Latent Orientation Field Estimation via Convolutional Neural Network (ConvNet)

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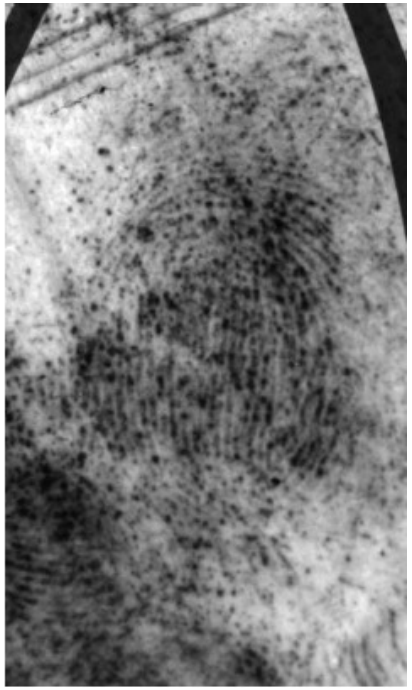
State of the Art AFIS

Rolled fingerprint

Plain fingerprint



Latent fingerprint

Rank-1 identification rates:

- Plain to plain matching = 99.3% (NIST FpVTE 2012)
- Latent to rolled matching = 67.2% (NIST ELFT 2012)

Importance of Orientation Field (OF)

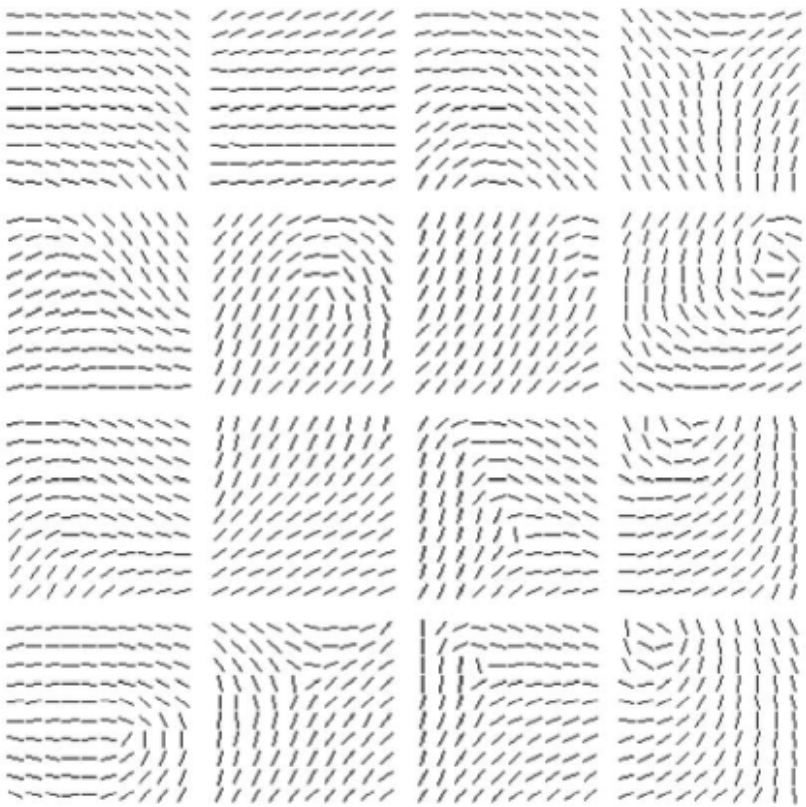
Orientation field

1) ridge structure enhancement
2) segmentation
3) classification/indexing
4) matching

