Latent Fingerprint Image Quality (LFIQ)

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Image Quality

- **Image quality** indicates "perceived" image degradation with/without relation to a reference image
- Factors affecting image quality
  - Sharpness, contrast, noise, distortion, resolution, dynamic range,..
- Quality assessment
  - Qualitative (Good/bad/ugly)
    vs.
    Quantitative (SNR)

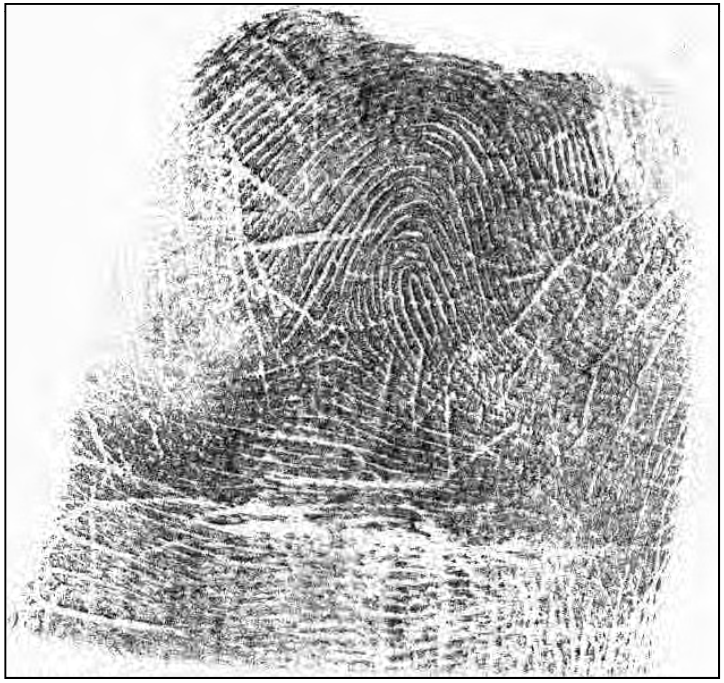
Standard Definition High Definition

Fingerprint Image Quality

- Prediction of AFIS performance for feature extraction and matching
  - "Perceived" fingerprint image quality may not necessarily correlate with AFIS performance

Good quality fingerprint (NFIQ* = 1)

Poor quality fingerprint (NFIQ = 5)



* NIST Fingerprint Image Quality; value is from 1 (highest quality) to 5 (lowest quality)

Latent Quality Assessment by Examiners

- ACE-V methodology
- Examiner determines latent value in **analysis** phase:
  - Value for Individualization (**VID**)
  - Value for Exclusion Only (**VEO**)
  - No Value (**NV**)
- Only VID or VEO latents are searched via AFIS
- Concern: Reliability and consensus of value determination by latent examiners
  - Visual perception, expertise of examiners, workload, etc.

Value vs. Identification Rate

	Value for Identification	Value for Exclusion Only	No Value
NIST SD27* (258 latents)	210	41	7
WVU (449 latents)	370	74	5
Rank-1 ID Rate	491 (85%)	46 (40%)	1 (8%)
Rank-100 ID Rate	525 (91%)	72 (63%)	7 (58%)

A significant number of VEO or NV latents can be successfully identified by AFIS

Identification rate is obtained by combining multiple AFIS; if the mate of a latent is retrieved within rank m by *any* of the AFIS, it is considered as a successful match within rank m

* Hicklin *et al*., "Latent Fingerprint Quality: A Survey of Examiners", Journal of Forensic Identification, 61(4), 2011

Reliability of Examiners' Value Determination

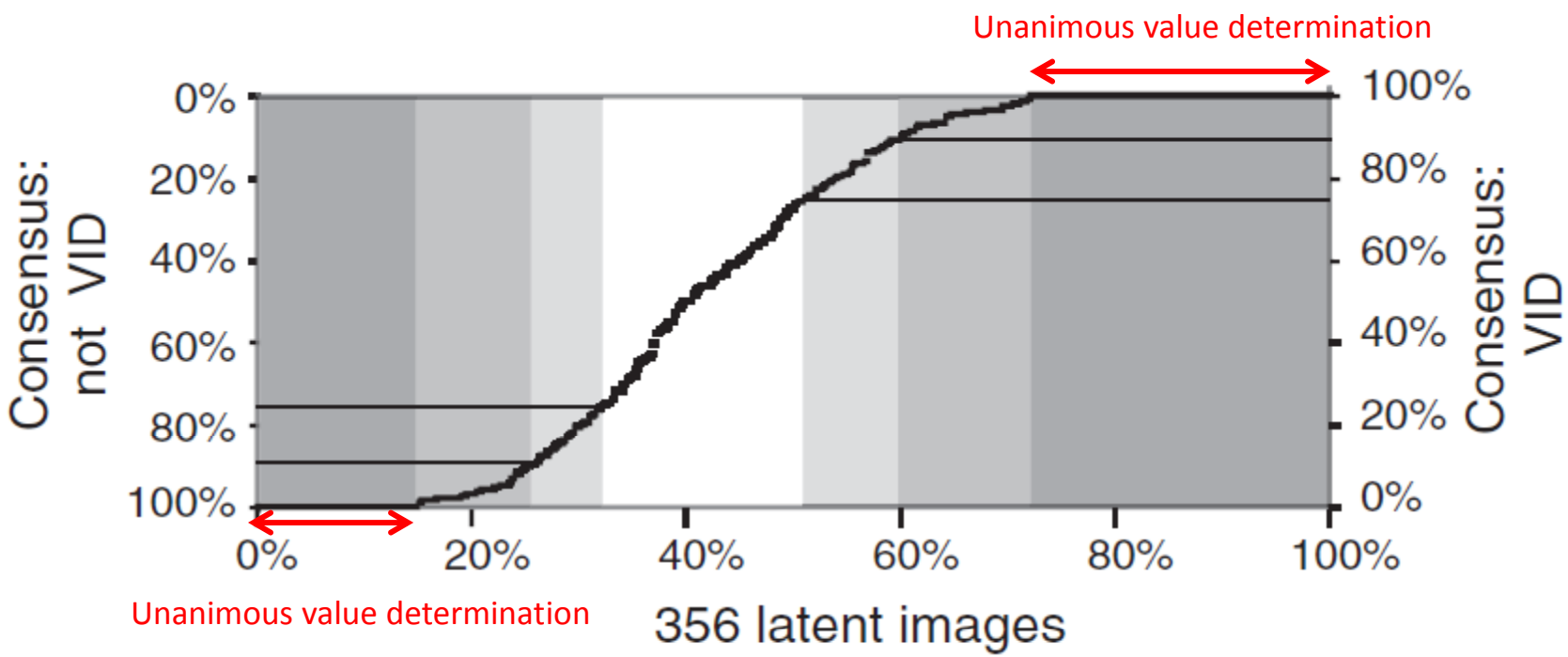
- NV and VEO latents successfully matched at rank 1 by AFIS

