Latent Fingerprint Image Quality (LFIQ)

Anil Jain, Soweon Yoon, Kai Cao, and Eryun Liu
Michigan State University
biometrics.cse.msu.edu
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)
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

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

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

Reliability of Examiners’ Value Determination

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

<table>
<thead>
<tr>
<th>Retrieval Rank</th>
<th>AFIS 1</th>
<th>AFIS 2</th>
<th>AFIS 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proprietary Minutiae</td>
<td>32</td>
<td>561</td>
<td>222</td>
</tr>
<tr>
<td>Markup Minutiae</td>
<td>31,997</td>
<td>156</td>
<td>1</td>
</tr>
</tbody>
</table>
Local Ridge Quality

• Ridge Clarity

Local Block \times \text{Gaussian Mask} = \text{Power Spectrum}

• Ridge Continuity

Continuous blocks

Discontinuous blocks

Orientation

Frequency

Phase
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

Dictionary Elements

\[ PD = \{ d_m | m = 1, 2, \ldots, M \} \]

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

\[ Q_m = \max \{ \text{SSIM}(P, D) \} \]

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

• Reference point is determined as the point where the curvature is maximum
Quality Score

• For each triangle $T_i$,

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

$Q_{r_i}$: Average ridge quality in $T_i$
$Q_{m_{ij}}$: Reliability of the j-th minutia of $T_i$
$W_{m_{ij}}$: 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

Quality Index = 1
to race just a
their breakup
to involve you
Performance: Rank-1 Identification Rate

![Graph showing performance metrics](image)

- **Rank-1 Identification Rate (%)**
- **High Quality** (High matching accuracy expected)
- **Low Quality** (Low matching accuracy expected)

Legend:
- **Ideal Case**
- **COTS Tenprint Quality Measure**
- **LFIQ**
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