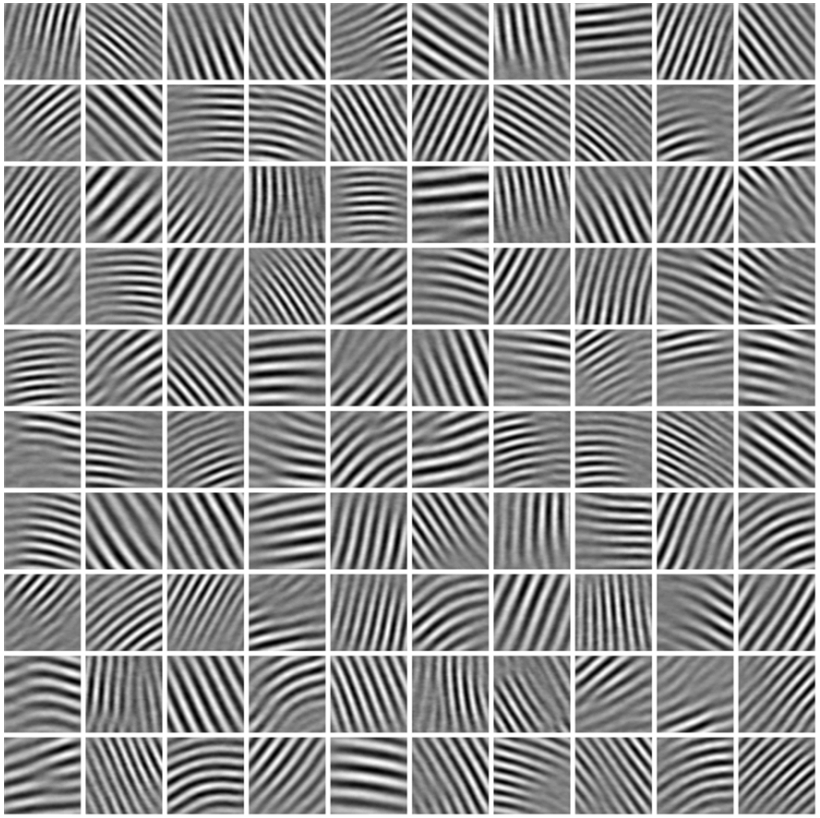
….

Latent OF Estimation

Orientation patch dictionary
(patch size =160X160)



Ridge structure dictionary
(patch size = 64X64 & 32X32）

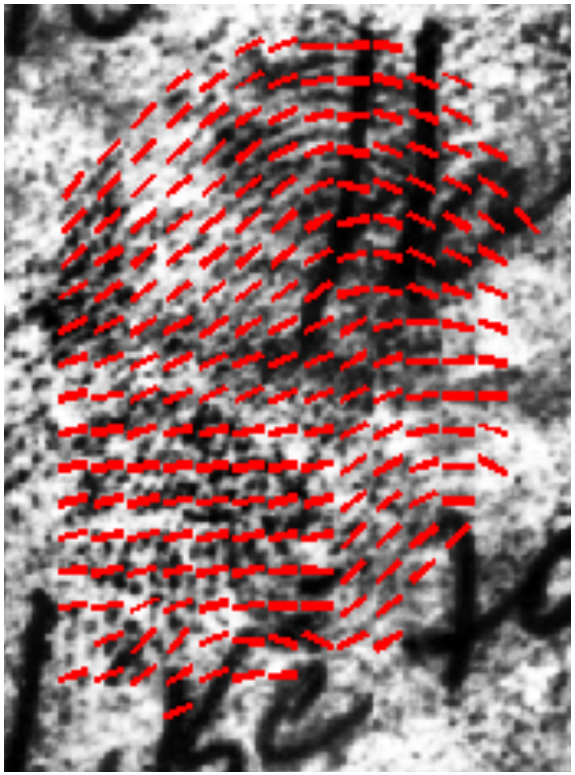


Feng et al., Orientation field estimation for latent fingerprint enhancement. *TPAMI,* 2013.