'No Value' (NV) Latent

'Value for Exclusion Only' (VEO) Latent

Consensus of Examiners' Value Determination

- Each latent was evaluated by an average of 23 examiners
- Unanimous value determination was made on only 43% of the latents (either VID or not-VID)



Ulery *et al*., "Repeatability and reproducibility of decisions by latent fingerprint examiners", PLOS One, 7(3), 2012

Goals of Our Study

- Provide an objective measure of latent quality to avoid misleading conclusions in subjective quality evaluation
- Identify latents which can be processed in “Lights-out” mode

Tenprint Quality vs. Latent Quality

- Tenprint quality assessment
  - Clean background; central part of the finger
  - Usually defined in terms of clarity of ridge and valley structures
- Latent quality assessment
  - Severe background noise, off-center finger position, skin distortion, etc.
  - Local ridge clarity measures alone cannot properly determine latent quality

Latent Quality Definition

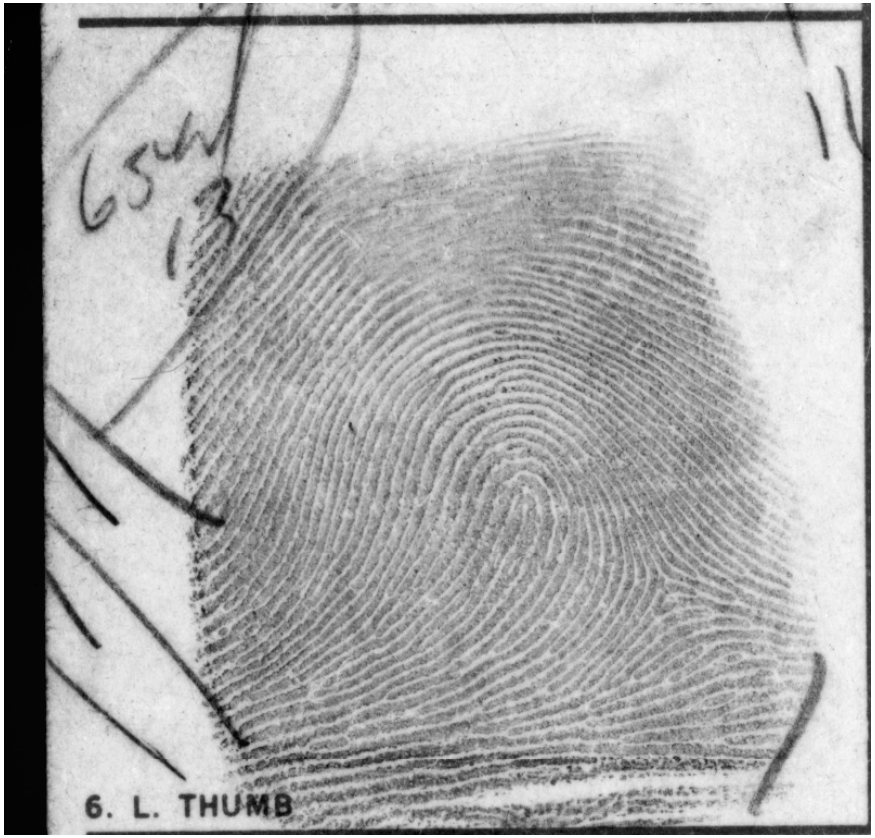
- Features
  - Local ridge clarity in presence of severe background noise
  - Vicinity of good quality ridge areas
  - Position of mark
  - Minutiae reliability

- Matcher-independent vs. matcher-dependent

Matcher-Independent vs. Matcher-Dependent

- Matcher-Independent Quality Measure
  - A latent is considered **VID** if *any* one of the AFIS can successfully retrieve its mate from a reference database within the candidate list
- Matcher-Dependent Quality Measure
  - A latent is considered **VID** if *a specific* AFIS can successfully retrieve its mate from a reference database within the candidate list

