Automatic Latent Value Determination

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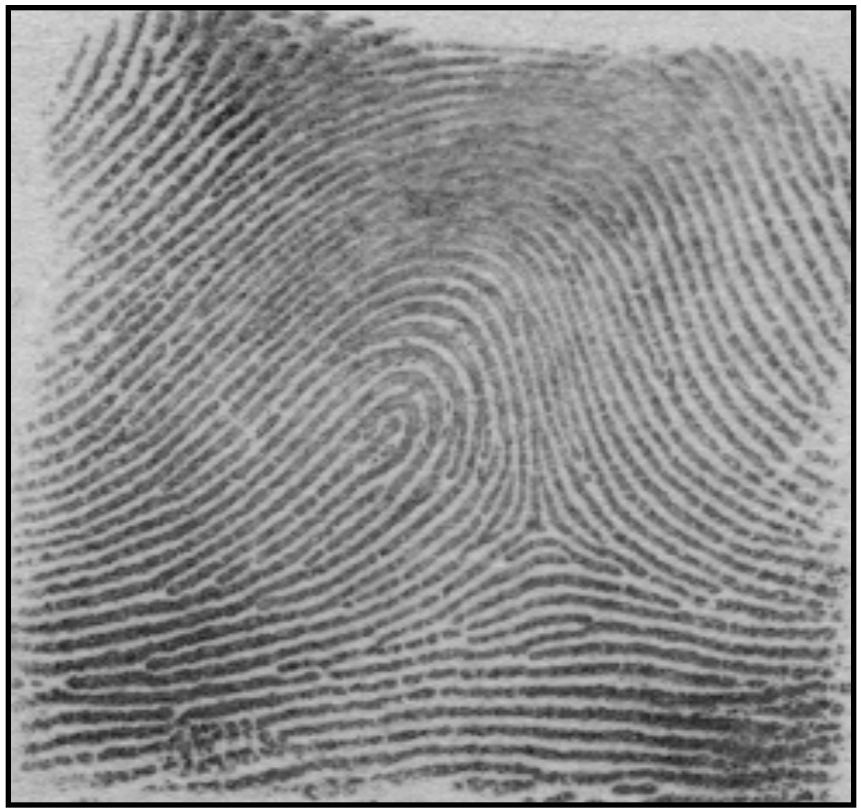
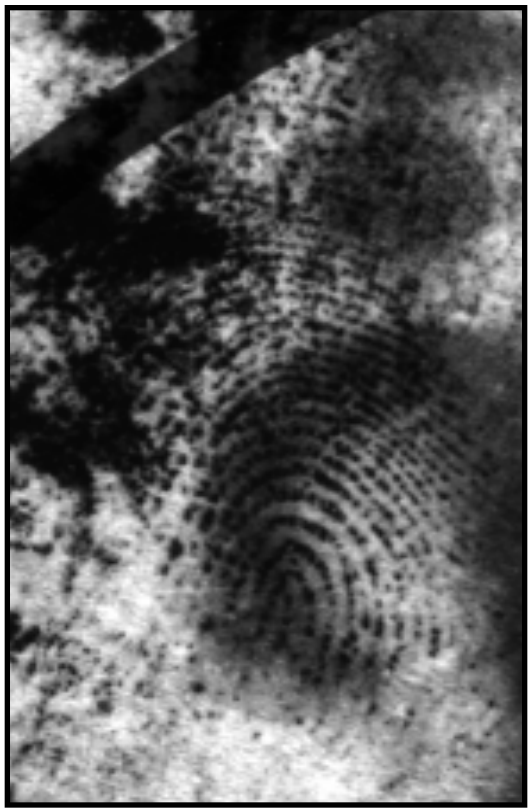
What are Latent Fingerprints?



Rolled

Plain



Latent

Challenges in Latent Matching

Poor Ridge Clarity

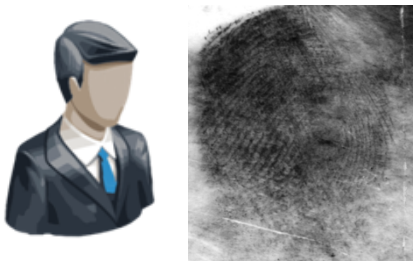
Partial Ridge Area

Complex Background

- AFIS Performance (Rank-1 accuracy)
  - Plain: 98.5%
  - **Latent: 67.2% (70.2% with image + markup)**

C. Watson, G. Fiumara, E. Tabassi, S. L. Cheng, P. Flanagan, W. Salamon. Fingerprint Vendor Technology Evaluation, NISTIR, 8034, 2012.
* M. Indovina, V. Dvornychenko, R. Hicklin, and G. Kiebuzinski. ELFT-EFS Evaluation of Latent Fingerprint Technologies: Extended Feature Sets, NISTIR, 2012.

Latent Matching: ACE-V Protocol



Fingerprint examiner

Value for Individualization (VID)
Value for Exclusion Only (VEO)

Value Determination

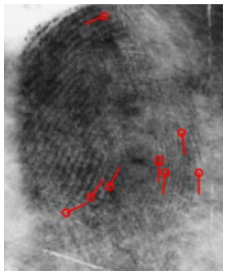
Of Value

No Value(NV)