Cao et al., Segmentation and enhancement of latent fingerprints: A coarse to fine ridge structure dictionary. *TPAMI,2014.*

Latent OF Estimation

Latent image

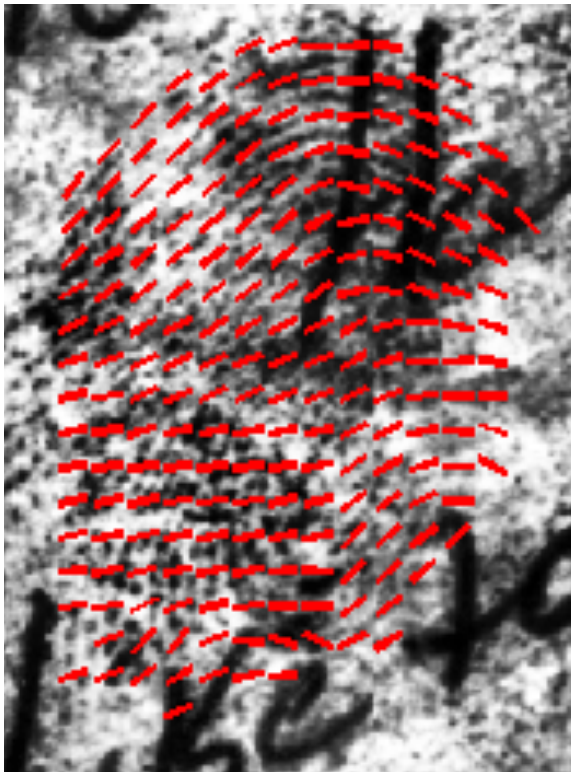


Orientation patch dictionary

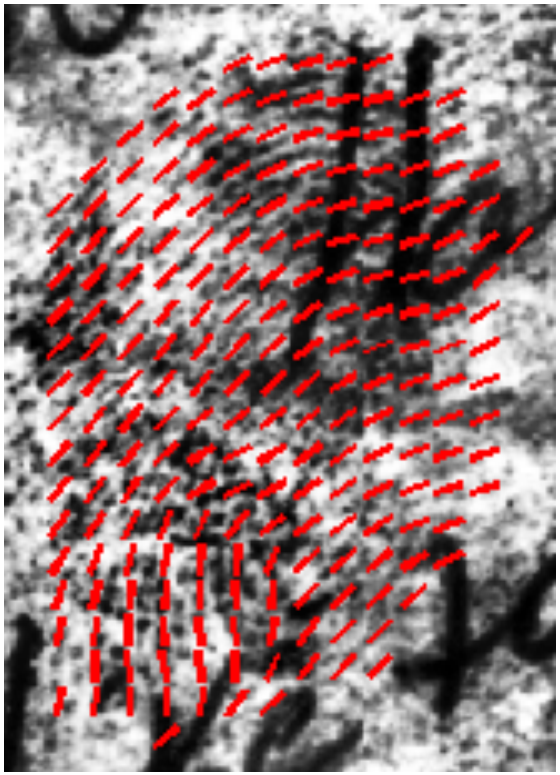
The initial orientation field is not reliable