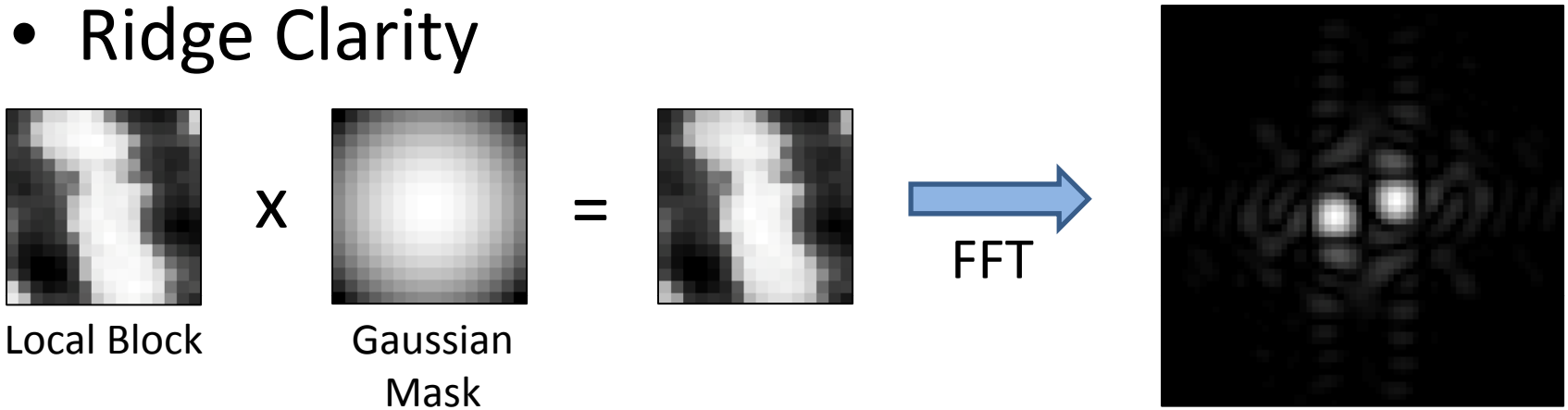
AFIS Interoperability



Retrieval Rank	AFIS 1	AFIS 2	AFIS 3
Proprietary Minutiae	32	561	222
Markup Minutiae	31,997	156	1