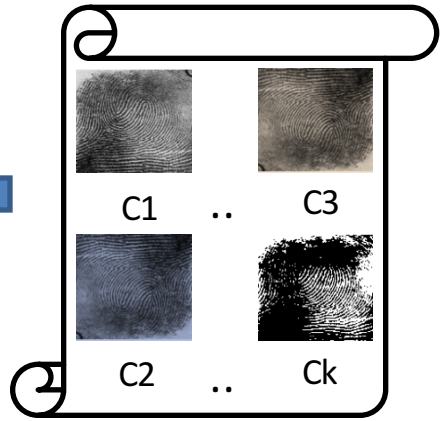
Retain/Discard

Analysis

Feature Markup



Comparison AFIS



Candidate List

Evaluation

Decision

Individualization
Exclusion
Inconclusive

Verification by second examiner

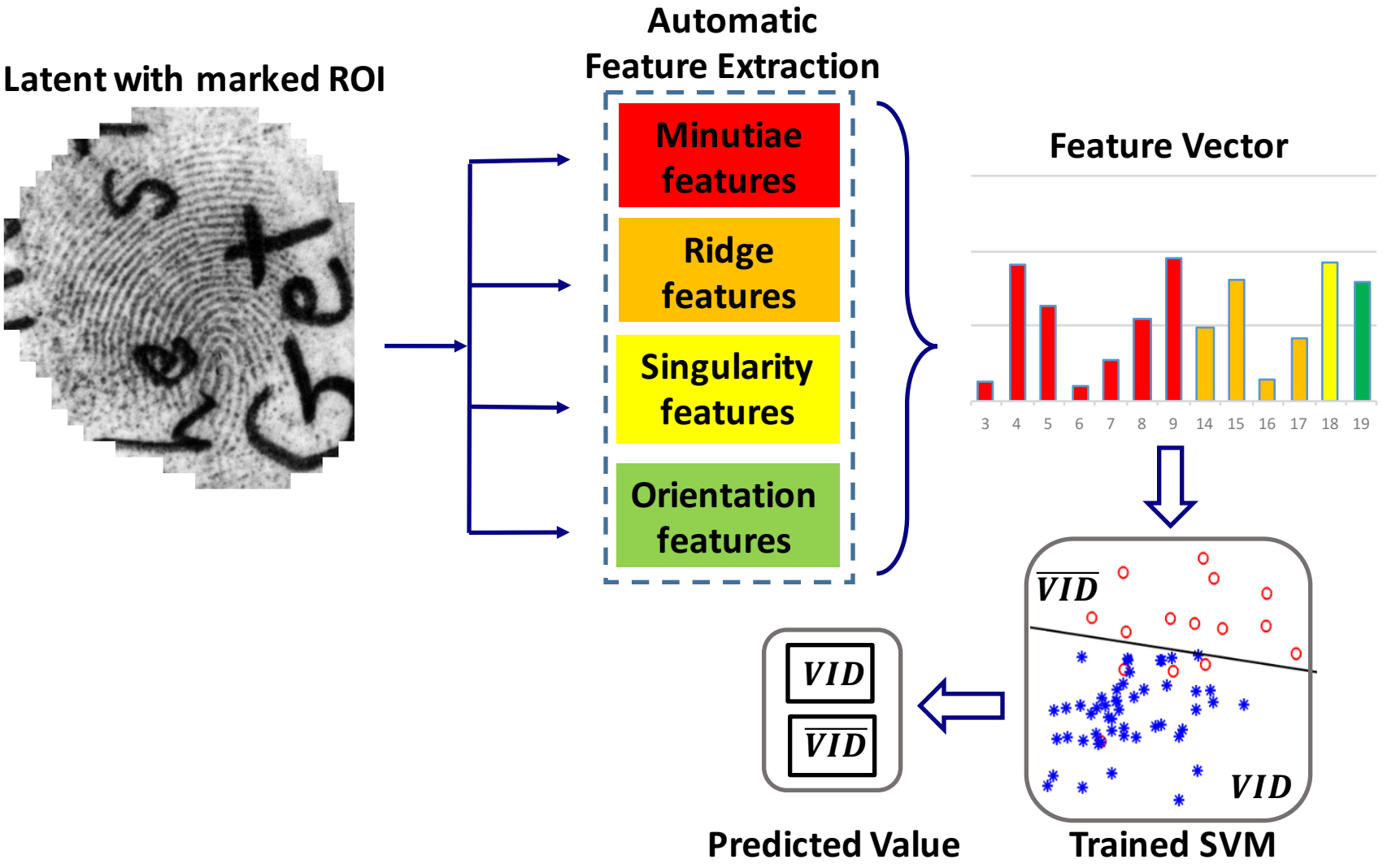
Limitations of Examiner Value Determination

- Highly subjective
  - repeatability (intra-examiner variability): 84.6%
  - reproducibility (inter-examiner similarity): 75.2%
- Depends upon examiner's skill and experience
- Time-consuming

Need for automatic value determination

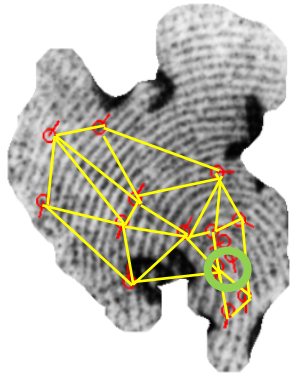
Ulery et al.,"Repeatability and reproducibility of decisions by latent fingerprint examiners," PloS one, 7(3):e32800, 2012.
Ulery et al., "Accuracy and reliability of forensic latent fingerprint decisions," PNAS, 108(19):7733–7738, 2011.

