BIOMETRICS RESEARCH GROUP

MICHIGAN STATE UNIVERSITY

Latent Fingerprint Matching: Fusion of Manually Marked and Derived Minutiae

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CAPES

FULBRIGHT

Introduction

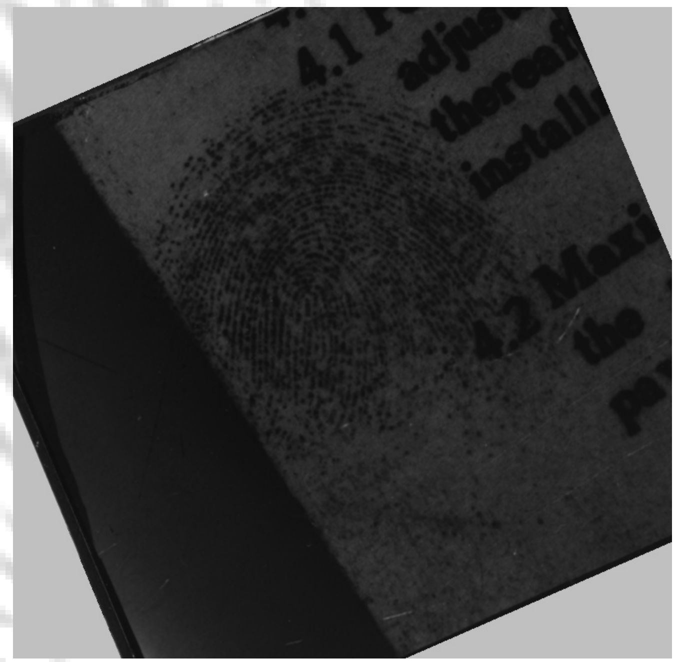
- Fingerprints have been used as a method for person identification for more than a century.
- A fingerprint is the impression of the friction skin on a finger.
- Its individual characteristics are determined during fetal development and its formation starts at approximately 6 or 7 weeks of gestational age.
- A minor change in the flow of amniotic fluids or in the position of the fetus in the uterus cause the minute skin structures around palm or finger tips to differentiate.

Introduction

- Examples of fingerprints obtained by different acquisition methods:

Rolled fingerprint obtained by inking method

Plain fingerprint obtained by live-scan device



Latent fingerprint

Latent Fingerprints

- Latent fingerprints (or simply latents) are fingerprints lifted from surfaces of objects that are inadvertently touched or handled by a person in a crime scene.
- Latents can be linked to suspects who are enrolled in a large fingerprint database using fingerprint recognition.
- Latents are usually smudgy and blurred, capture only a small finger area, have large nonlinear distortion due to pressure variations, and present a large amount of noise.
- Because of these characteristics, latents have a significantly smaller number of minutiae compared to rolled and plain prints.
- This makes latent fingerprint matching much more difficult than rolled or plain fingerprint matching.