Local Ridge Quality

- Ridge Clarity

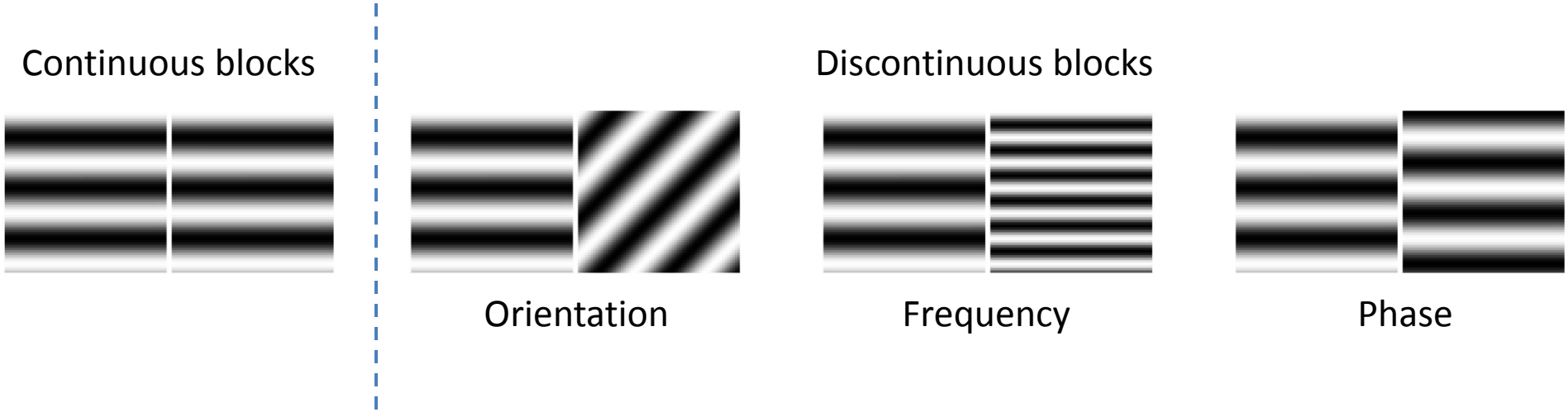


Local Block

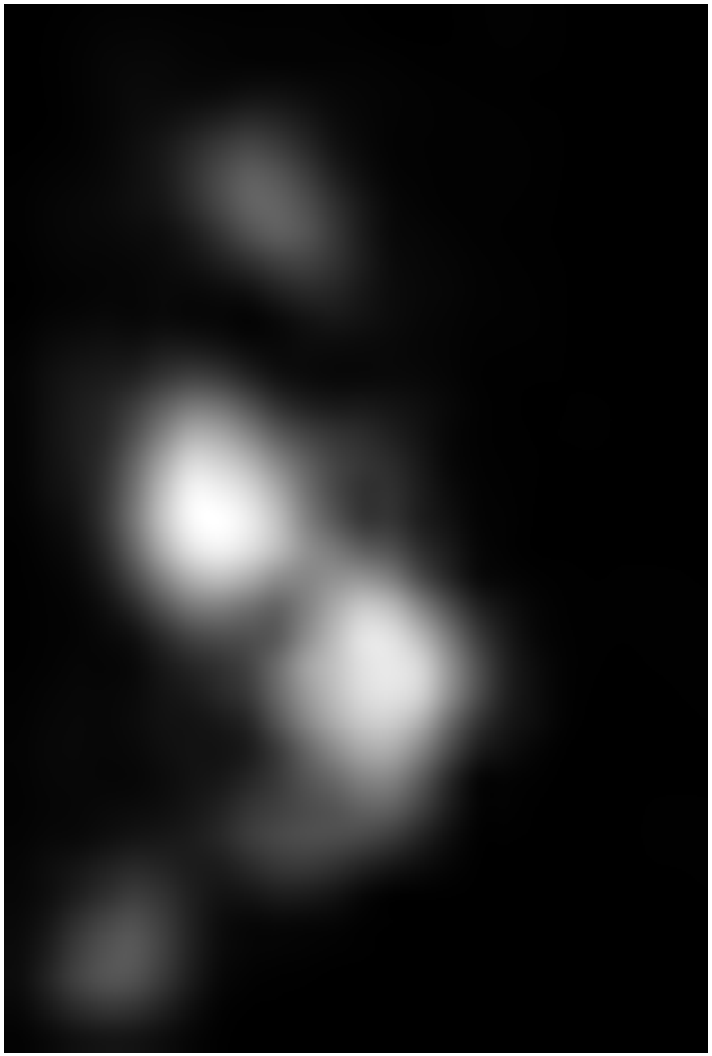
Gaussian Mask

Power Spectrum

- Ridge Continuity



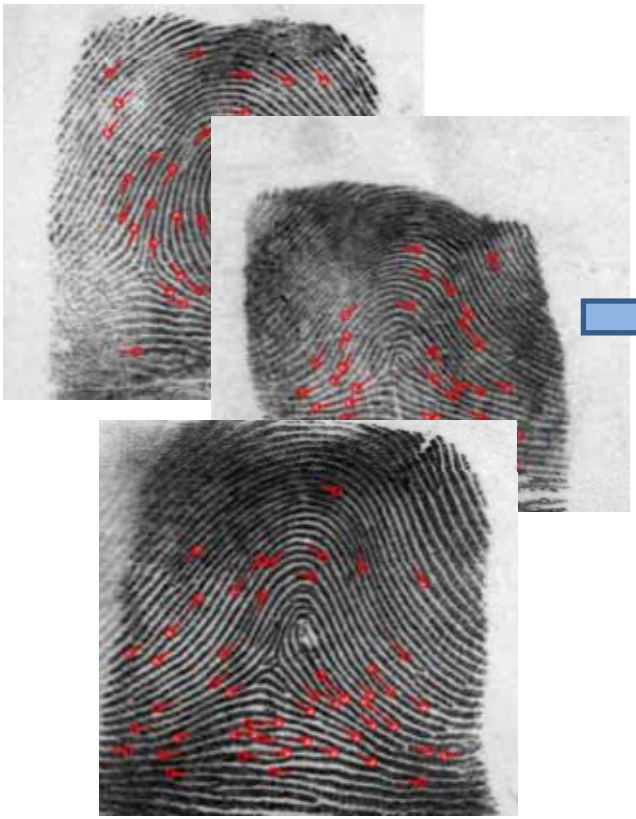
Local Ridge Quality



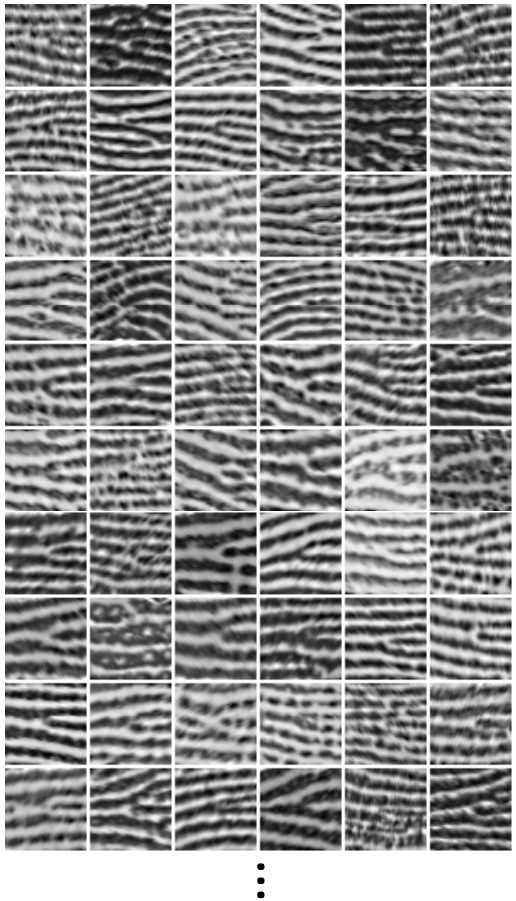
Minutiae Reliability: Learning

- Minutiae patch dictionary learning

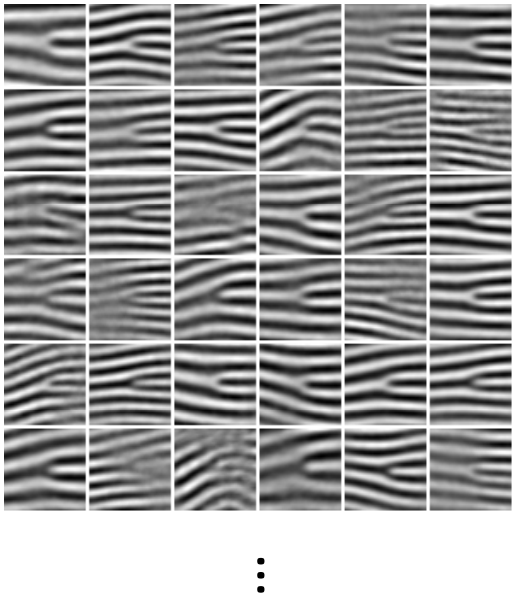
High Quality Fingerprints



High Quality
Minutiae Patches (48x48)