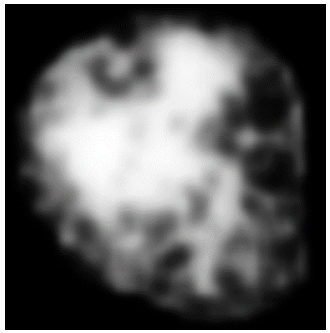
Proposed Automatic Method for Value Determination



Features for Value Assessment

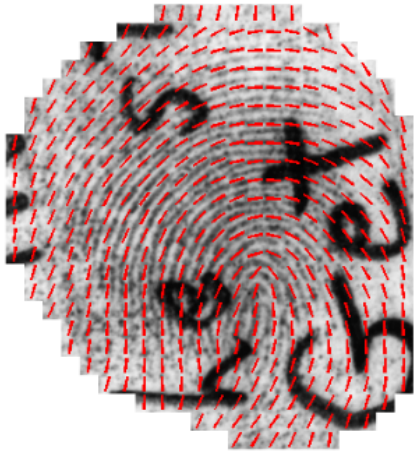
Feature No.	Description
1	**Number of minutiae**
2 - 8	Sum of **minutiae reliability** with reliability ≥ t, t= 0, 0.1, ..., 0.6
9	**Average area** of minutiae Delaunay triangulation
10	Area of the convex hull of minutiae set
11 - 17	Sum of **ridge quality** blocks with quality value ≥ t, t= 0, 0.1, ..., 0.6
18	Number of **singular points** (core and delta)
19	**Standard deviation of the ridge flow** in the foreground





