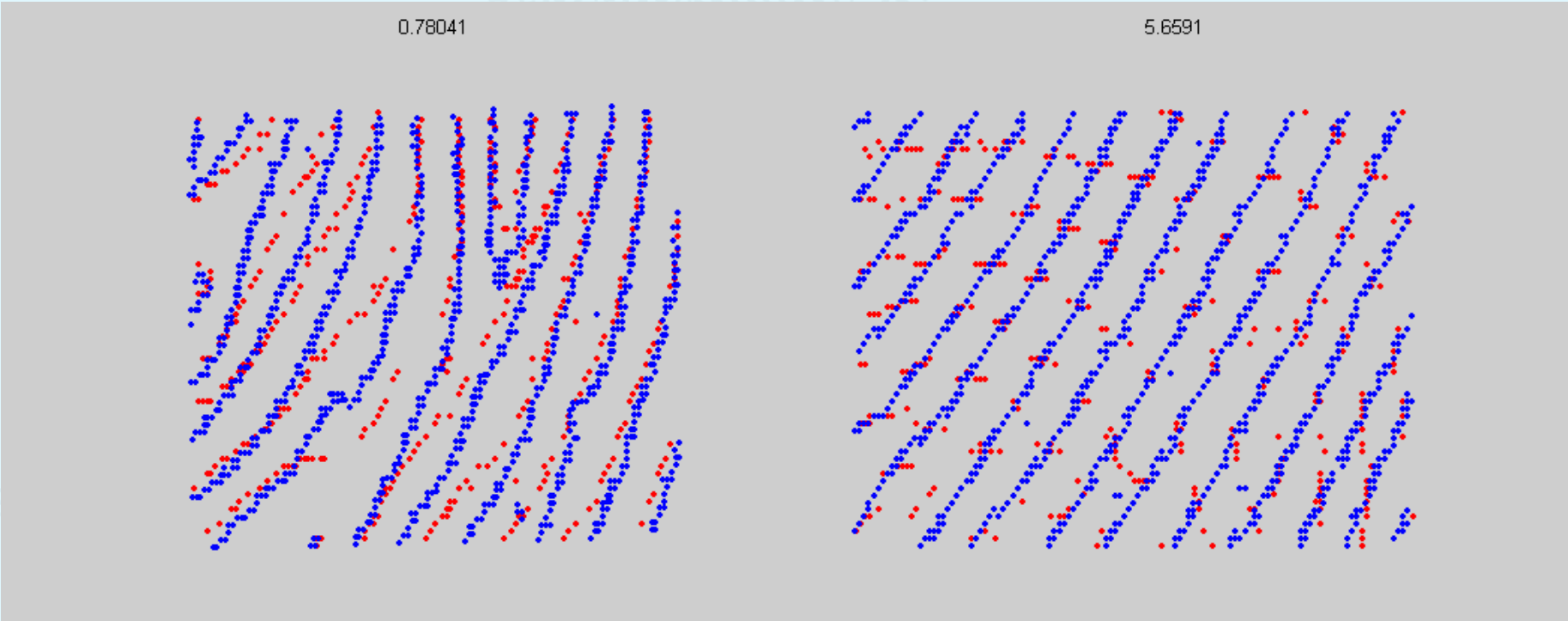
Skin Distortion



Localized Matching



ICP algorithm (Demo)