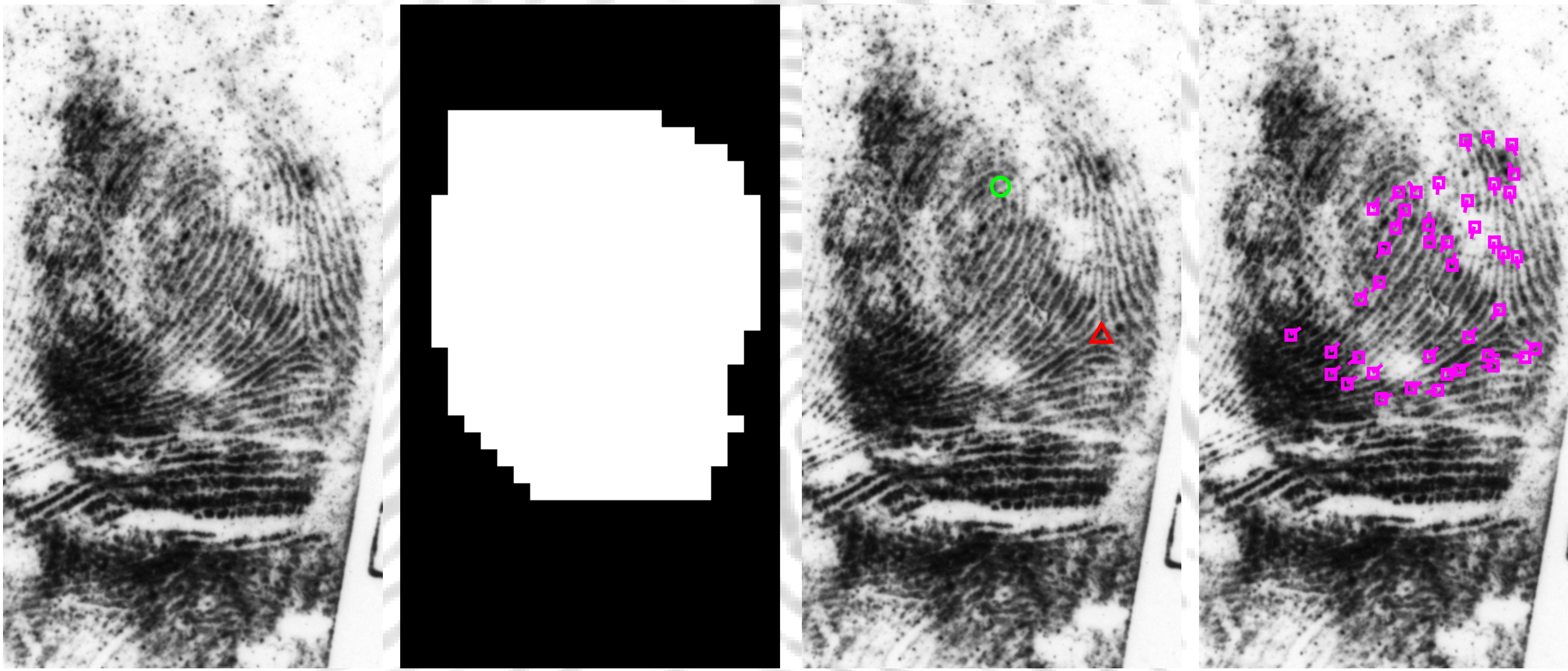
Latent Fingerprint Matching

- A typical latent matching procedure performed by an expert consists of the following steps:
  - Manually mark the features;
  - Launch an AFIS (Automatic Fingerprint Identification System) search;
  - Visually verify the candidate fingerprints returned by AFIS.
- Existing latent matching techniques are not satisfactory in terms of accuracy and speed.
- Two strategies:
  - "Lights-out"
  - Require additional manually marked features.

Our Main Goal

- A fully automatic system is desired, but given the difficulty of the problem and the poor latent matching performance of available fully automated systems, manual input is still needed.
- Therefore, our goal is ***to improve the performance of latent fingerprint matching, while using a small amount of manual input.***

