Latent Fingerprint Recognition: Role of Texture Template

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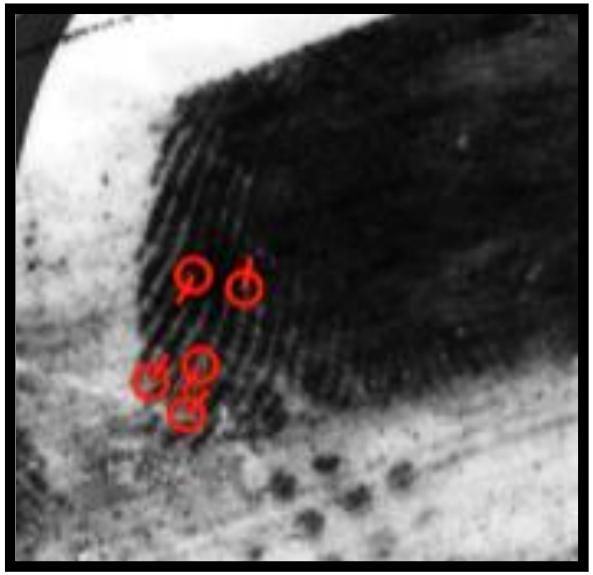
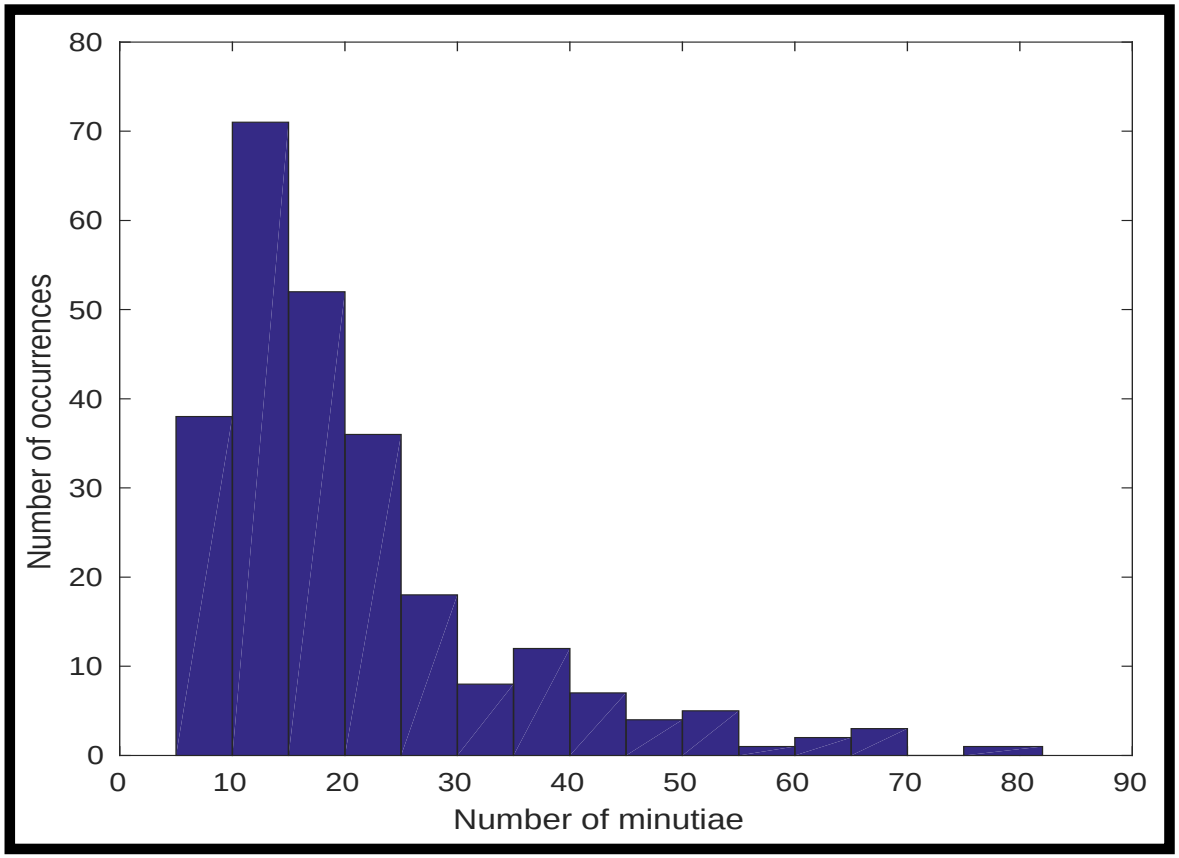
Limited Minutiae in Partial Fingerprints