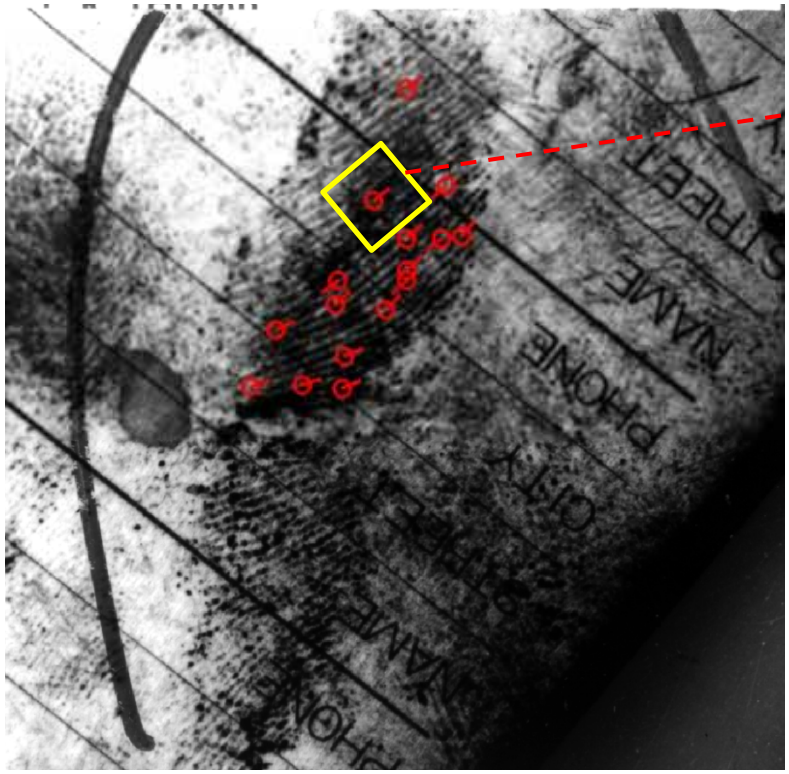


Dictionary Elements

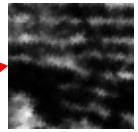


Minutiae Reliability

Latent Fingerprint

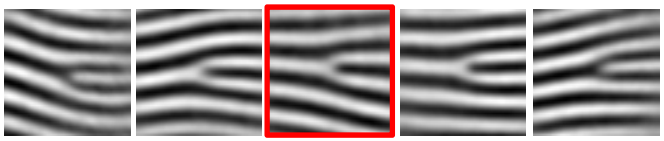


Minutia Patch



P

Dictionary Elements



…

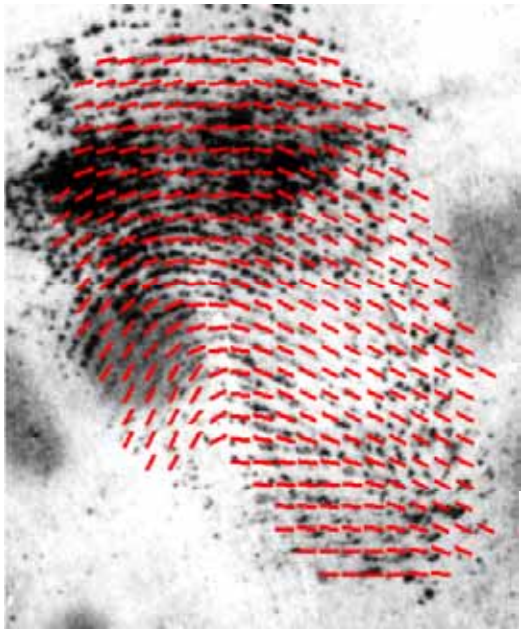
$D = \{d_m | m = 1, 2, \ldots, M\}$

Reliability of patch P (Q_m) is defined as the Structural SIMilarity (SSIM) between P and its closest dictionary element d_m:

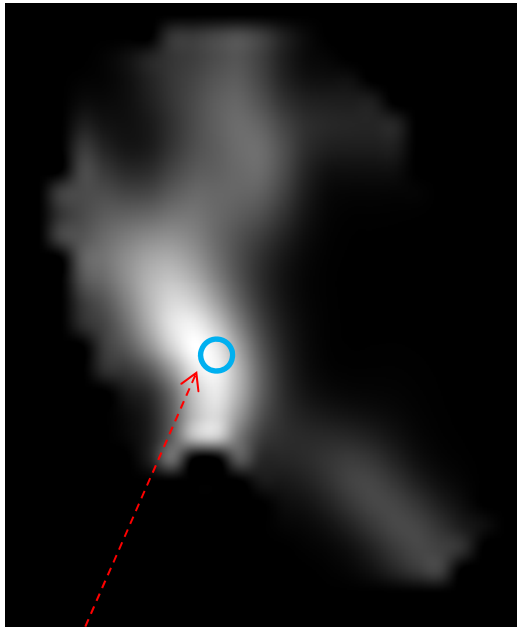
$$Q_m = \max \{SSIM(P, D)\}$$

Wang *et al.*, Image Quality Assessment: From Error Visibility to Structural Similarity, TIP, 13(4), 2004

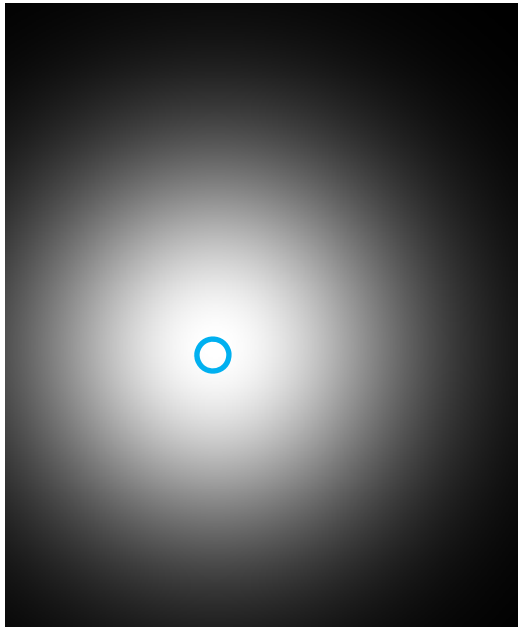
Reference Point Detection



Orientation Field
(Reconstructed from minutiae)