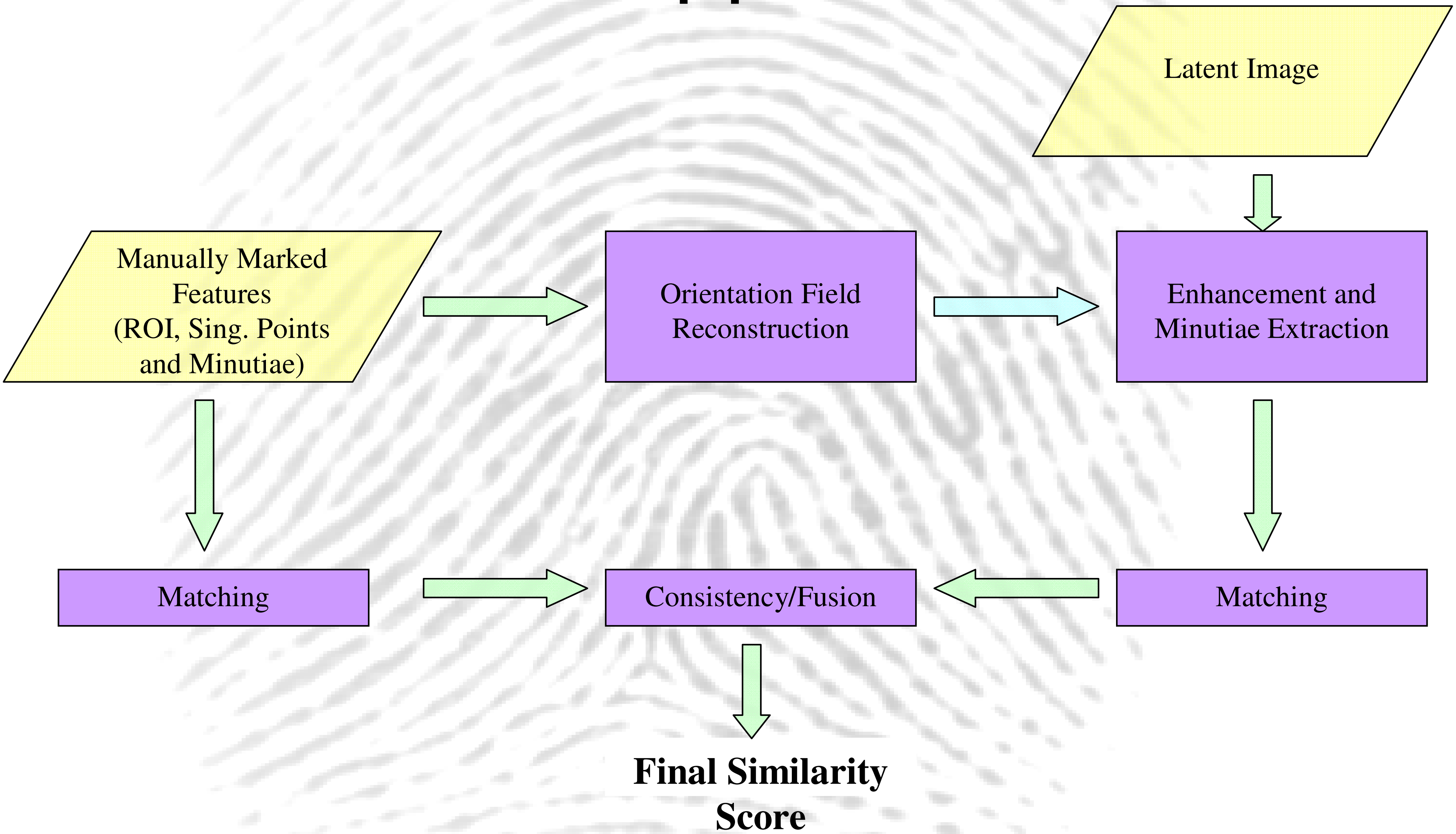
Manually Marked Features



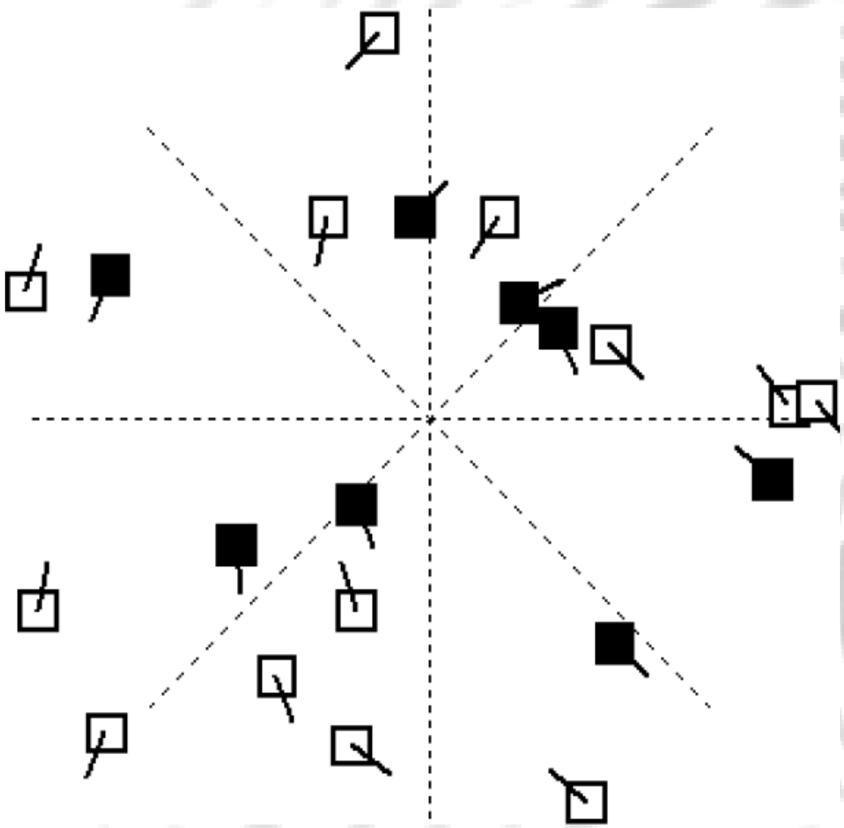
Original Image | Region of Interest | Singular Points | Minutiae

Manually marking these features in latents is a routine in forensics.

Our Approach



Orientation Field Reconstruction (ROF)[1]



$$u = \sum_{k=1}^{K} cos(2\alpha_k) w_k,$$

$$v = \sum_{k=1}^{K} sin(2\alpha_k) w_k,$$

$$D(m,n) = \frac{1}{2} \arctan \frac{v}{u}.$$

$$D_s(m,n) = \sum_{i=1}^{N_s} t_{s_i} \arctan \frac{n - n_{s_i}}{m - m_{s_i}},$$

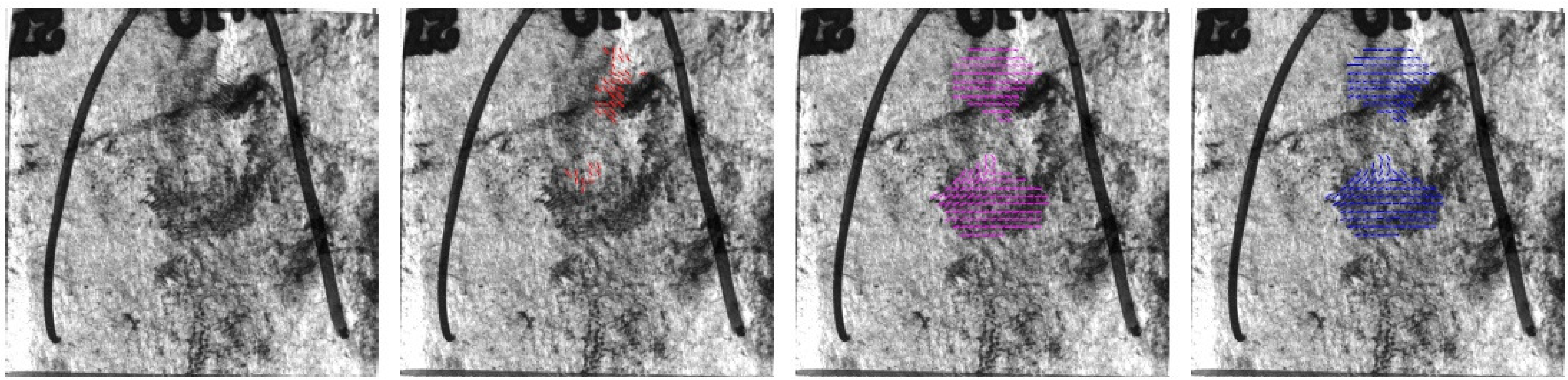
$$O(m,n) = \frac{2D(m,n) + D_s(m,n)}{2}.$$

[1]J. Feng and A. K. Jain, "Fingerprint Reconstruction: from minutiae to phase," *IEEE Trans. PAMI*, 2010.