Feature Extraction

Input Latent with ROI

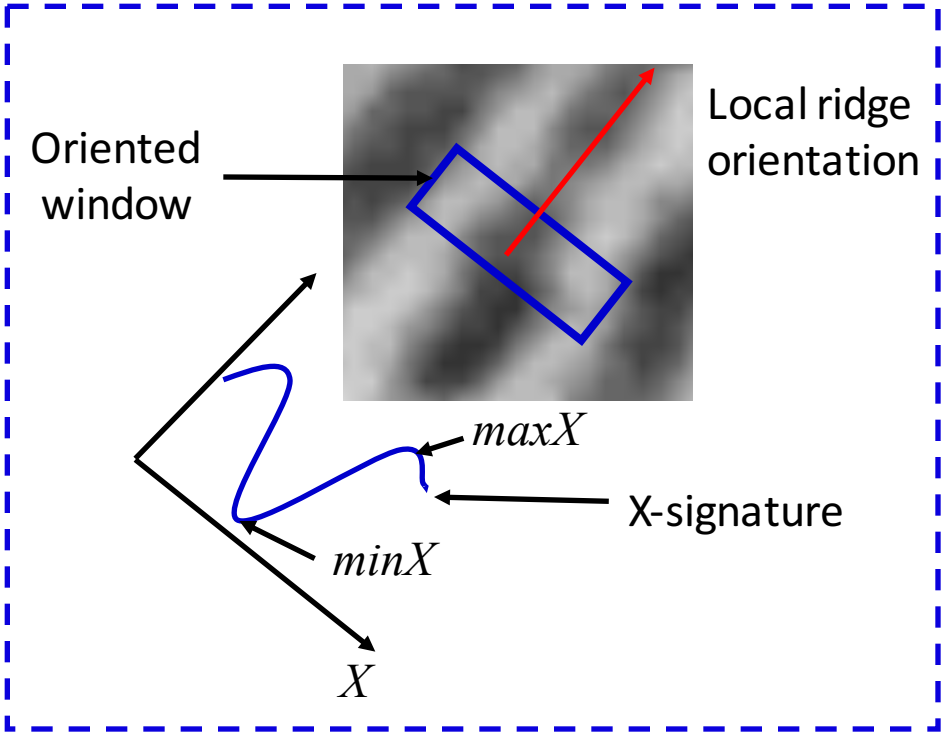


Ridge Flow Estimation

Normalization

K. Cao and A. K. Jain, *Latent Orientation Field Estimation via Convolutional Neural Network*, ICB, 2015

Image Normalization



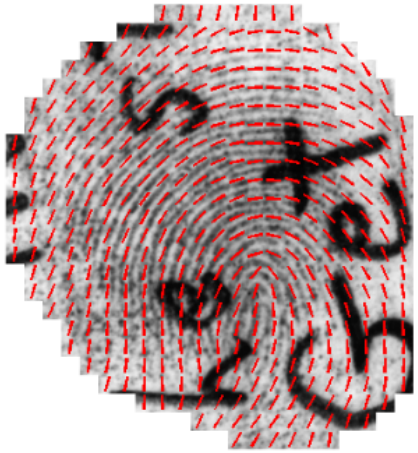
Oriented window and X-signature

Input latent image

Normalized image

Feature Extraction

Input Latent with ROI



Ridge Flow Estimation

Normalization

Ridge Enhancement

Ridge Enhancement

- Dictionary construction
- Ridge enhancement using dictionary

Input latent

Enhanced by Gabor filtering

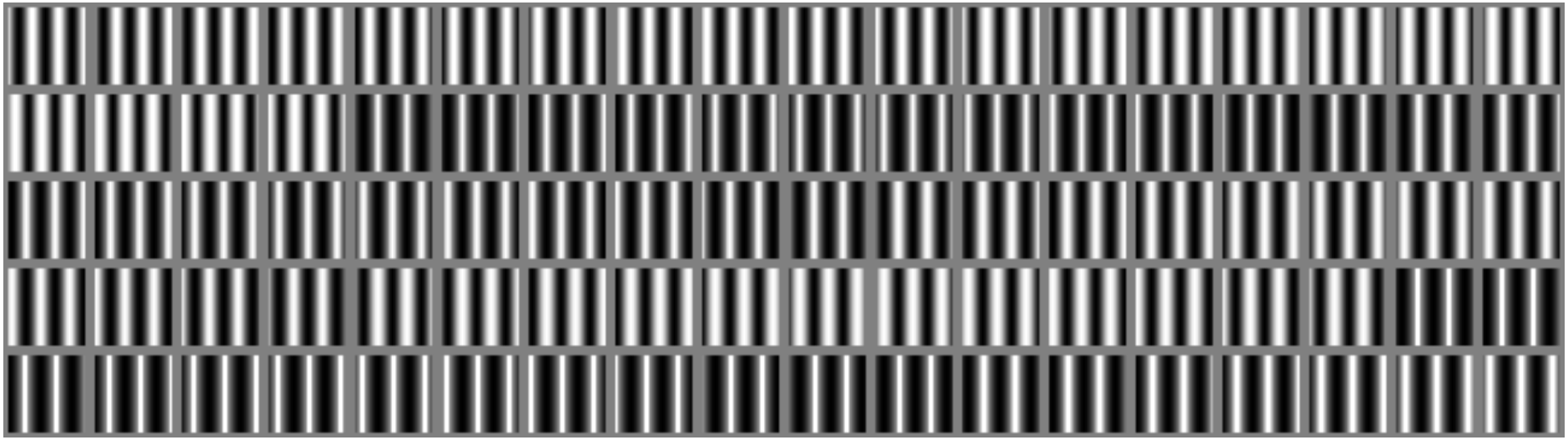
Enhanced by dictionary

Ridge Enhancement

- Dictionary construction

Dictionary element | Valley image | Ridge image