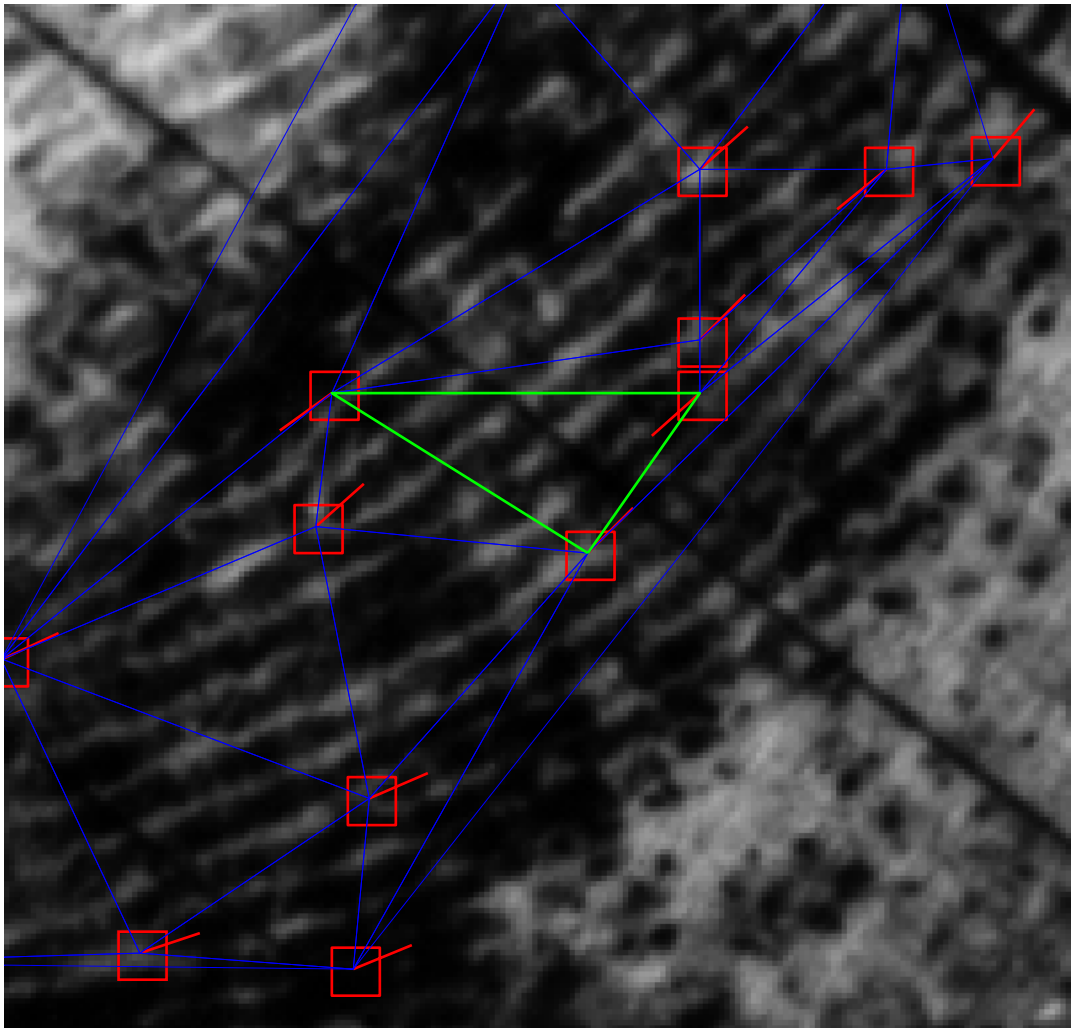
Curvature map



Weight Map

- Reference point is determined as the point where the curvature is maximum

Quality Score



- For each triangle T_i,

$$Q_{T_i} = Q_{r_i} \sum_{j=1}^{3} Q_{m_{ij}} W_{m_{ij}}$$

Q_{ri}: Average ridge quality in T_i
Q_{mij}: Reliability of the j-th minutia of T_i
W_{mij}: Weight based on the finger position

- Quality score of a latent:

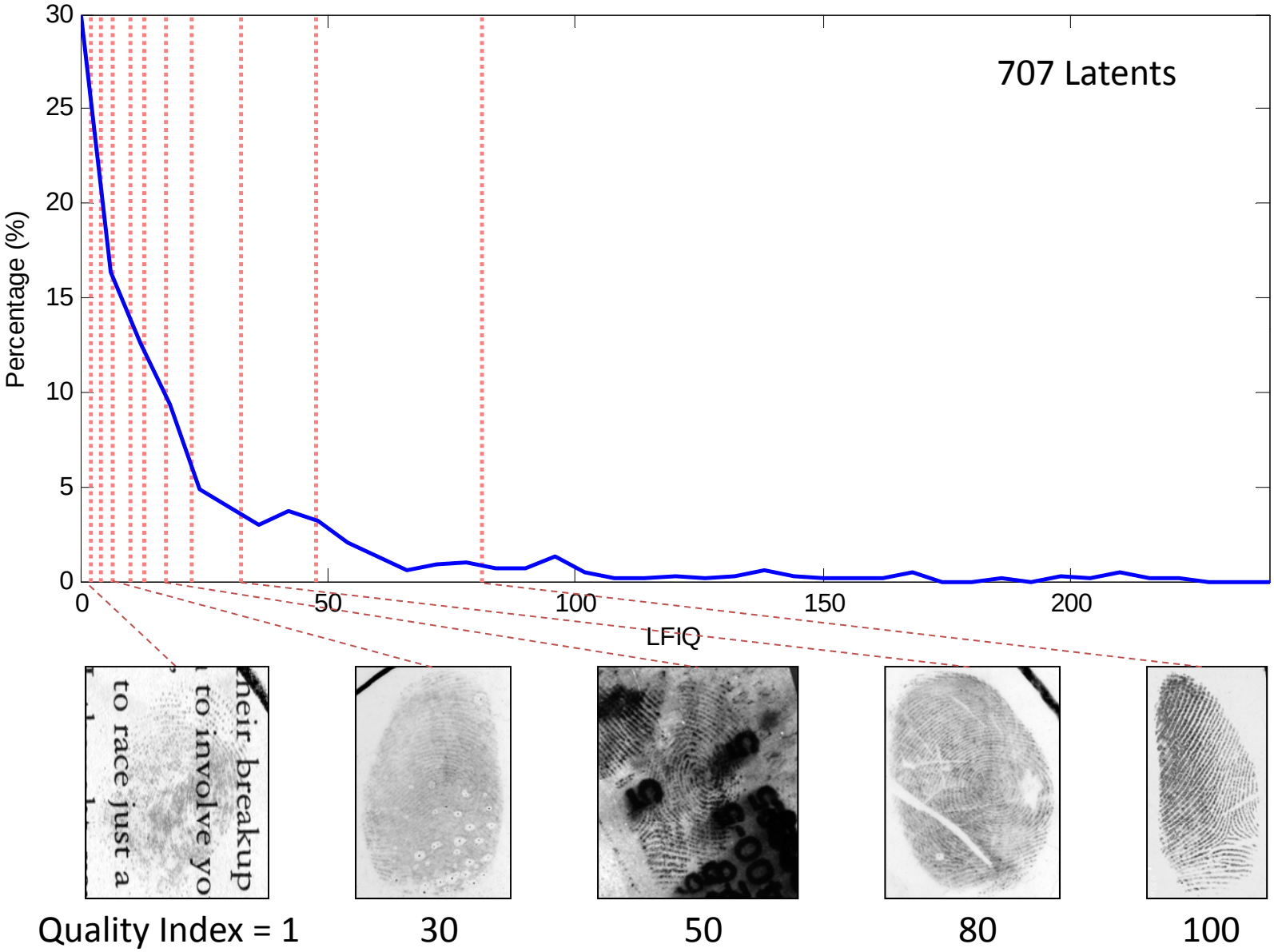
$$LFIQ = \sum_{i=1}^{N} Q_{T_i}$$

N: Number of triangles in latent

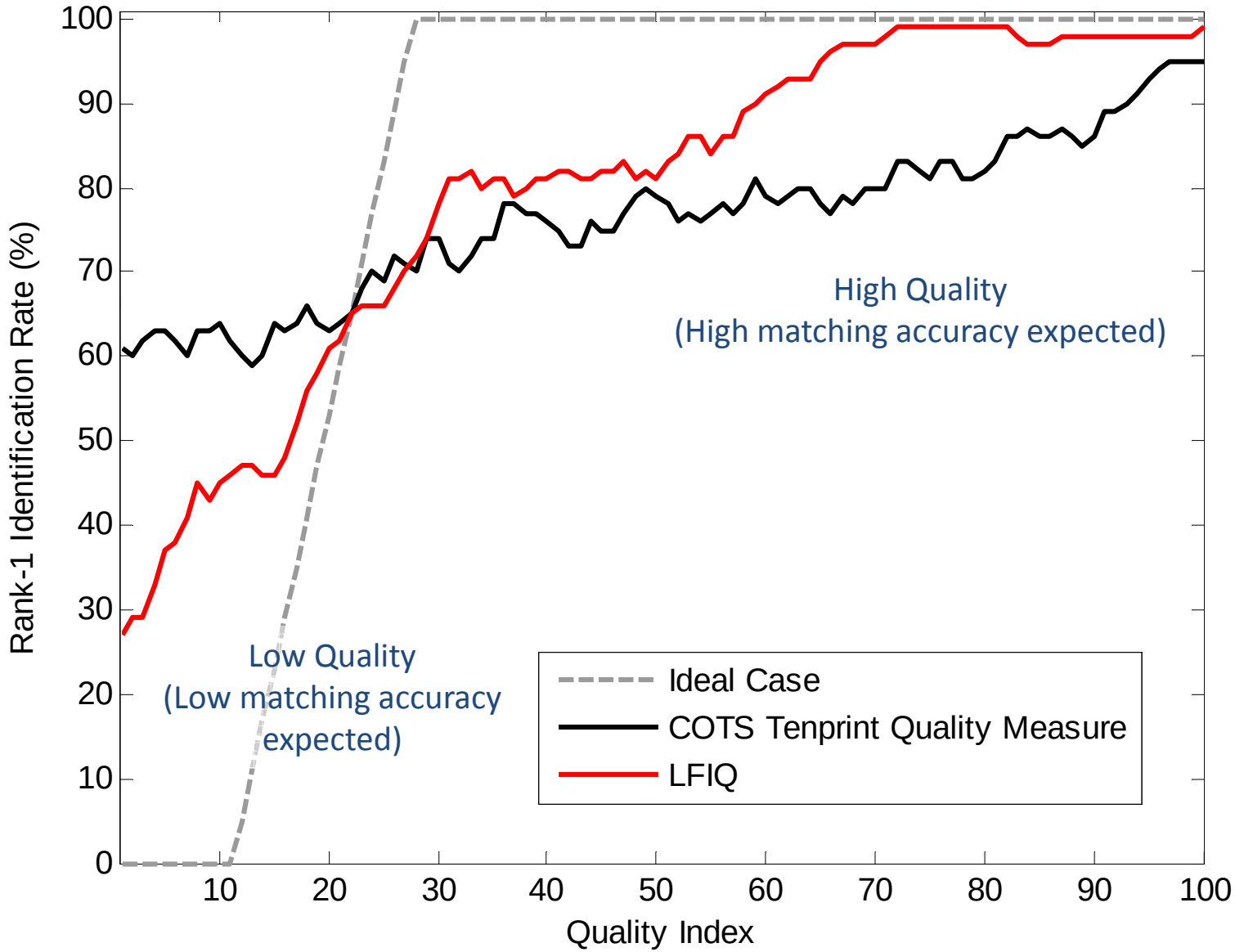
Experiments

- Latent Databases (707 latents)
  - NIST SD27: 258 latents
  - WVU Latent DB: 449 latents
- Exemplar Databases (31,997 rolled prints)
  - NIST SD27: Mated 258 rolled prints
  - WVU: Mated 449 rolled prints; 4,290 rolled prints
  - NIST SD14: 27,000 rolled prints
- Matcher: Three COTS matchers
- Matcher-independent approach
- Using markup minutiae for preliminary study