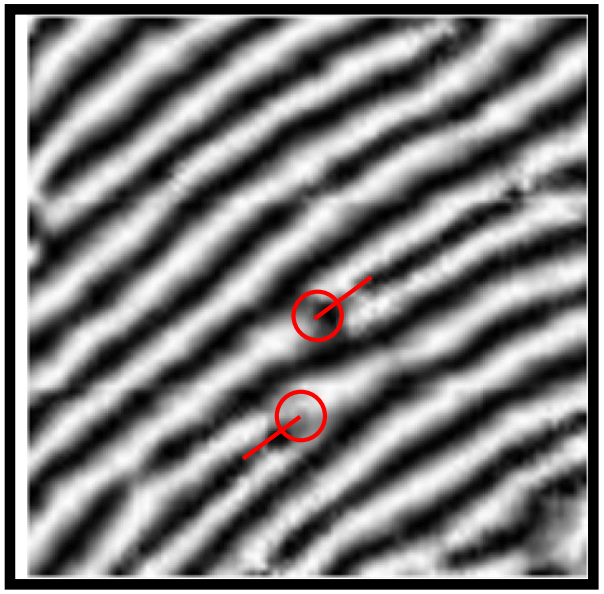


Five minutiae in a latent image



Minutiae frequency: NIST SD27

Limited Minutiae in Partial Fingerprints



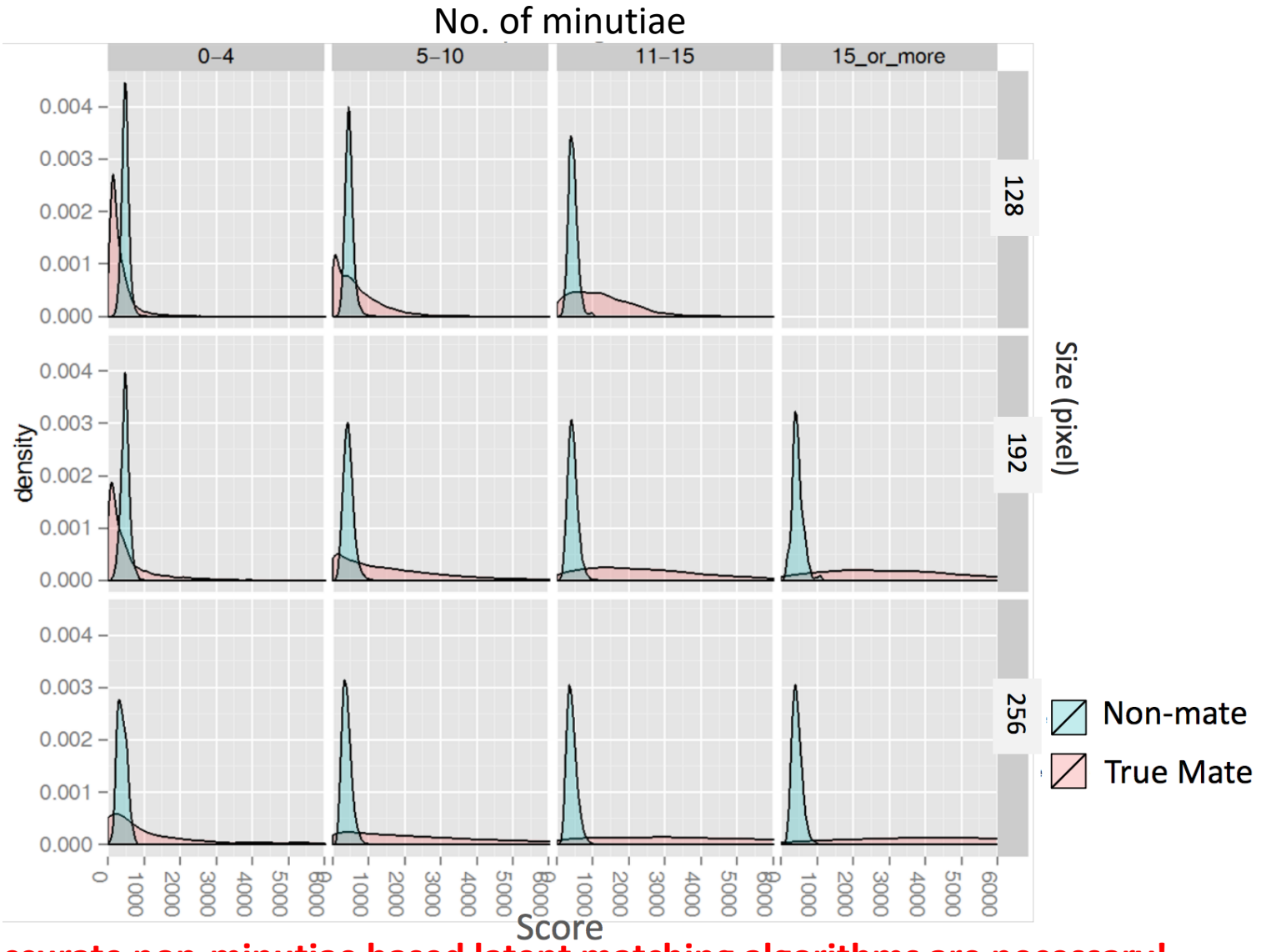
96x96 pixels at 500 ppi

Two minutiae in capacitive smartphone fingerprint

Capacitive fingerprint reader in a smartphone

https://c.slashgear.com/wp-content/uploads/2014/11/mx4.jpg

NIST Study: similarity scores as a function of patch size

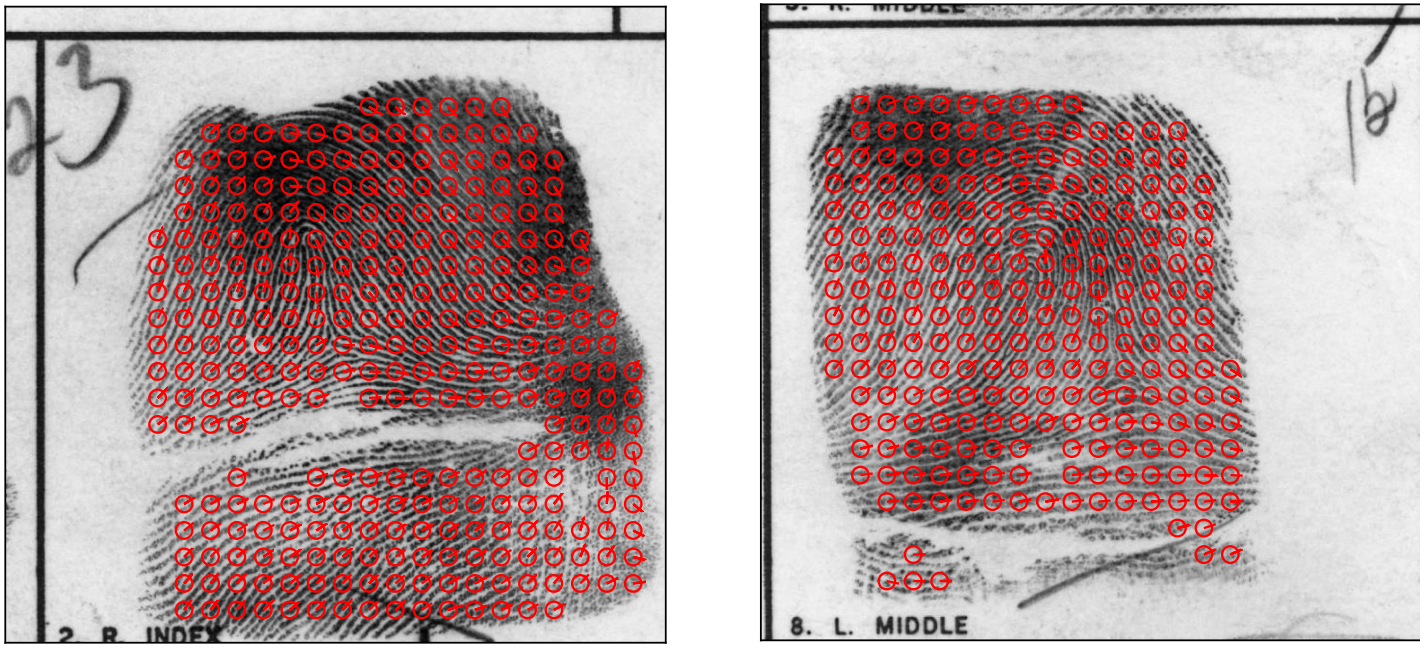


Accurate non-minutiae based latent matching algorithms are necessary!