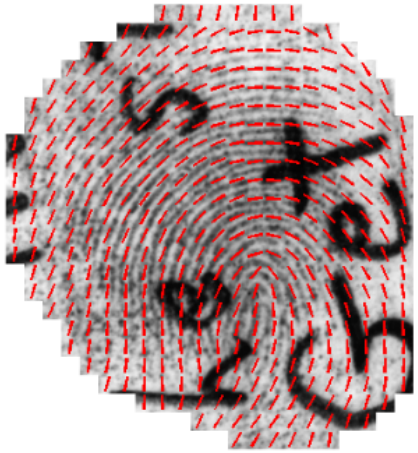
Note that ridge and valley widths can be different



A subset of dictionary elements used for latent ridge enhancement

Feature Extraction

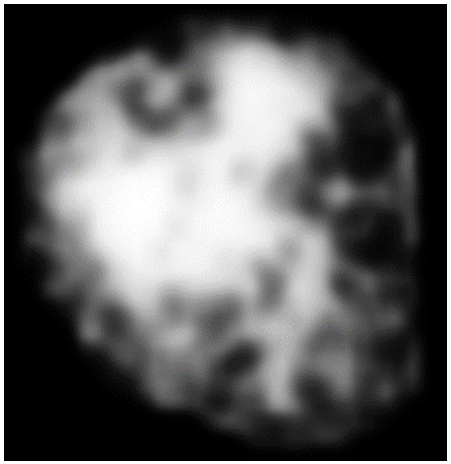
Input Latent with ROI



Ridge Flow Estimation

Normalization

Ridge Enhancement

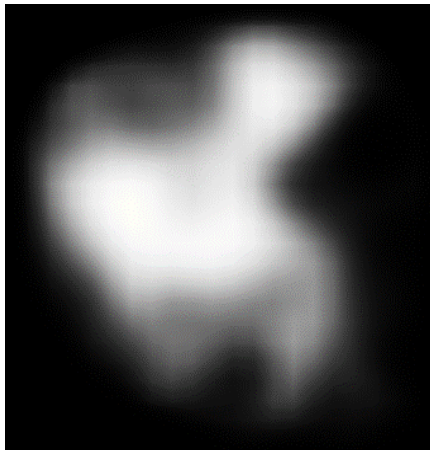


Ridge Quality Estimation

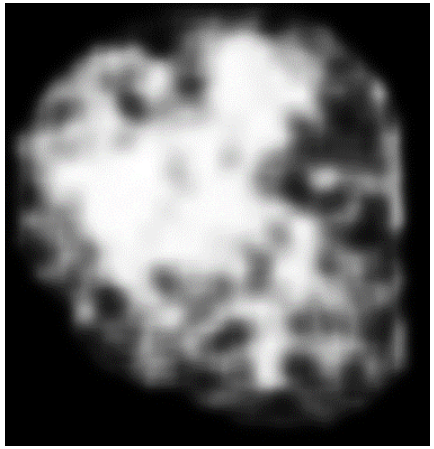
Ridge Quality Estimation

(a) Normalization of input latent

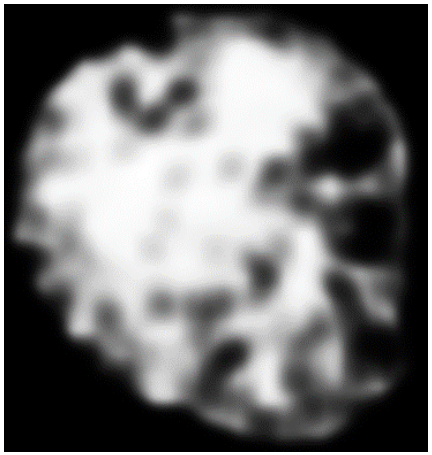
(b) Normalization of Enhanced latent



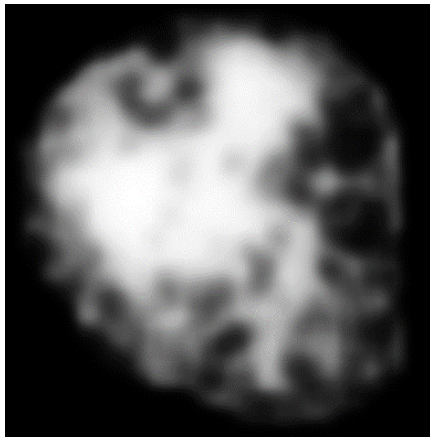
(e) Similarity between (a) and (b)



(c) Orientation coherence of (a)



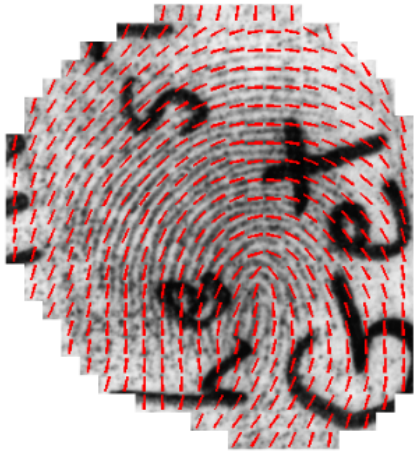
(d) Orientation coherence of (b)