Some Examples – Orientation Field

Original latent | OF from image | Reconstructed OF | Manually Marked OF

(a) (b) (c) (d)



(e) (f) (g) (h)

Enhancement[1]

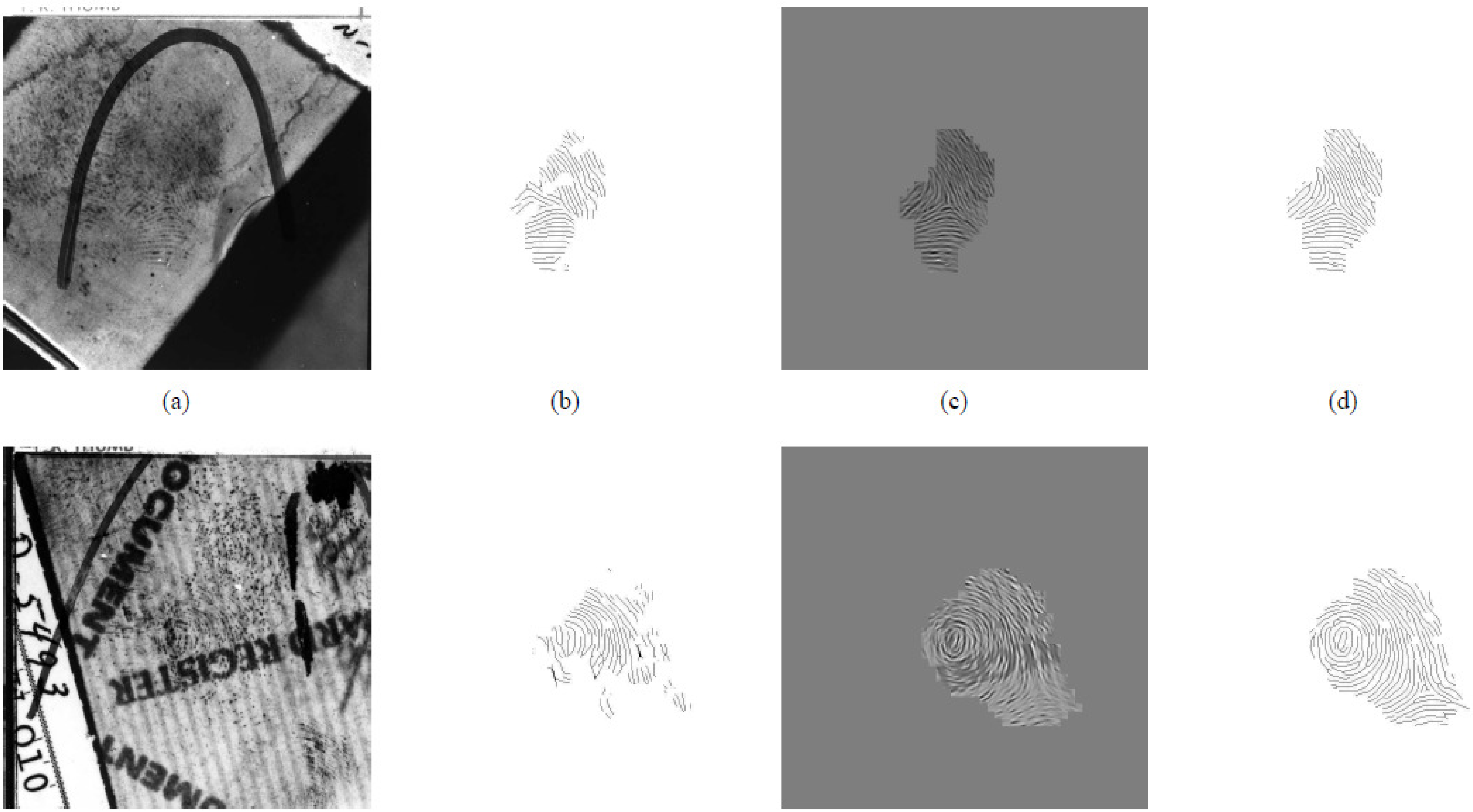
- Ridges and valleys can be viewed as sinusoidal-shaped waves that vary slowly in a local constant orientation, and the parallel configuration of the ridges and valleys defines a frequency in a local area.
- Gabor filters have frequency and orientation properties that can be selected.
- Therefore, the use of Gabor filters for fingerprint images is appropriate to remove noise and preserve true ridge/valley structures.

[1]L. Hong, Y. Wan, and A. K. Jain, "Fingerprint Image Enhancement: Algorithm and Performance Evaluation," *IEEE Trans. PAMI*, vol. 20, no. 8, pp. 777-789, August 1998.