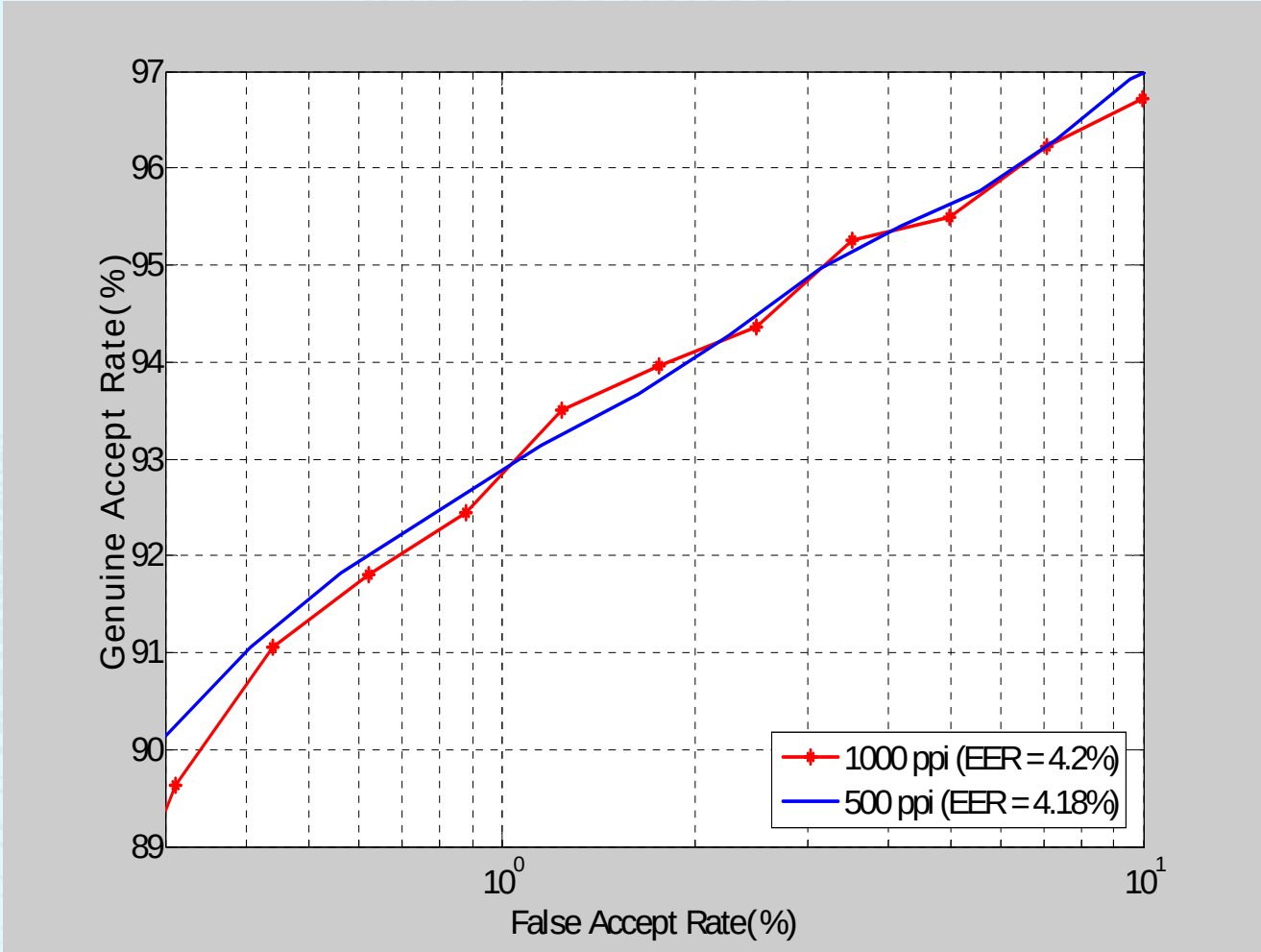
Genuine Matching
(Level 3)

Impostor Matching
(Level 3)