https://www.samsi.info/wp-content/uploads/2016/03/Tabassi_august2015.pdf

Virtual Minutiae

- A virtual minutia, similar to a real minutia, consists of location and orientation
- Location and orientation determined by a raster scan and ridge flow, respectively

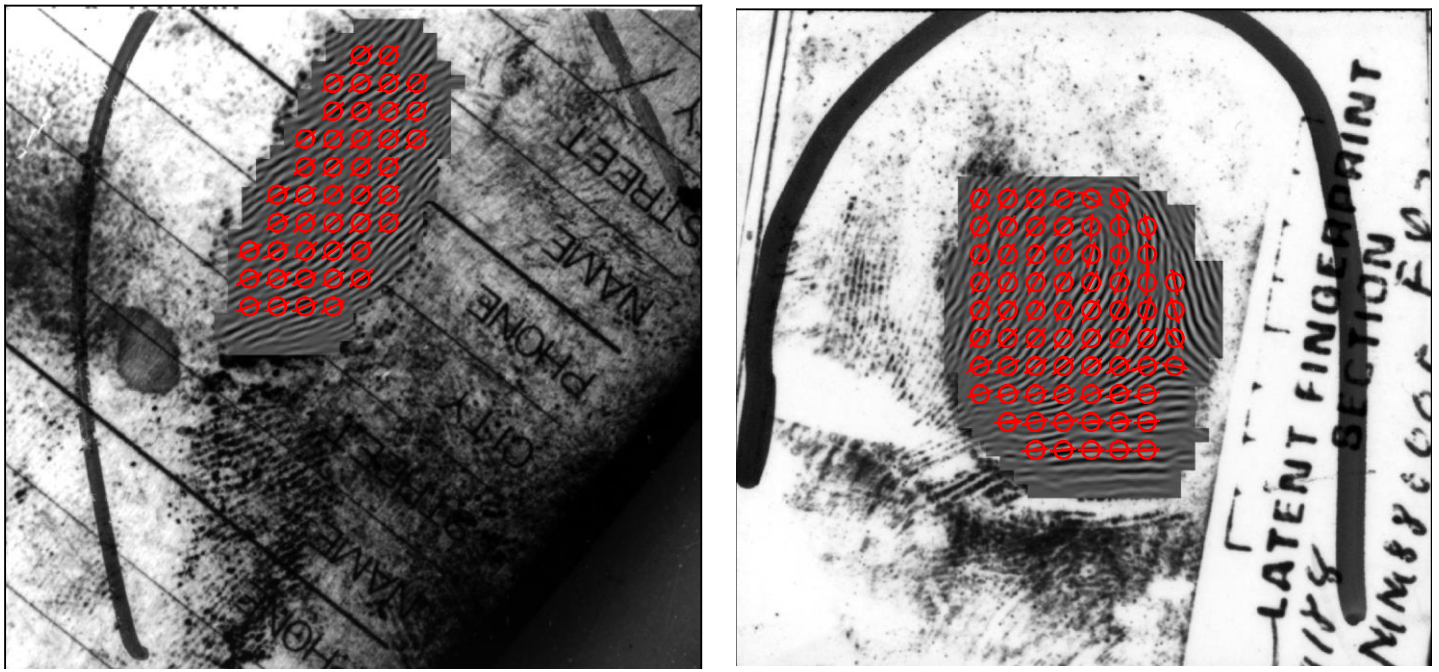


Virtual minutiae on rolled prints

[1] K. Cao and A. K. Jain. Automated latent fingerprint recognition. *IEEE TPAMI, DOI 10.1109/TPAMI.2018.2818162*, 2018.

Virtual Minutiae

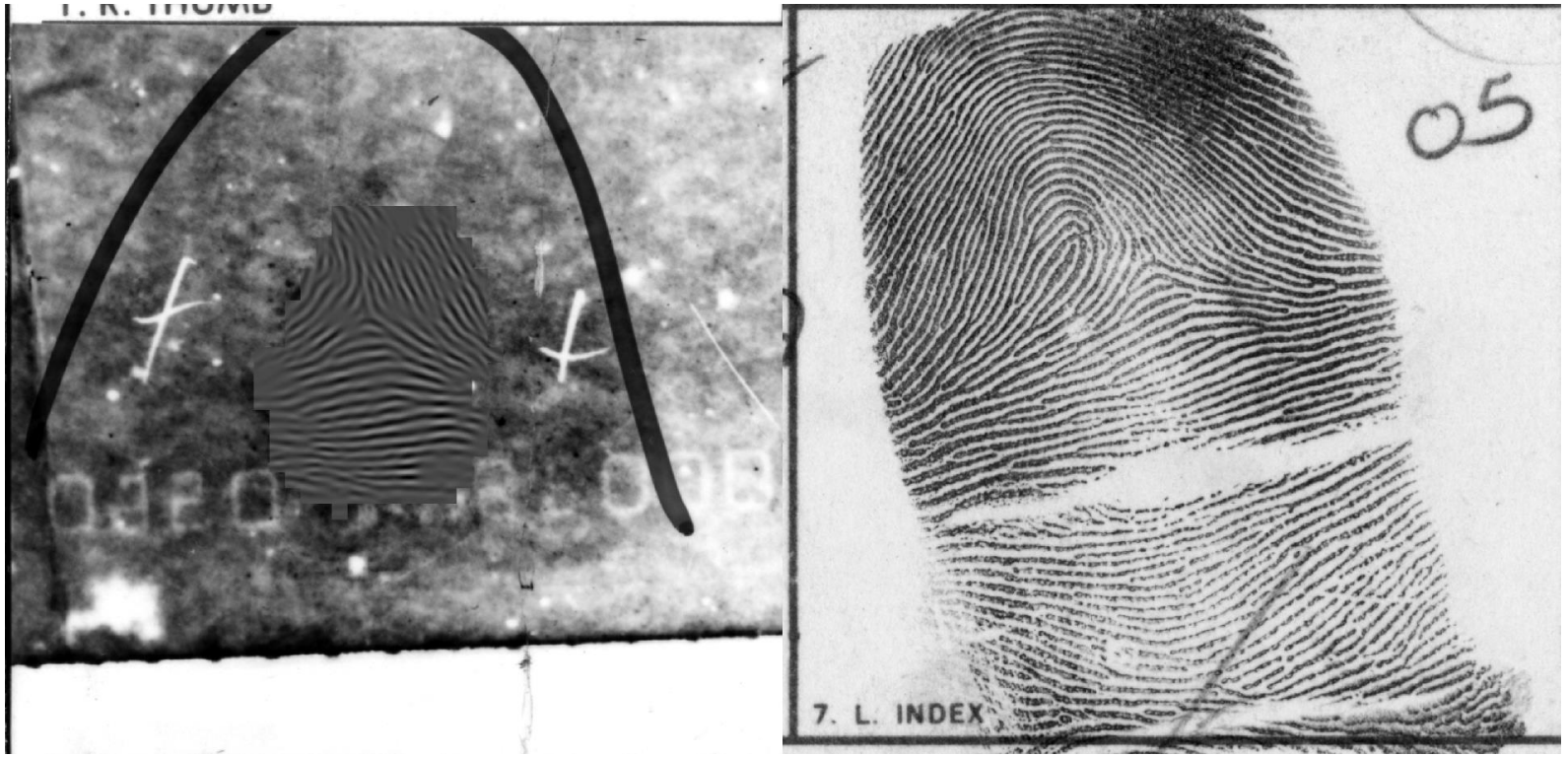
- A virtual minutia, similar to a real minutia, consists of location and orientation
- Location and orientation determined by a raster scan and ridge flow, respectively
- At each grid in a latent, there are two virtual minutiae with opposite orientations to handle the ambiguity in ridge orientation