(f) Fused Quality map of (c), (d) & (e)

Feature Extraction

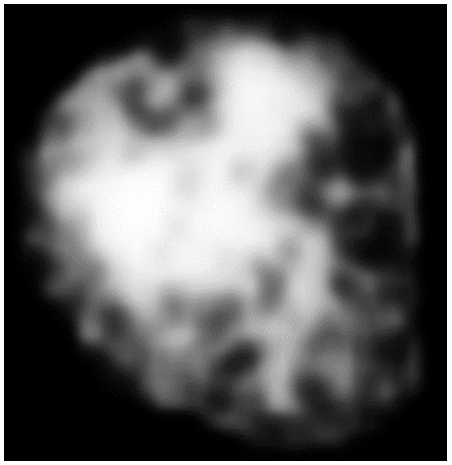
Input Latent with ROI



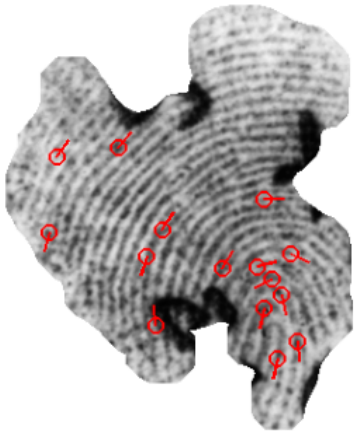
Ridge Flow Estimation

Normalization

Ridge Enhancement

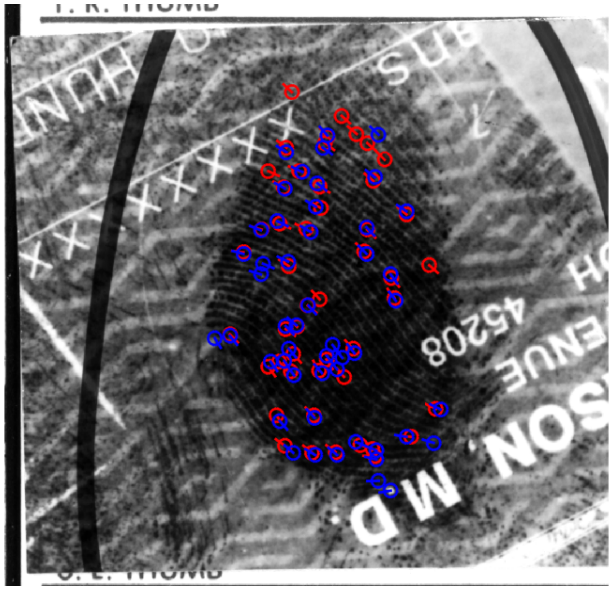


Ridge Quality Estimation

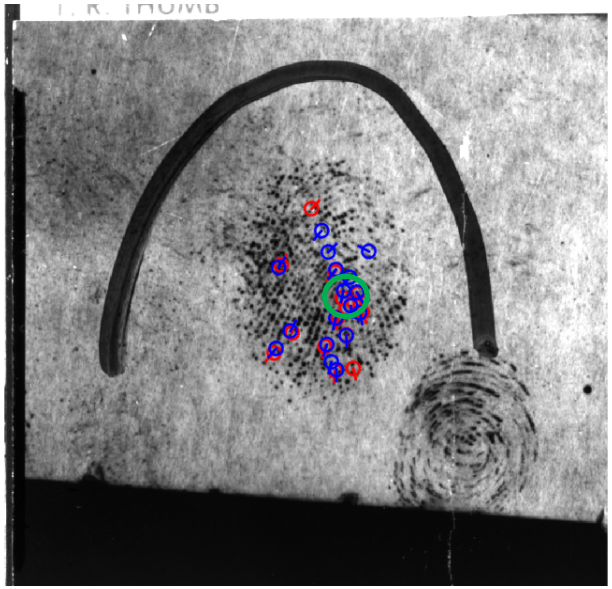


Minutiae Extraction

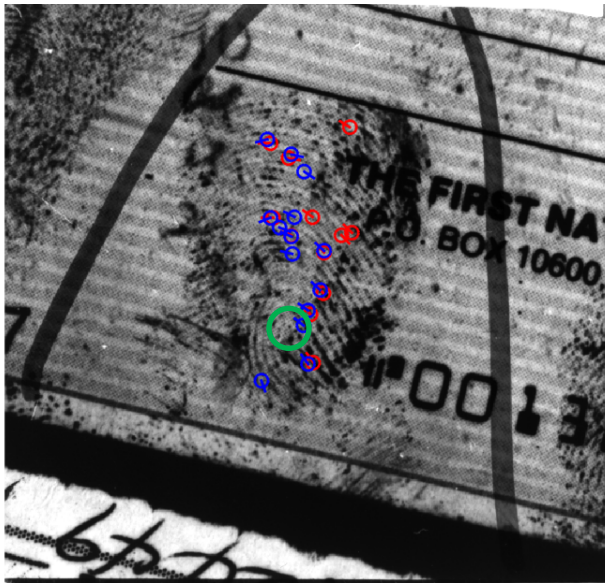
Minutiae and Singular Points Extraction



Latent ID: G007



Latent ID: B106



Latent ID: U228

Manually marked minutiae

Automatic extracted minutiae

Automatic detected core point

N. K. Ratha, S. Chen and A. K. Jain, "Adaptive flow orientation-based feature extraction in fingerprint images", *Pattern Recognition*, *1995*