Enhancement

Original latent and skeleton

Enhanced latent and skeleton



(a) (b) (c) (d)

(e) (f) (g) (h)

Score-level Fusion

- Given two similarity scores ***a*** and ***b***:
  - min(***a***, ***b***) – min rule
  - max(***a***, ***b***) – max rule
  - ***a***. ***b*** – Product rule
  - ***a*** + ***b*** – Sum rule
  - Boosted Max

Boosted Max

- Goal: to increase the score for pairs that present consistency between their transformation matrices.

$$T_{MR}, T_{ER}, T_{ME} \qquad T_{MER} = T_{ER} T_{ME}$$

If rotation difference and translation difference between the transformation matrices (manually marked to rolled and manually marked to enhanced to rolled) are less than some threshold, then the pair is considered consistent.

$$S_{bm} = \begin{cases} w_1 \max(s_1, s_2) + w_2 \min(s_1, s_2), & if \\ & consistent \\ \max(s_1, s_2), & otherwise. \end{cases}$$

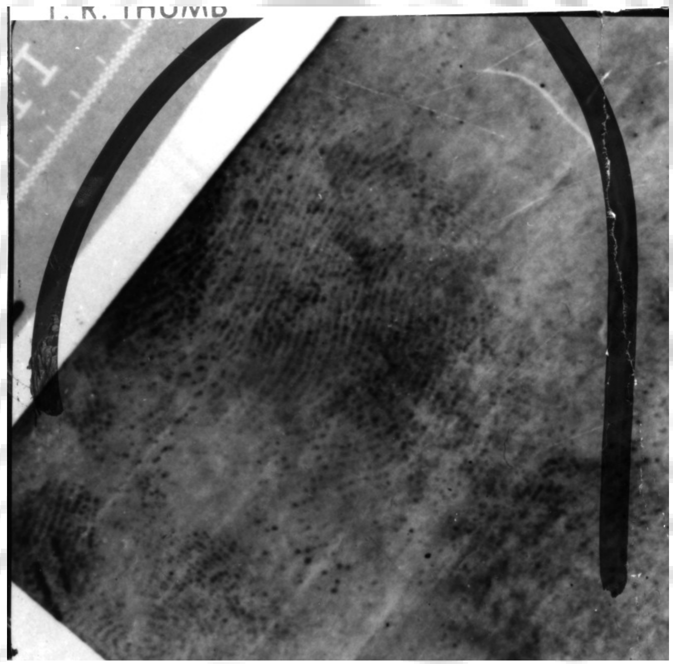
Experiments

- Database: NIST Special Database 27 (258 latent fingerprints with their mated rolled prints)
  - Background database size: 27,258 by adding 27,000 images from NIST 14 database.
- Fingerprint Matcher: VeriFinger (commercial)

NIST SD 27

- NIST SD 27 contains latent images of three different qualities: good, bad and ugly.