LFIQ Distribution



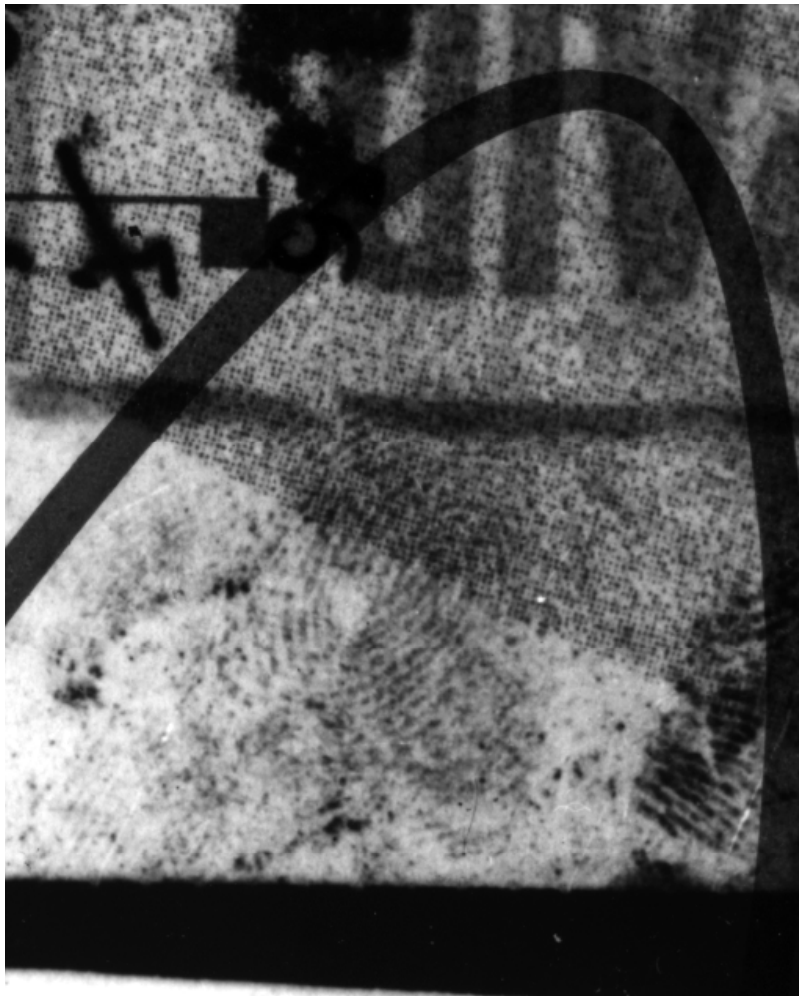
Performance: Rank-1 Identification Rate



Successful Prediction

- Quality Index 74 (LFIQ = 26); Mate retrieved at rank 1; examiner labeled it as VEO latent

Latent



Mated Rolled Print

Unsuccessful Prediction

- High quality, but low matching performance

Latent

Mated Rolled Print

- Quality Index 92 (LFIQ = 51)
- Value determination by examiner: VID
- Retrieval rank of the mate: 600

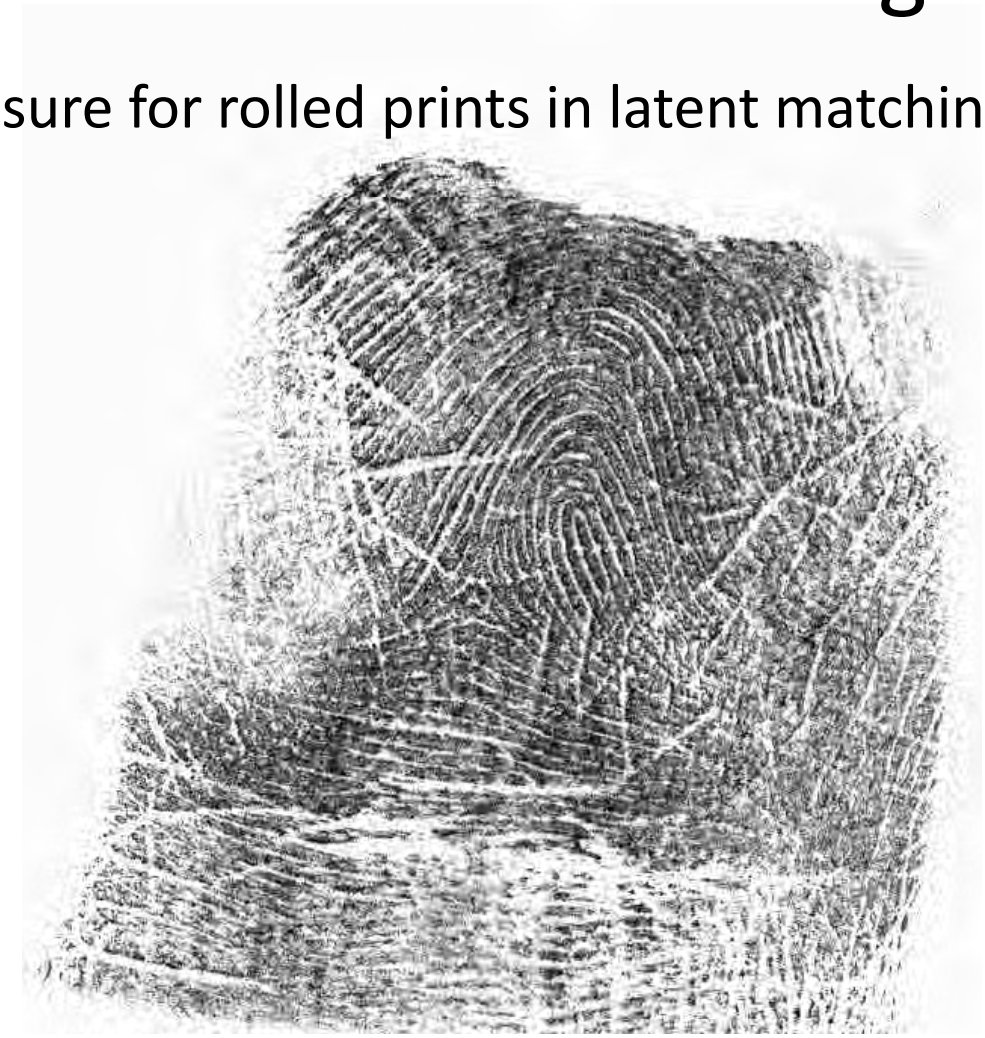
Quality of Exemplars in Latent Matching

- NFIQ = 5
- Is this still adequate for latent matching?

Quality of Exemplars in Latent Matching

- May need to relax quality measure for rolled prints in latent matching

Latent print



Mated rolled print

AFIS can successfully match the pair

Conclusions

- Latent fingerprint image quality (LFIQ) assessment is crucial for properly determining **latent value** as forensic evidence
- LFIQ is an objective measure of latent quality
  - Distinguish latents that can be processed in “lights-out” mode
  - Complement latent examiners’ value determination
- Investigated various features (ridge quality, minutiae quality, position of mark) in defining LFIQ

Thank you