Virtual minutiae on latents

[1] K. Cao and A. K. Jain. Automated latent fingerprint recognition. *IEEE TPAMI, DOI 10.1109/TPAMI.2018.2818162*, 2018.

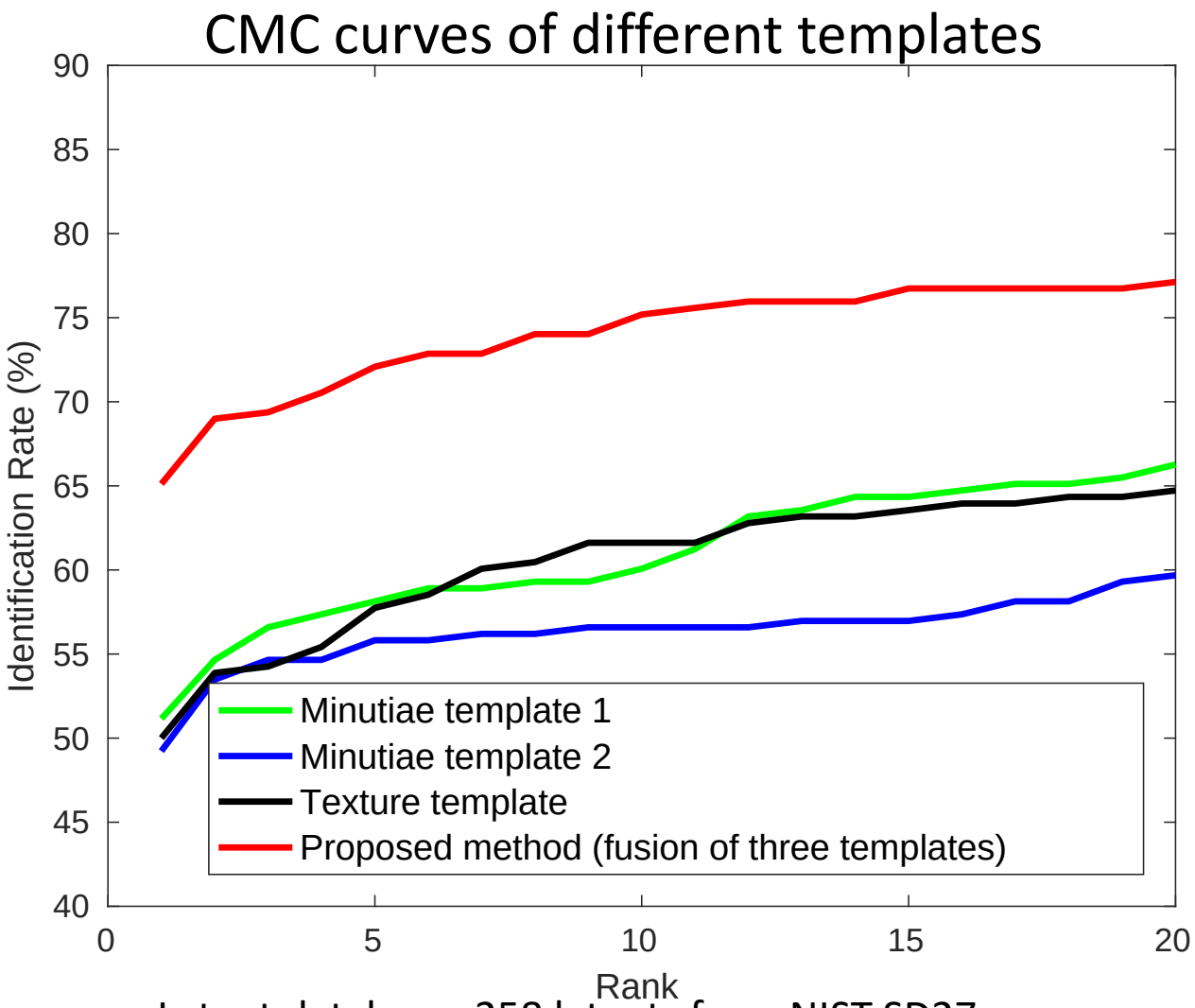
Virtual Minutiae Matching



Main steps:

- Compute virtual minutiae similarity using their descriptors
- Select the top 200 virtual minutiae correspondences
- Remove false correspondences using second- and third-order graph matching