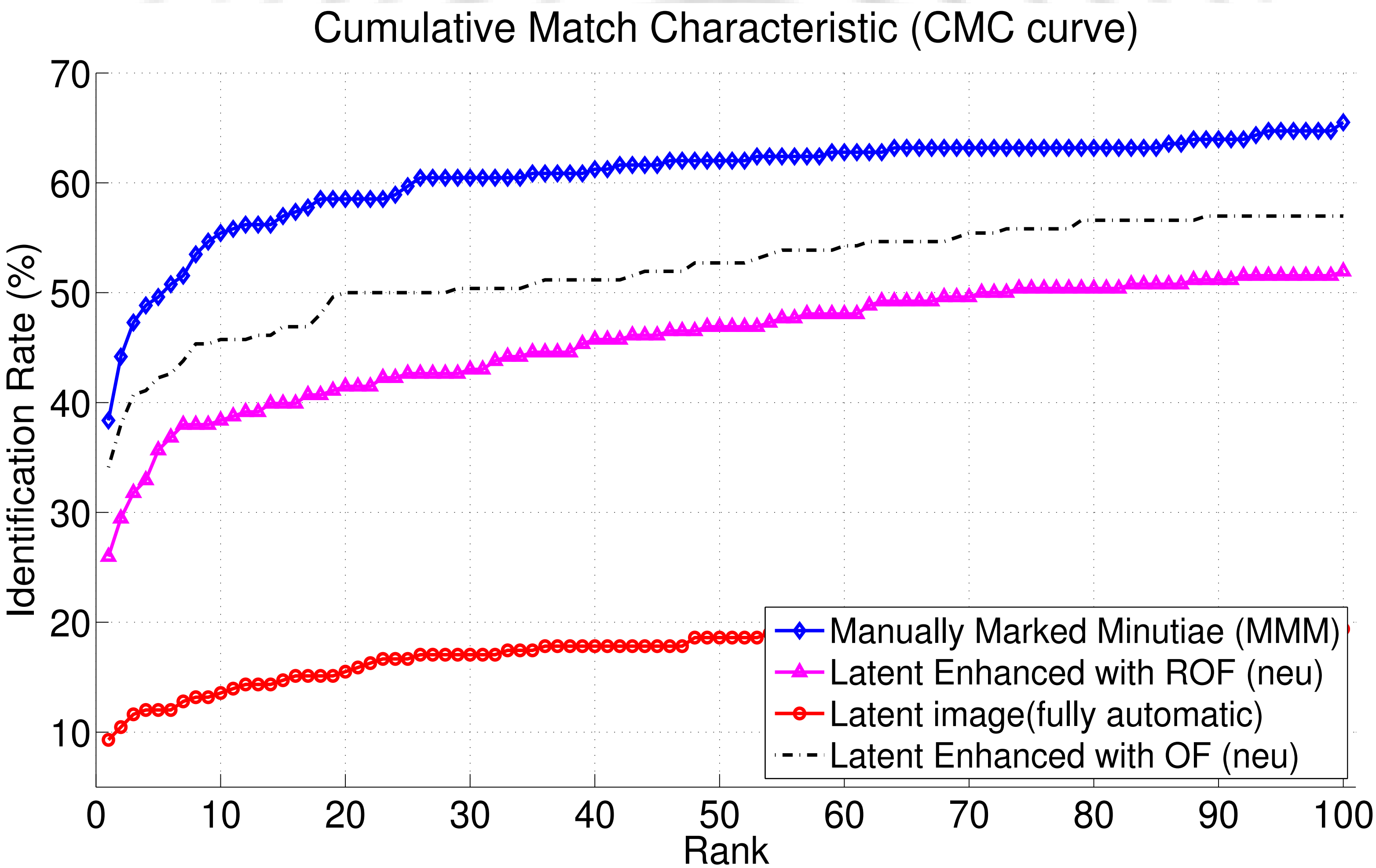
Good



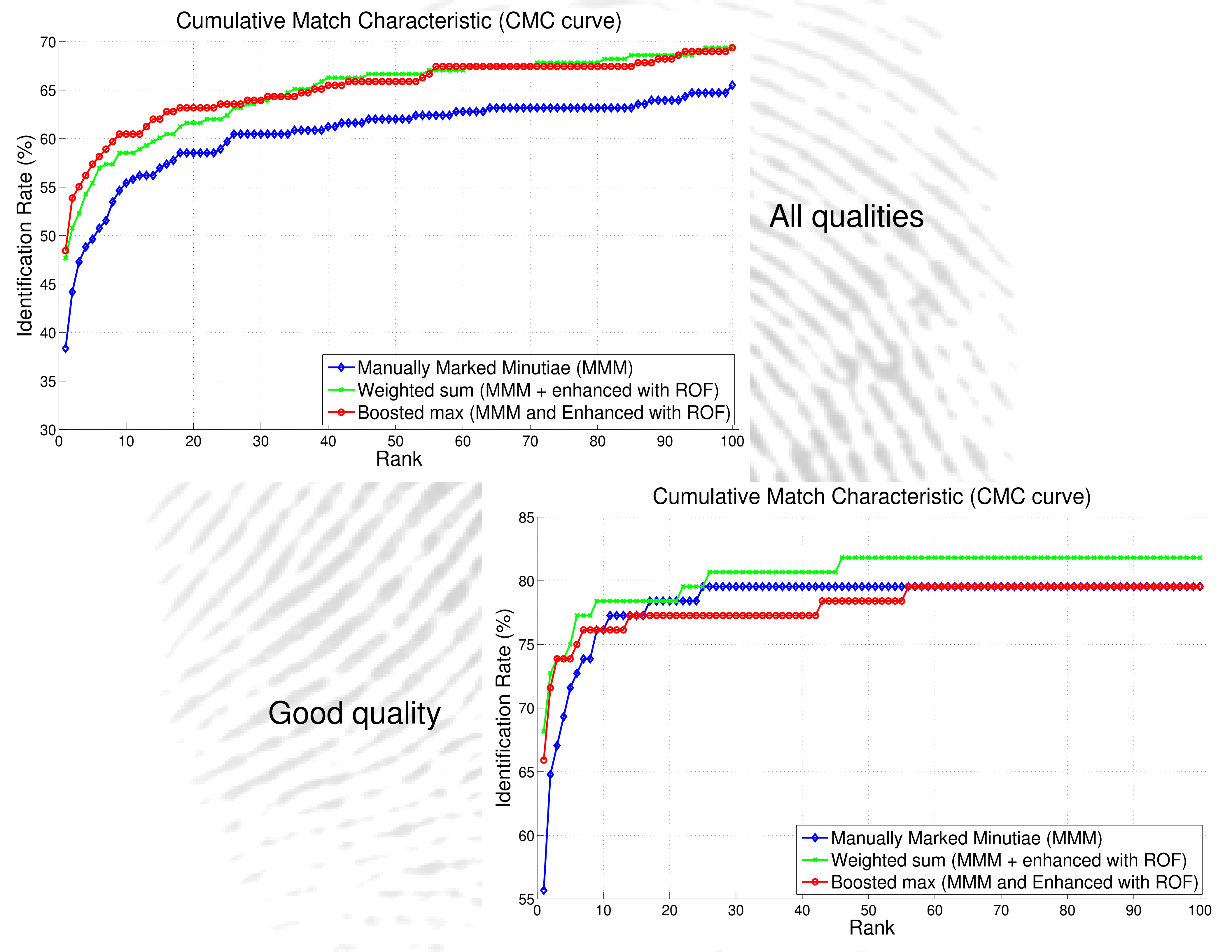
Bad

Ugly

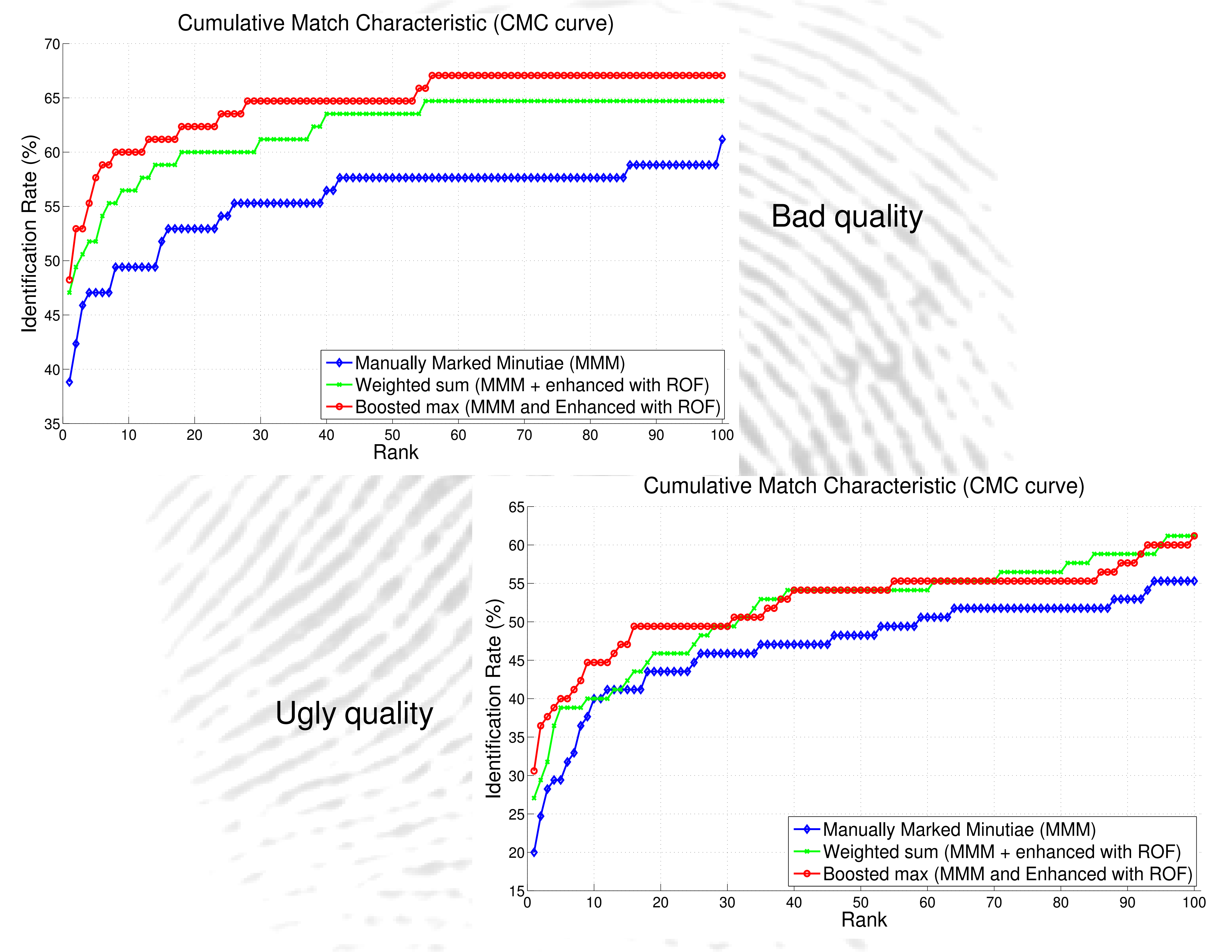
Experimental Results



Comparison of the performance of latent enhanced with Reconstructed Orientation Field (ROF) and with manually marked Orientation Field (OF)



Cumulative Match Characteristic (CMC curve)
Identification Rate (%)
Rank
Manually Marked Minutiae (MMM)
Weighted sum (MMM + enhanced with ROF)
Boosted max (MMM and Enhanced with ROF)
All qualities
Good quality
Cumulative Match Characteristic (CMC curve)
Identification Rate (%)
Rank
Manually Marked Minutiae (MMM)
Weighted sum (MMM + enhanced with ROF)
Boosted max (MMM and Enhanced with ROF)