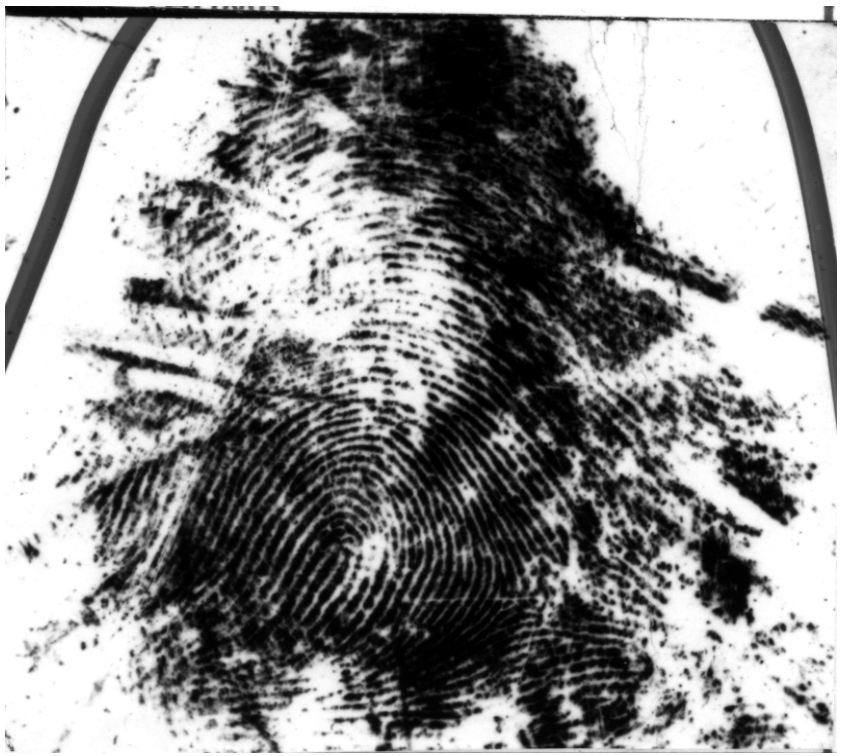
Experiments

- Latent Databases (Total of 707 latents)
  - NIST SD27: 258 latents
  - WVU Latent DB: 449 latents
- Latent value determination posed as two class (VID and not-VID) classification
- Two sources of ground truth
  - Value Determination by Examiners
  - Value Determination by latent AFIS*
    - Latent mates retrieved at Rank-1 determined to be VID
- 10-fold cross validation protocol

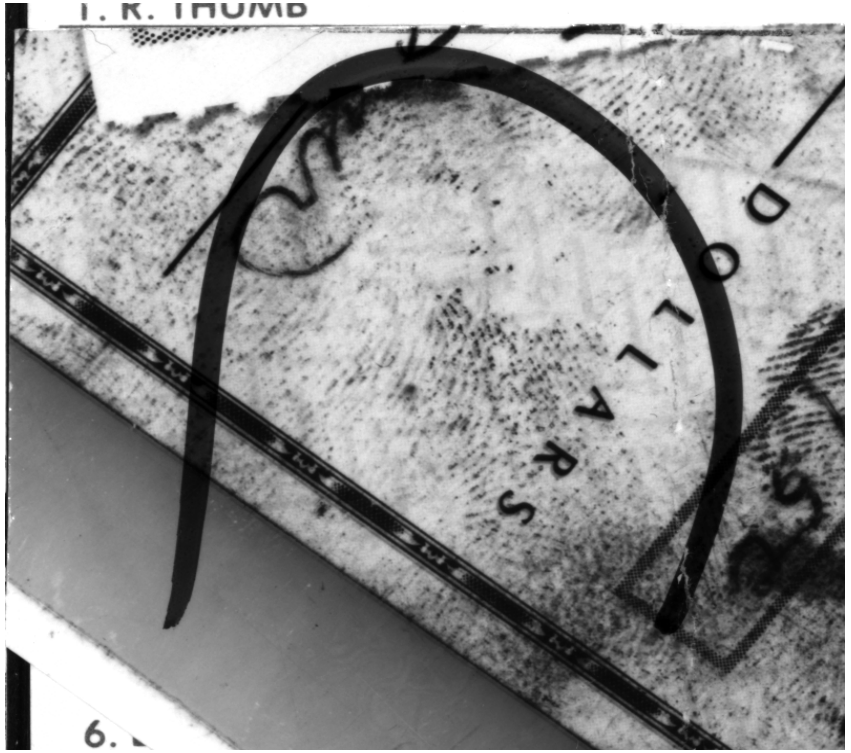
* One of the best performing latent AFIS in ELFT evaluation

Ground Truth Consistency

Agreement



AFIS: VID
Examiner: VID



AFIS: $\overline{\text{VID}}$
Examiner: $\overline{\text{VID}}$

Consistency : 77.8%

Ground Truth Consistency

Disagreement

AFIS: VID
Examiner: $\overline{\text{VID}}$

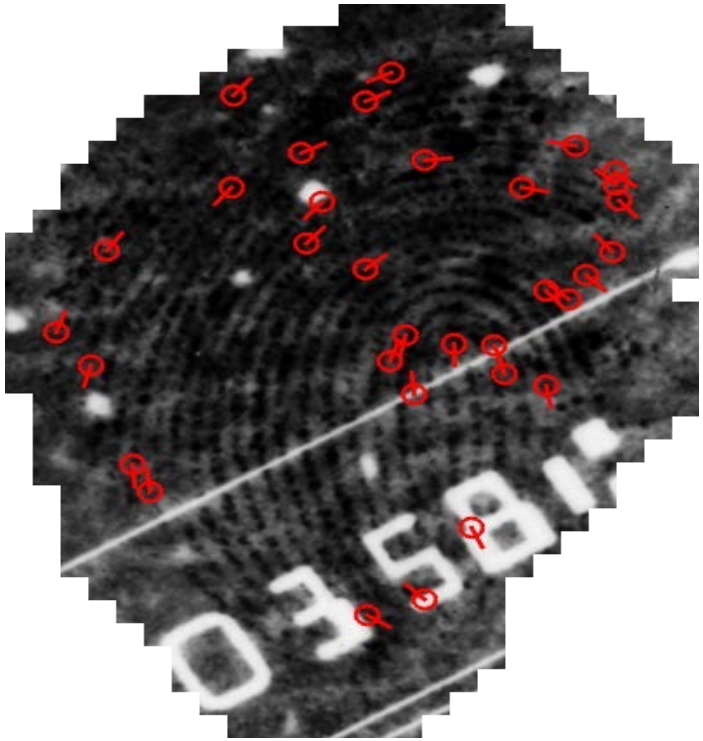
AFIS: $\overline{\text{VID}}$
Examiner: VID