Search Performance



Latent database: 258 latents from NIST SD27

Background database: 100K exemplar fingerprints

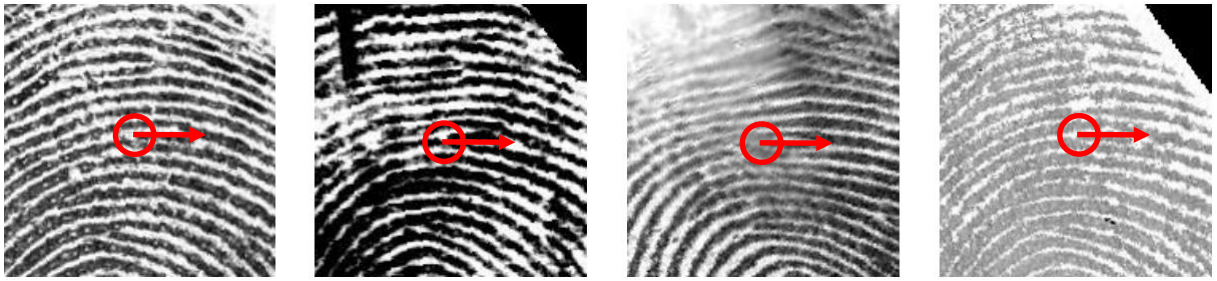
[1] K. Cao and A. K. Jain. Automated latent fingerprint recognition. *IEEE TPAMI, DOI 10.1109/TPAMI.2018.2818162*, 2018.

Challenges

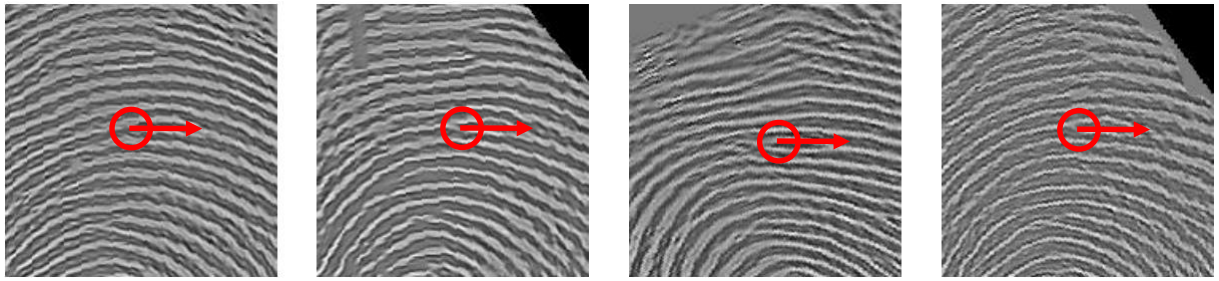
- Can we further improve the search performance?
  - Rank-1 accuracies: NIST SD27 (~50%), WVU (~58%)
- Can we improve the search speed?
  - Each virtual minutia descriptor is a 384 dimension feature
  - Second- and third-order graph matching takes 11ms (24 threads)

Virtual Minutiae Descriptor

Training dataset:
~800K patches from ~50K minutiae



Raw fingerprint patches



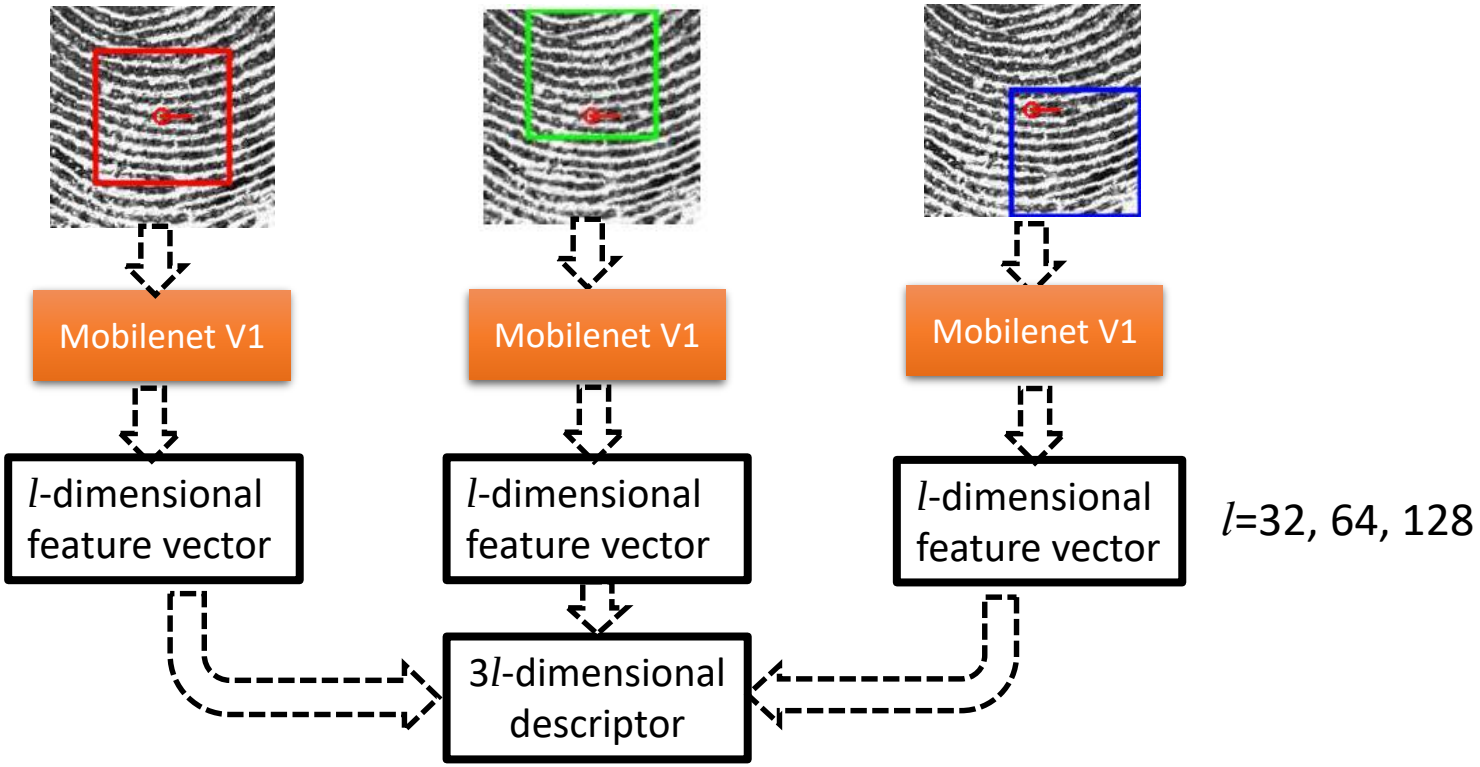
Enhanced fingerprint patches

- Increase the number of patches for each minutiae
- Improve the robustness of the descriptor extraction model