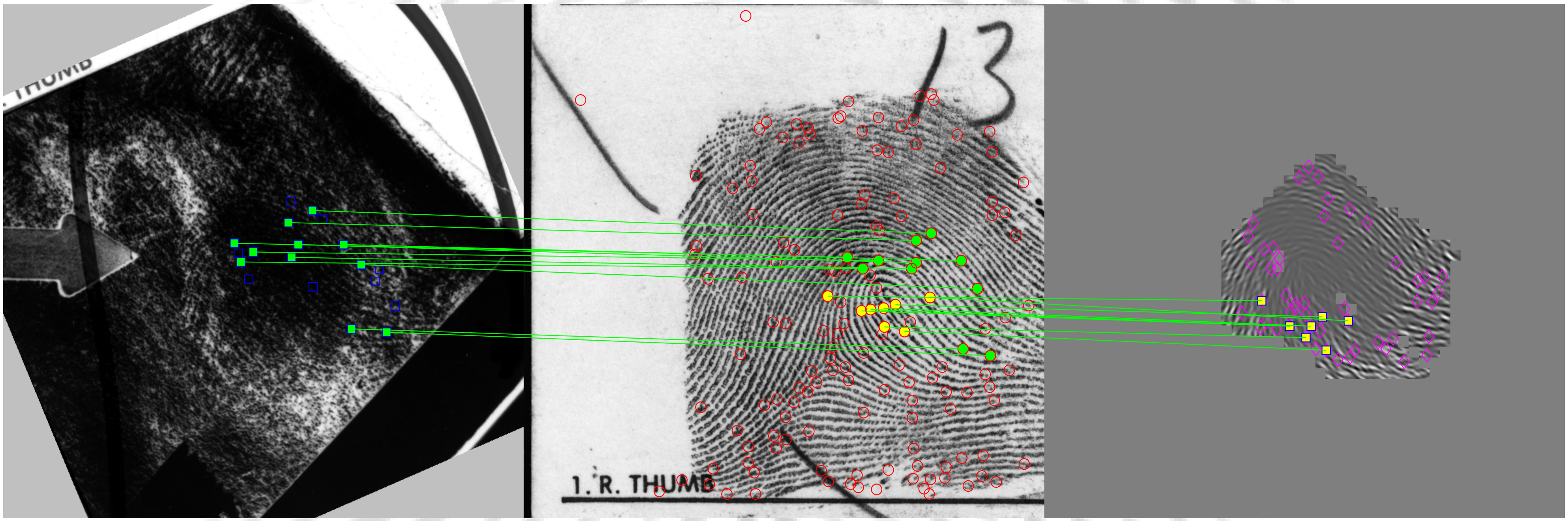


Cumulative Match Characteristic (CMC curve)
Identification Rate (%)
Rank
Manually Marked Minutiae (MMM)
Weighted sum (MMM + enhanced with ROF)
Boosted max (MMM and Enhanced with ROF)
Bad quality
Ugly quality
Cumulative Match Characteristic (CMC curve)
Identification Rate (%)
Rank
Manually Marked Minutiae (MMM)
Weighted sum (MMM + enhanced with ROF)
Boosted max (MMM and Enhanced with ROF)

Discussion

- In almost all cases, if the mated rolled fingerprint was ranked first in one of the matching experiments, it was also ranked first in the boosted max approach.
- Boosted max ranked true mated rolled fingerprints at a lower rank in only two cases that were ranked first by manually marked minutiae (meaning boosted max is not degrading the manually marked minutiae score for true mated pairs).
- Boosted max ranked true mated rolled fingerprints at rank 1 in eleven cases where the manually marked minutiae AND enhanced ranks were lower than 1.

Examples

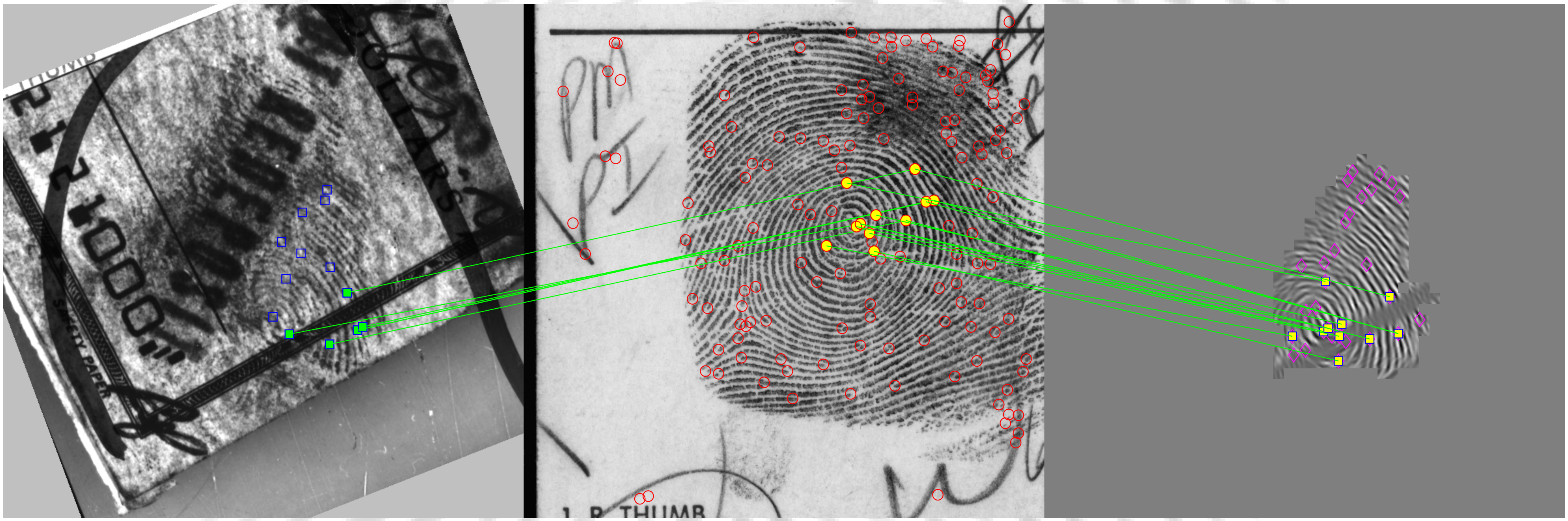


Manually marked minutiae rank: 1

Enhanced image rank: 2,403

Boosted max rank: 1

Examples



Manually marked minutiae rank: 268

Enhanced image rank: 2

Boosted max rank: 1

Conclusions

- The performance of manually marked minutiae in latents can be improved by utilizing automatically extracted minutiae from enhanced latent images.
- At rank 1, the improvement due to boosted max is approximately 10% over all image quality levels as well as for each quality level separately (~25 additional latents were correctly ranked after applying boosted max).
- Therefore, the proposed framework improves the latent matching performance for all quality levels, and it considers only manually marked minutiae, singular points and region of interest (ROI) as input.

Ongoing and Future work

- To improve orientation field reconstruction.
- To use orientation field information for matching.
- To develop a latent fingerprint matcher.

Contact Information

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