Latent OF Estimation

Original latent



Orientation patch dictionary



Ridge structure dictionary

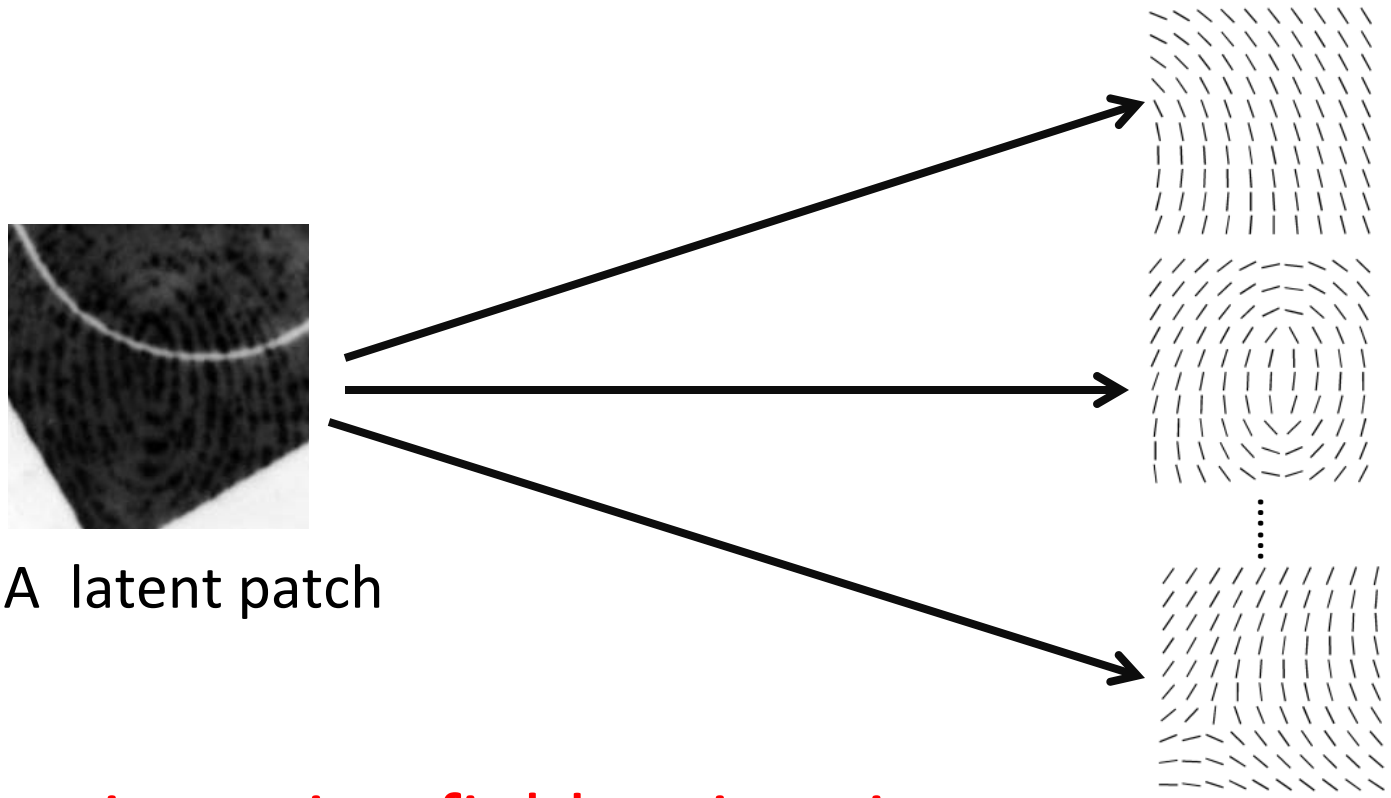
While ridge structure dictionary works better; it can be further improved by using larger patch size. But large patch size will significantly increase dictionary size

We need to learn orientation field from large patch size of varying quality

Dictionaries learnt from high quality fingerprints do not generalize very well!!

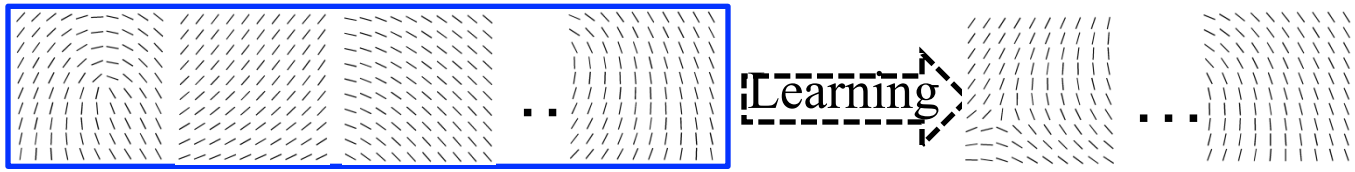
Convolutional Neural Network (ConvNet)