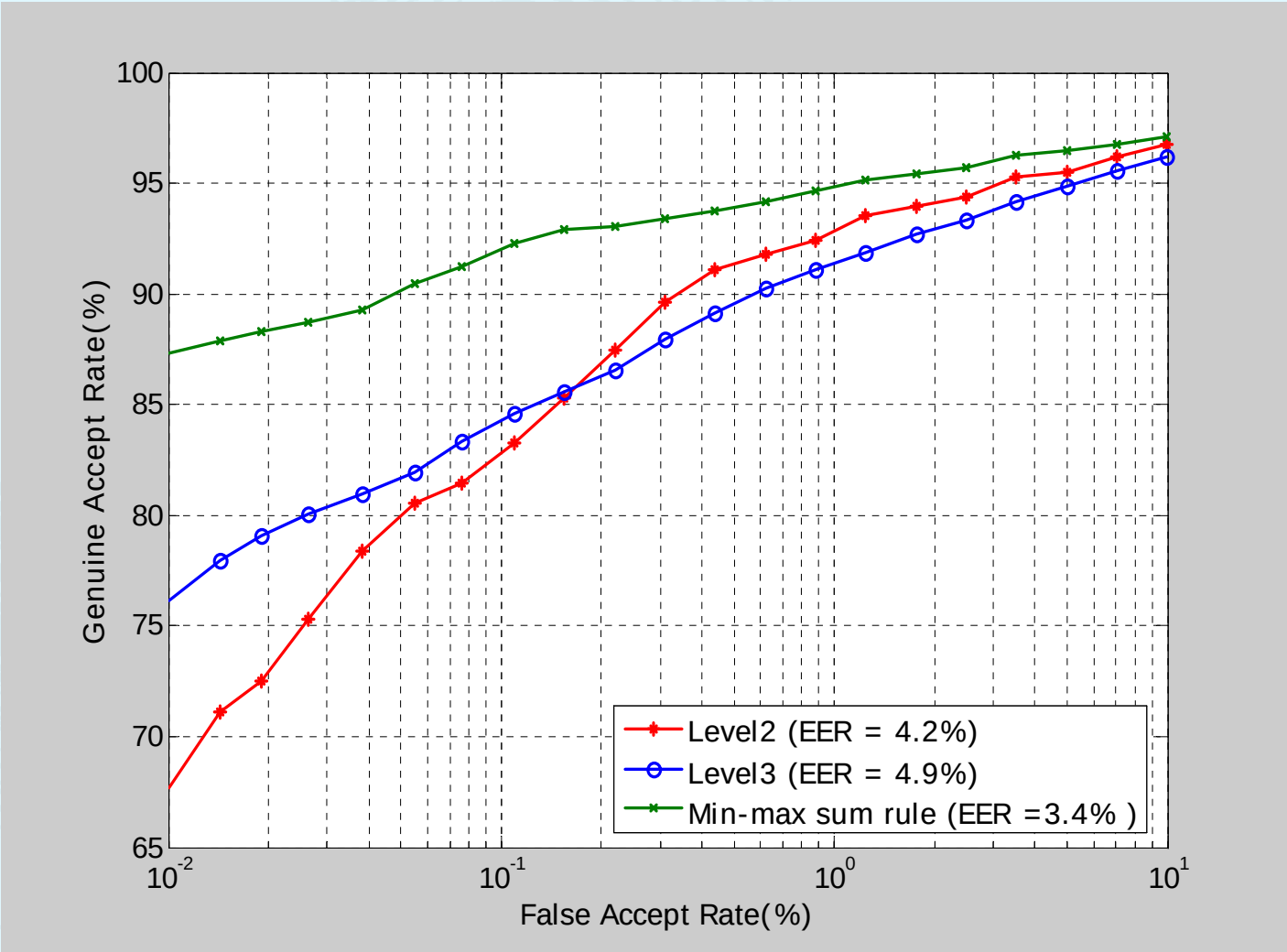
Experiments

- Database:
  - 1640 prints (41 subjects x 10 fingers x 2 impressions x 2 sessions)
  - 1000 ppi using CrossMatch ID1000
  - 83,845 impostor pairs & 2,460 genuine pairs

Level 2 Matching -- Different Resolution



Score-Level Fusion



Observations

- Merely increasing scan resolution does not improve the performance of matching at Level 2
- At 1000 ppi, ridge contours are more reliable Level 3 features, compared to pores
- Localized matching is needed to compensate for non-linear distortion
- Benefit of using Level 3 features increases when the fingerprint size decreases or if the number of Level 2 features is small
- Various levels of **fusion** of Level 2 and Level 3 features need to be investigated

Summary & Future Work

- We proposed a fingerprint matching system that automatically extracts and utilizes Level 3 features in 1000 ppi fingerprint images
- Testing the persistence of level 3 features across different image quality and scanning resolution needs to be pursued
- We are extending proposed approach to other Level 3 features (incipient ridges and creases)
- Some thoughts on the Mayfield case
  - Human vs. machine
  - Level 2 vs. Level 3 in poor quality images

"To accomplish anything whatsoever one must have **standards**. No one has yet accomplished anything without them… For any doctrine there must be three standards. There must be the basis, a *foundation;* there must be an *examination;* and there must be a *practical application*."

-- Mo Tzu, 450 B.C.