Virtual Minutiae Descriptor

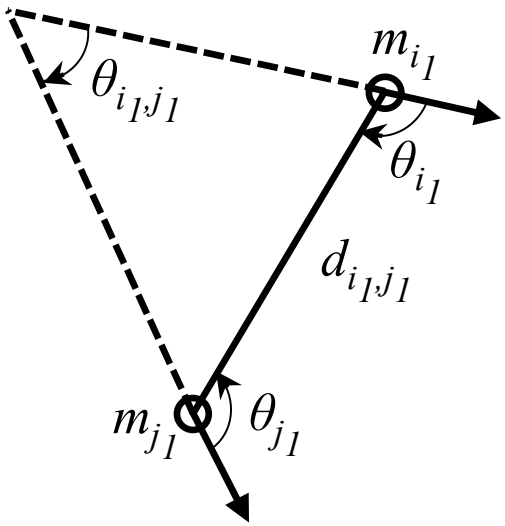
Descriptor extraction:

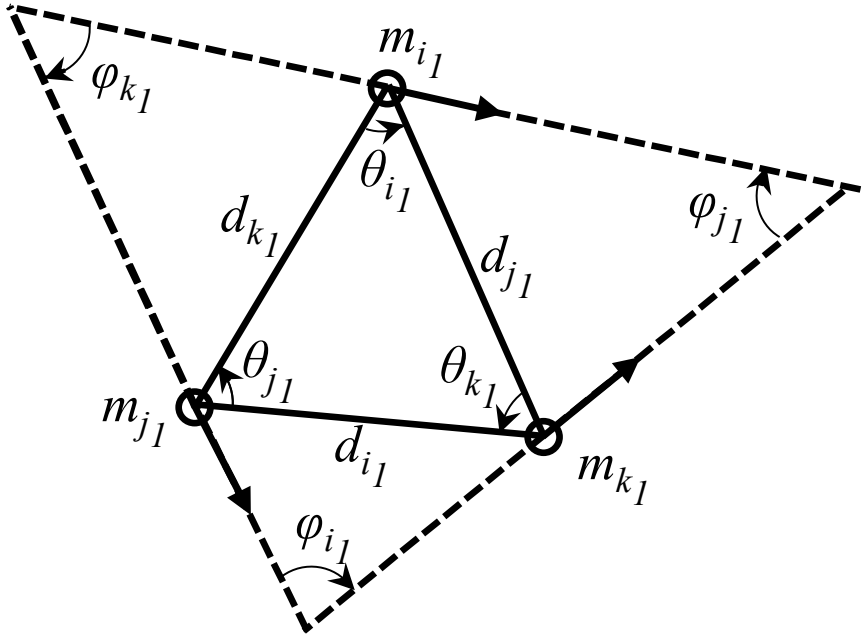
3l-dim descriptor for each minutiae



- 3 patches (96x96 pixels) cropped from each minutiae
- One model is trained for each patch type
- Each minutia is considered as an individual class
- Output of last fully connected lay used as descriptor

Graph Matching





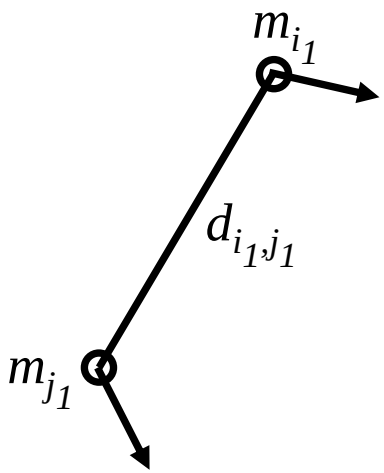
Second-order:

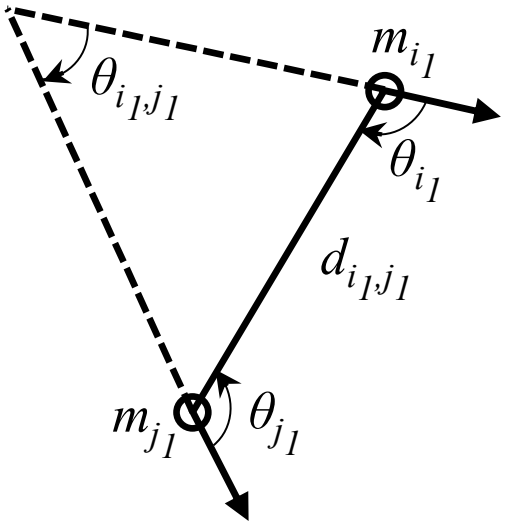
- n(n-1)/2 pairs
- 4 features per pair

Third-order:

- n(n-1)(n-2)/6 triples
- 9 features per triple

Modified Graph Matching





Euclidean second-order:

- n(n-1)/2 pairs
- 1 features per pair

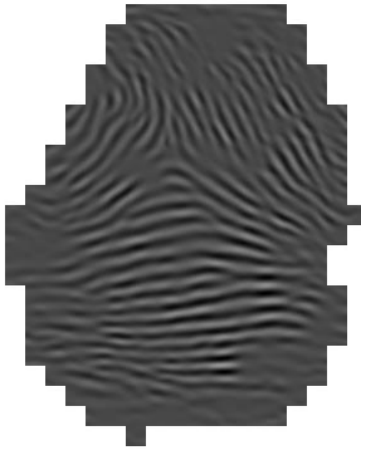
Full second-order:

- n(n-1)/2 pairs
- 4 features per pair

Dataset

Input latent

Enhancement T_{e1}



Enhancement T_{e2}

Decomposition T_t

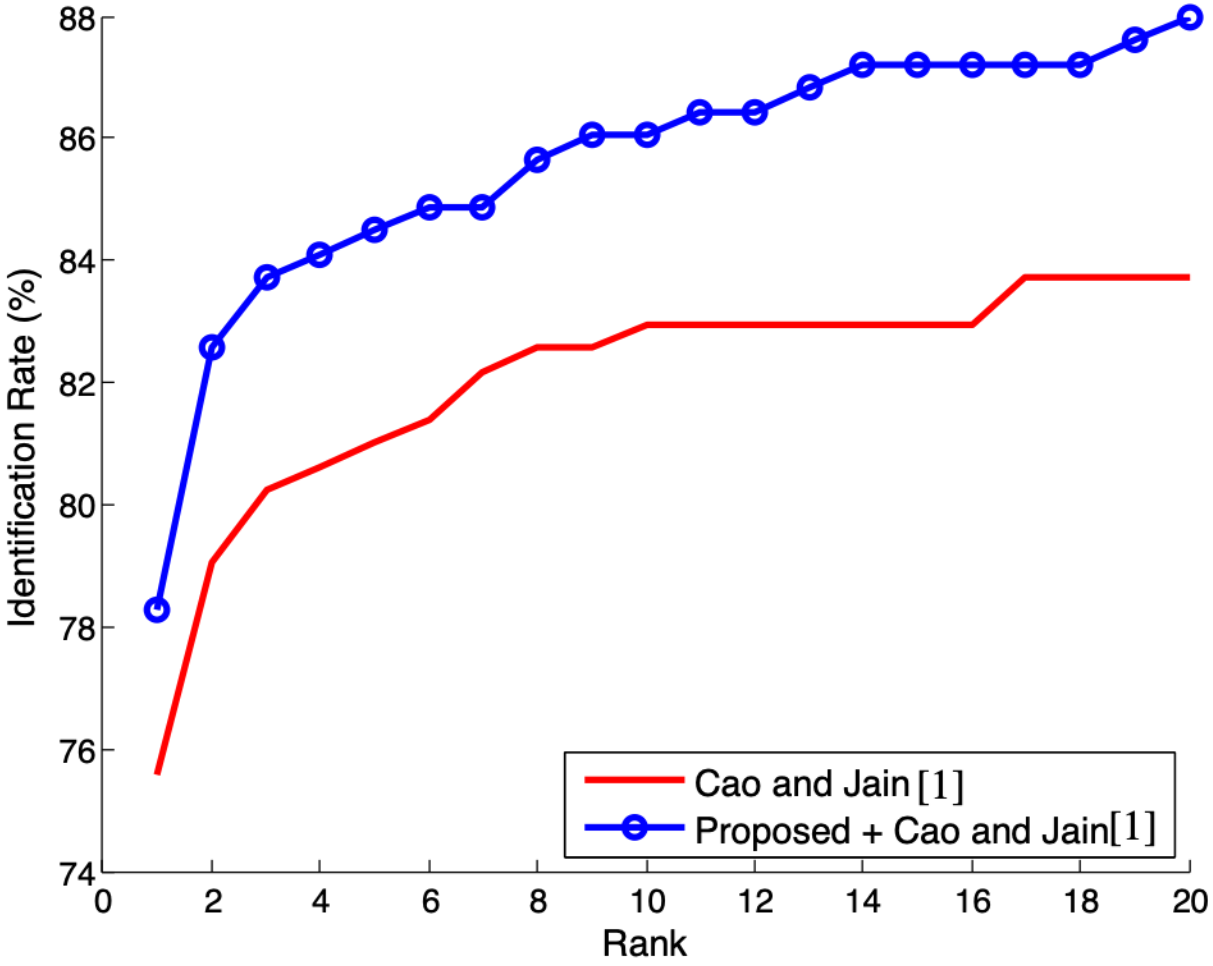
- Latent dataset: 258 latents from NIST SD27
- Background database: 10K exemplar fingerprints
- Latent processing: 3 different latent preprocessing approaches

Performance of Texture Template: Fusion Schemes

Input templates	descriptor length	rank-1 (%)	rank-5 (%)	rank-10 (%)
Cao&Jain [1]	384	59.30	70.16	73.26
T_{e_1}	192	68.22	73.64	74.81
T_{e_2}	192	66.67	72.48	74.42
T_t	192	60.47	67.83	70.93
$T_{e_1}+T_{e_2}$	192	**70.93**	74.81	77.91
$T_{e_1}+T_t$	192	**70.93**	76.36	79.07
$T_{e_2}+T_t$	192	67.05	75.19	77.13
$T_{e_1}+T_{e_2}+T_t$	192	70.16	**76.74**	**81.40**
T_{e_1}	384	69.38	75.58	77.13
T_{e_2}	384	66.28	72.48	73.64
T_t	384	58.91	66.28	69.77
$T_{e_1}+T_{e_2}$	384	70.16	75.58	78.29
$T_{e_1}+T_t$	384	69.38	76.74	77.91
$T_{e_2}+T_t$	384	67.83	74.03	75.97
$T_{e_1}+T_{e_2}+T_t$	384	**70.93**	75.97	78.68

Latent database: 258 latents from NIST SD27
Background database: 10K exemplar fingerprints