- ConvNet can learn feature representations, given a large number of image examples



Pose orientation field estimation as a classification problem

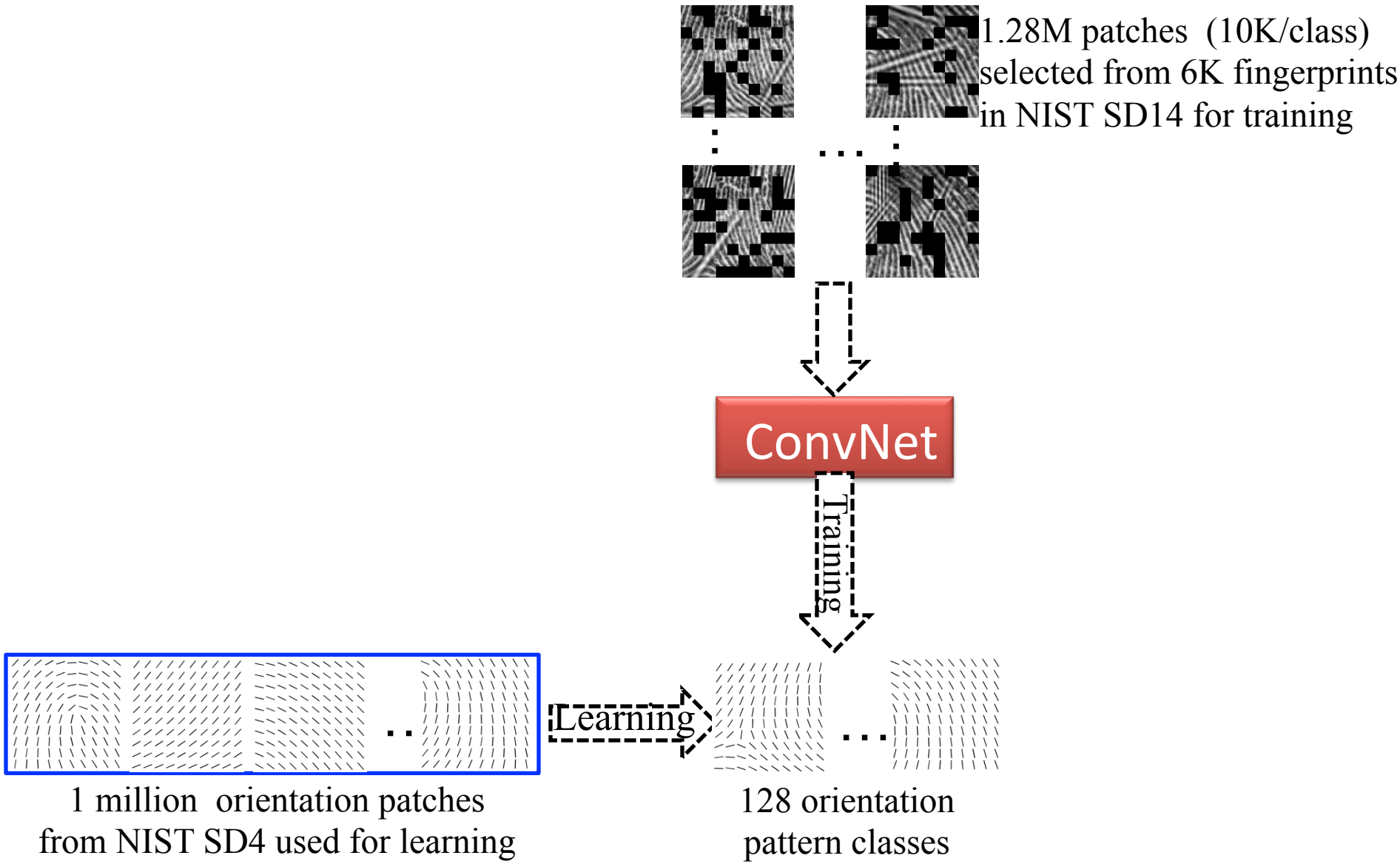
Framework for OF Estimation



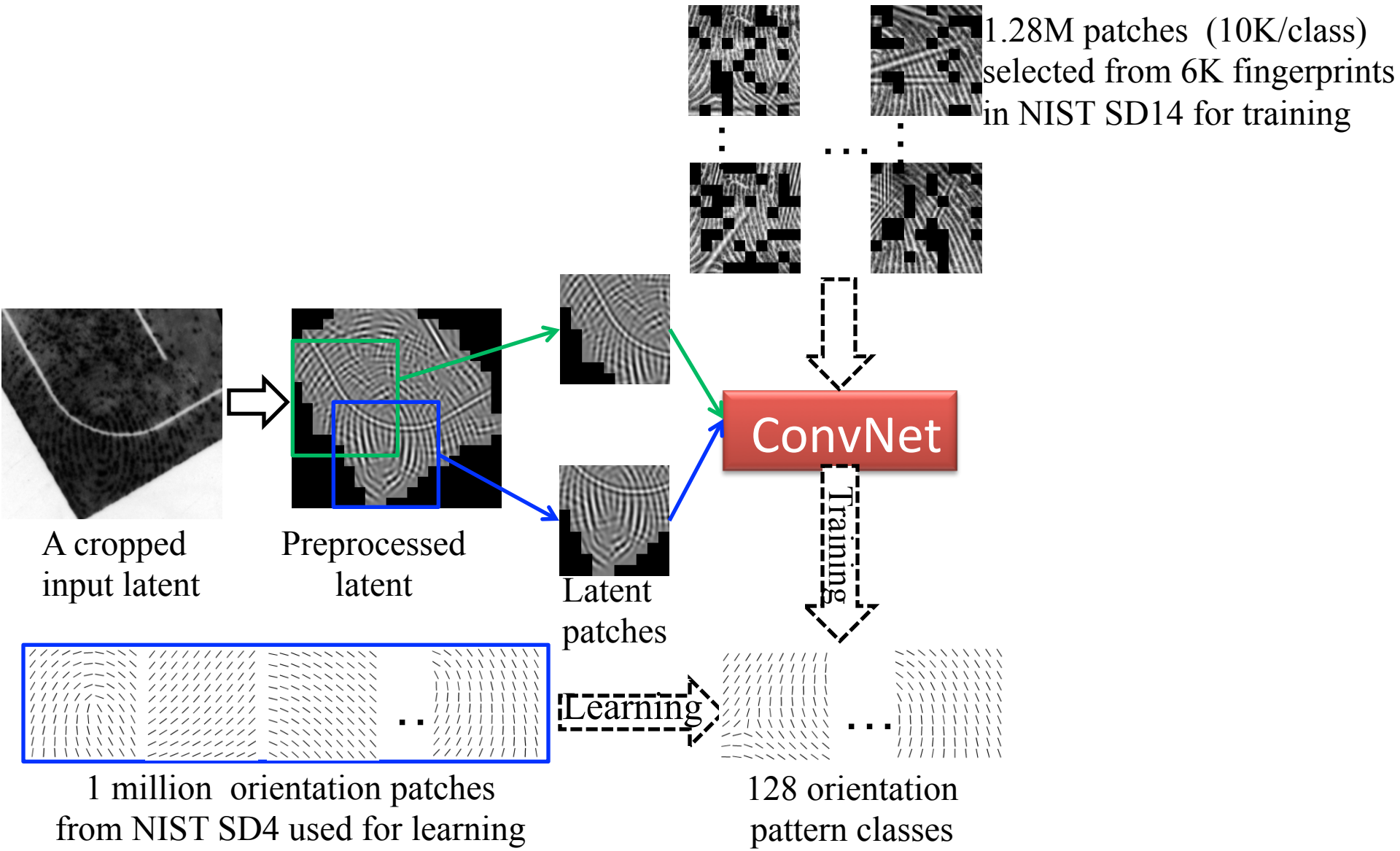
1 million orientation patches
from NIST SD4 used for learning