Consistency : 77.8%

Latent Value Ground Truth by Examiners

Correctly Classified

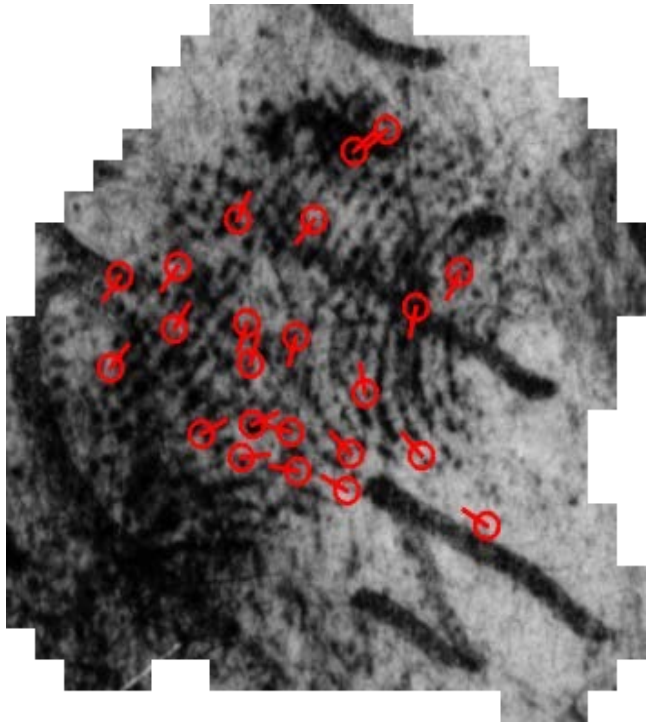
Latent ID: G020



Examiner: VID

Our Method: VID

Latent ID: U204



Examiner: $\overline{\text{VID}}$

Our Method: $\overline{\text{VID}}$

Classification Accuracy : 85.6 ± 2.4%

Latent Value Ground Truth by Examiners

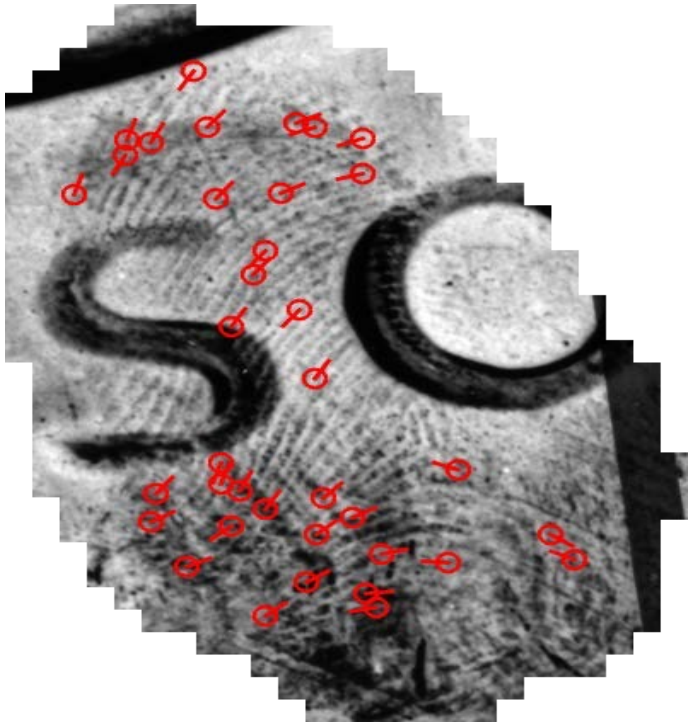
Incorrectly Classified

Latent ID: B120

Examiner: VID

Our Method: $\overline{\text{VID}}$

Latent ID: G057



Examiner: $\overline{\text{VID}}$

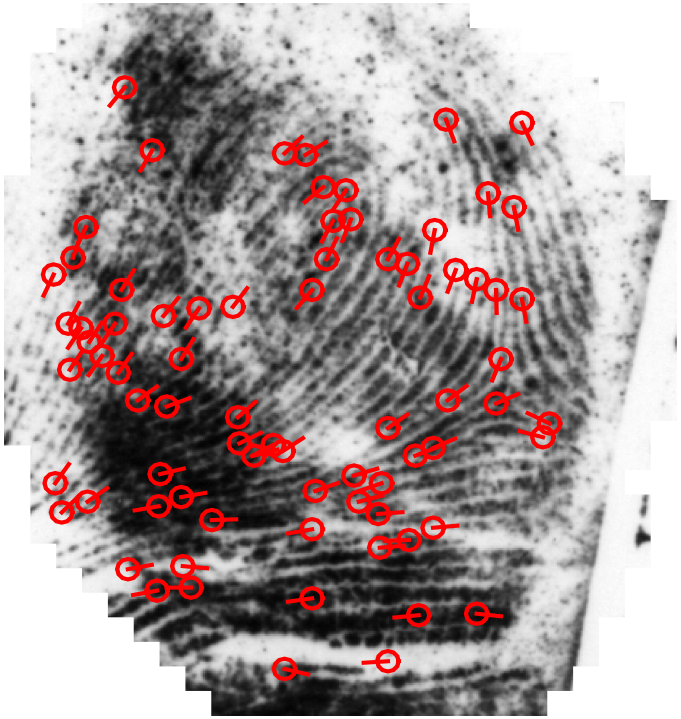
Our Method: VID

Classification Accuracy : 85.6 ± 2.4%

Latent Value ground truth by AFIS

Correctly Classified

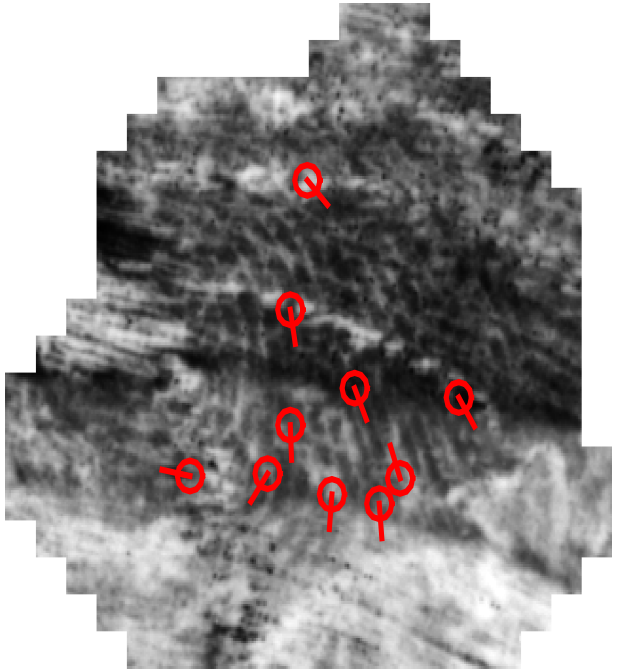
Latent ID: G004



AFIS: VID

Our Method: VID

Latent ID: U213



AFIS: $\overline{\text{VID}}$

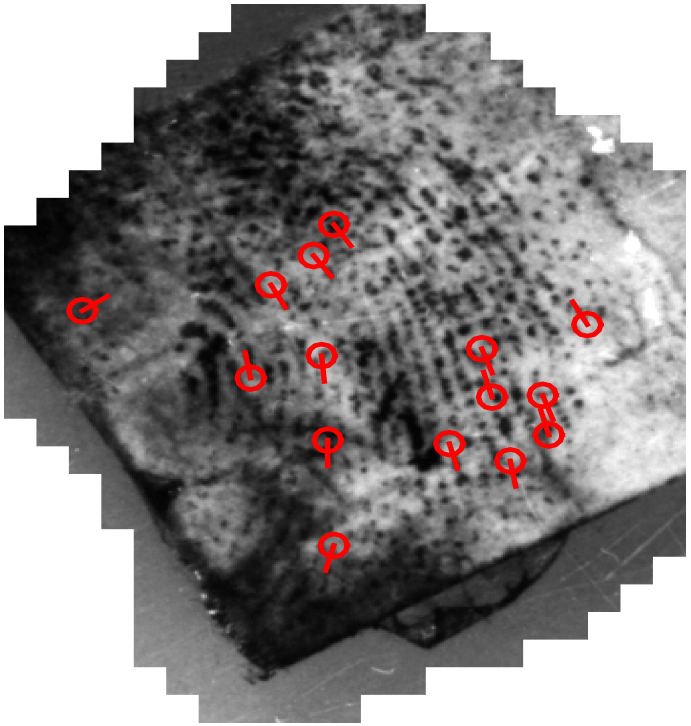
Our Method: $\overline{\text{VID}}$

Classification Accuracy : 79.5 ± 7.2%

Latent Value ground truth by AFIS

Incorrectly Classified

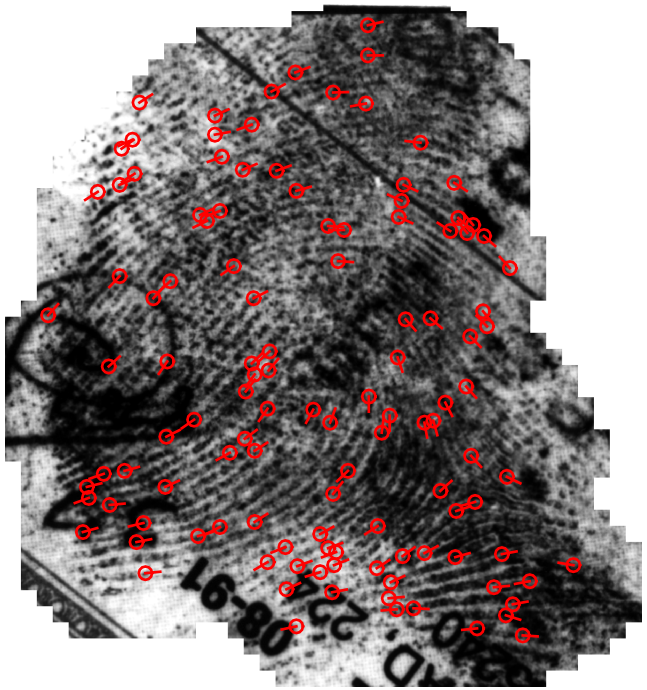
Latent ID: U260



AFIS: VID

Our Method: $\overline{\text{VID}}$

Latent ID: B148



AFIS: $\overline{\text{VID}}$

Our Method: VID

Classification Accuracy : 79.5 ± 7.2%

Conclusions

- Automatic and objective value determination of a query latent
- No manual feature markup is required
- Experimental results on NIST SD27 and WVU latent databases demonstrated the efficiency of proposed approach

Thank You

Any Questions?