CMC curves on NIST SD27



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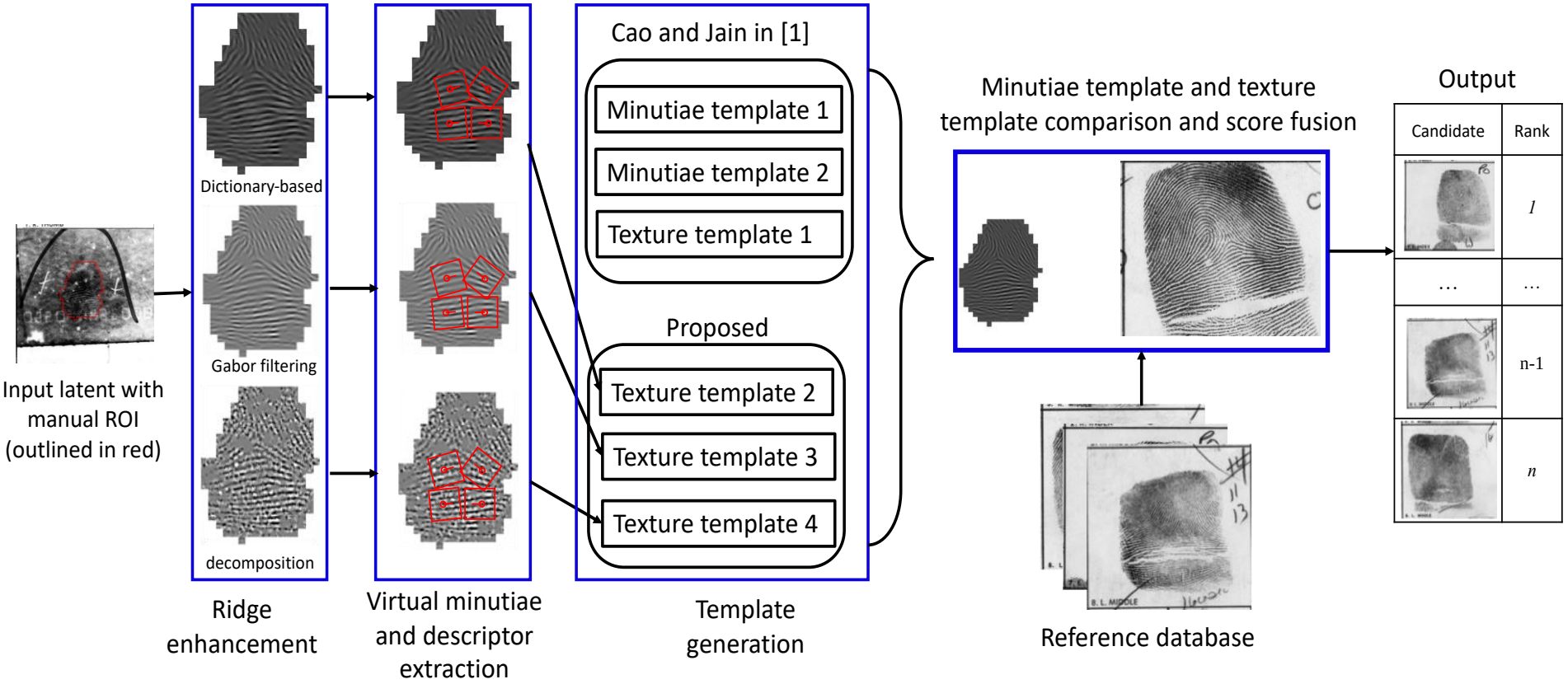
Summary and Future Work

- Improved the rank-1 identification rate from 59.3% to 68.2% for a 10K gallery
- Reduced the average latent to rolled texture template comparison time between 11ms (24 threads) to 7.7ms (single thread)
- Future works include:
  - reduce the texture template size,
  - further improve comparison speed
  - improve search accuracy

Thanks!

Flowchart of Proposed Approach



A texture template contains a set of virtual minutiae and their descriptors

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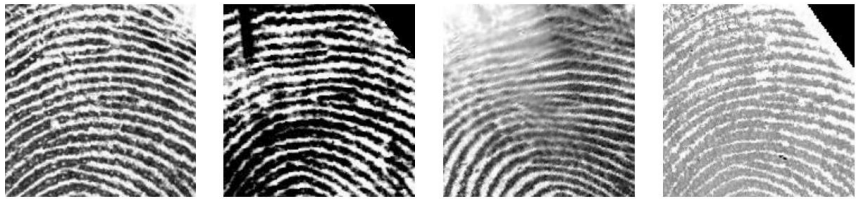

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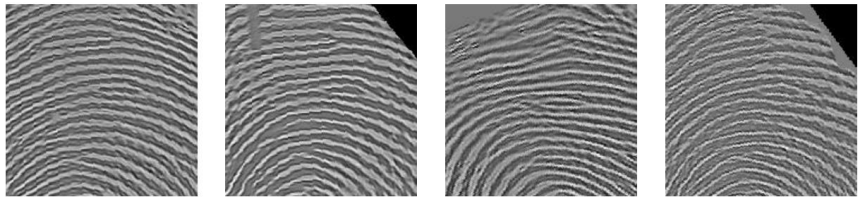

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Descriptor extraction:
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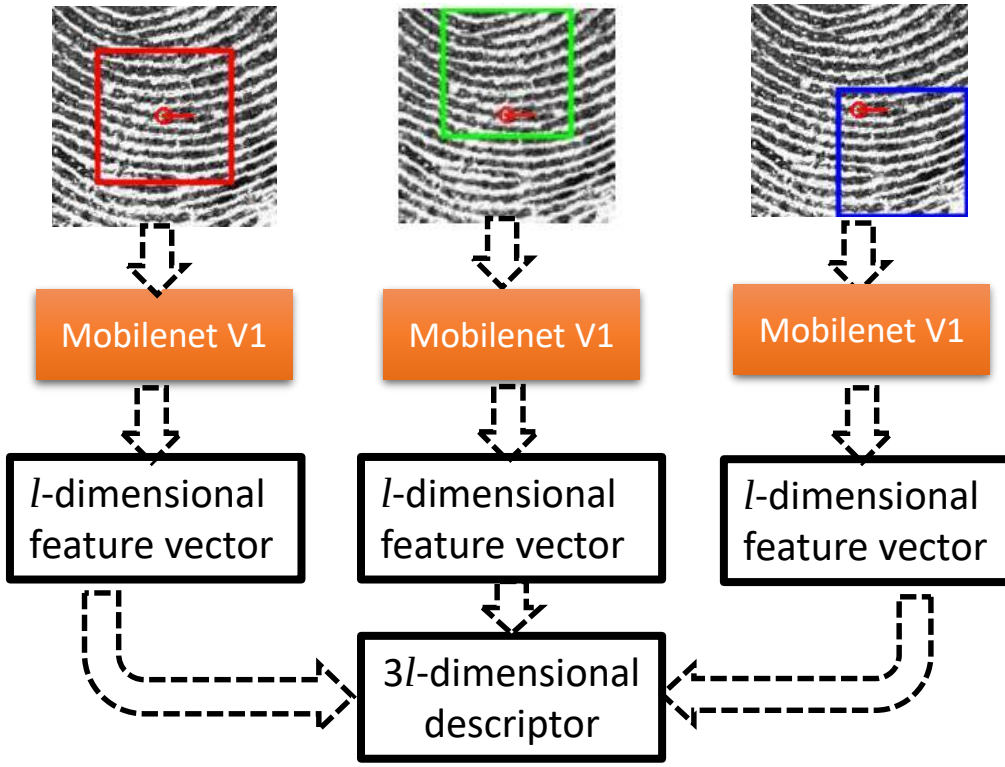

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