128 orientation
pattern classes

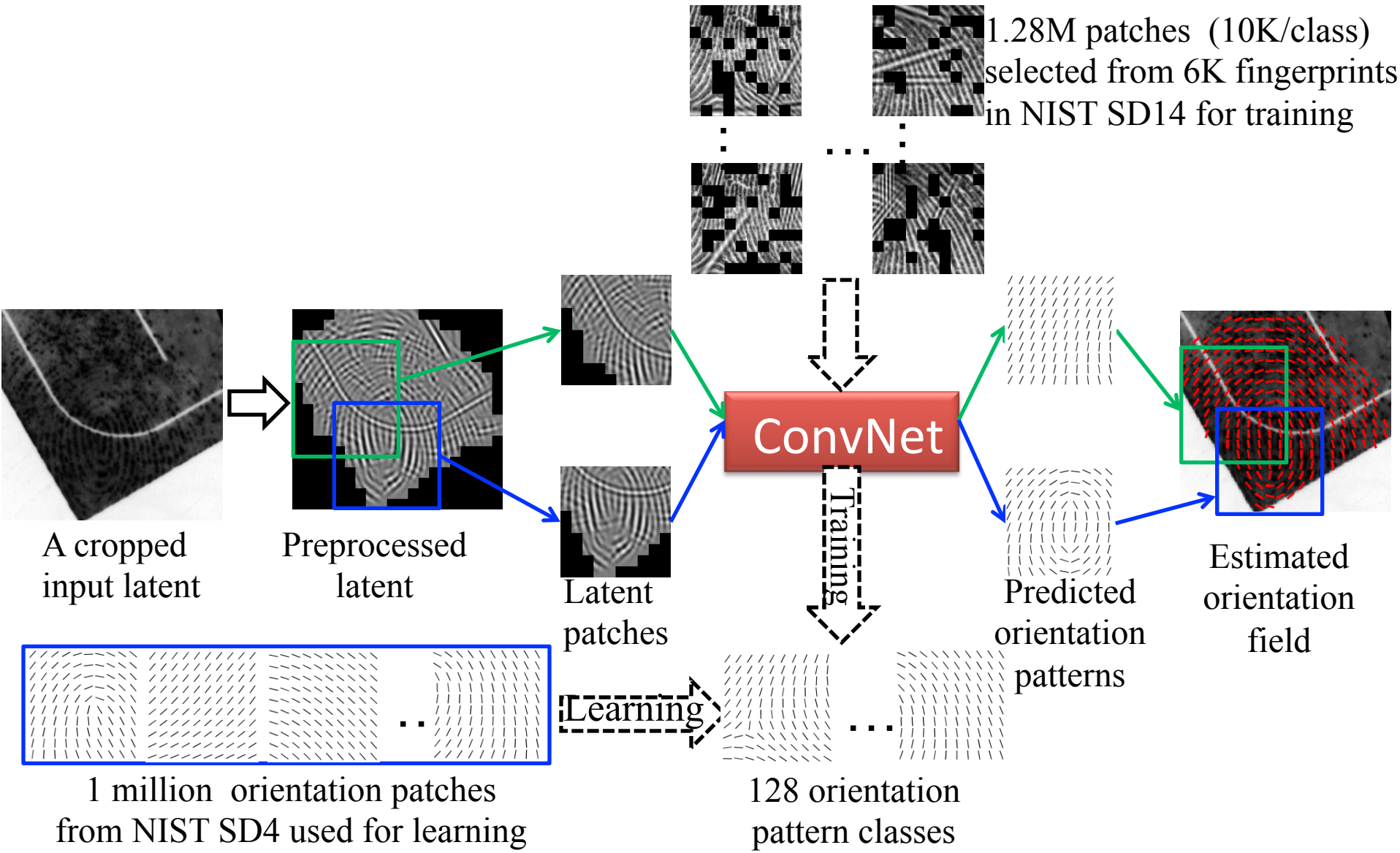
Framework for OF Estimation



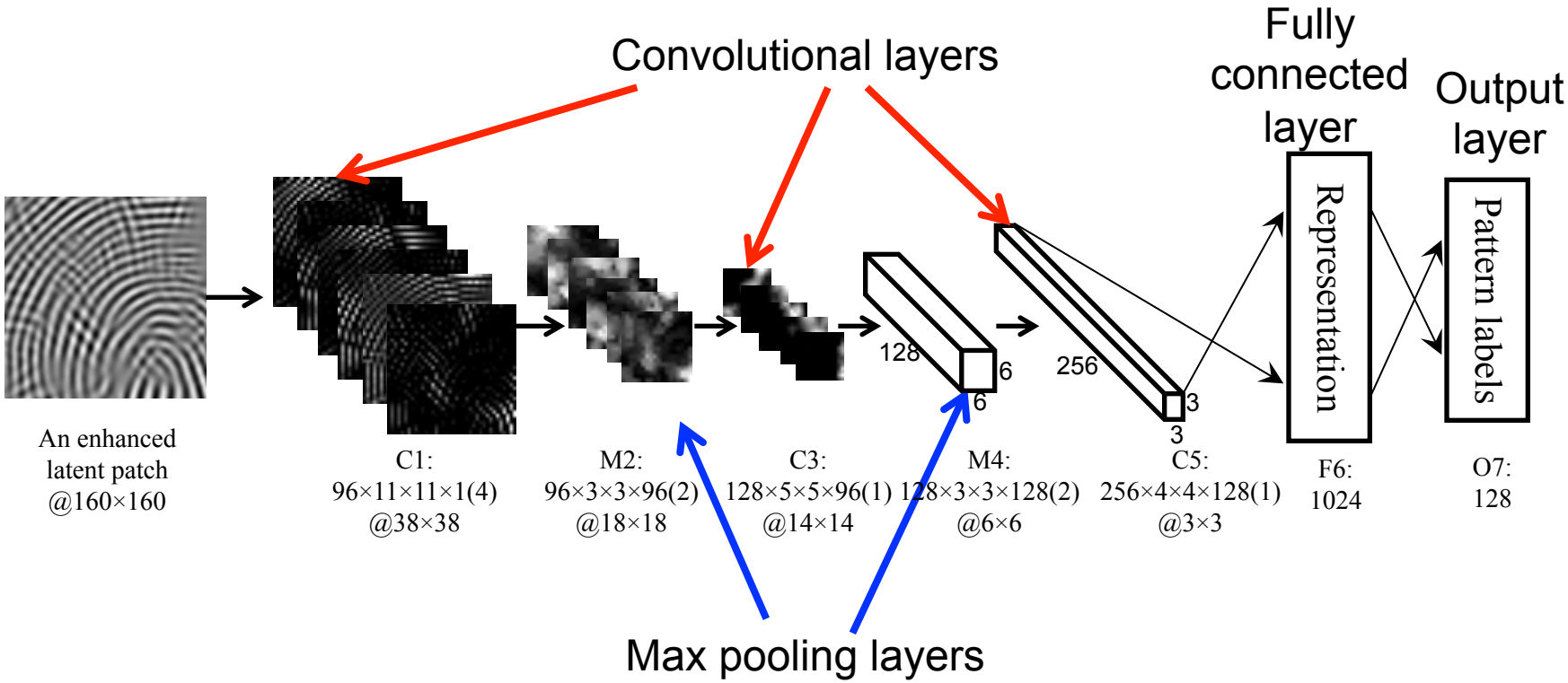
Framework for OF Estimation



Framework for OF Estimation



ConvNet Architecture

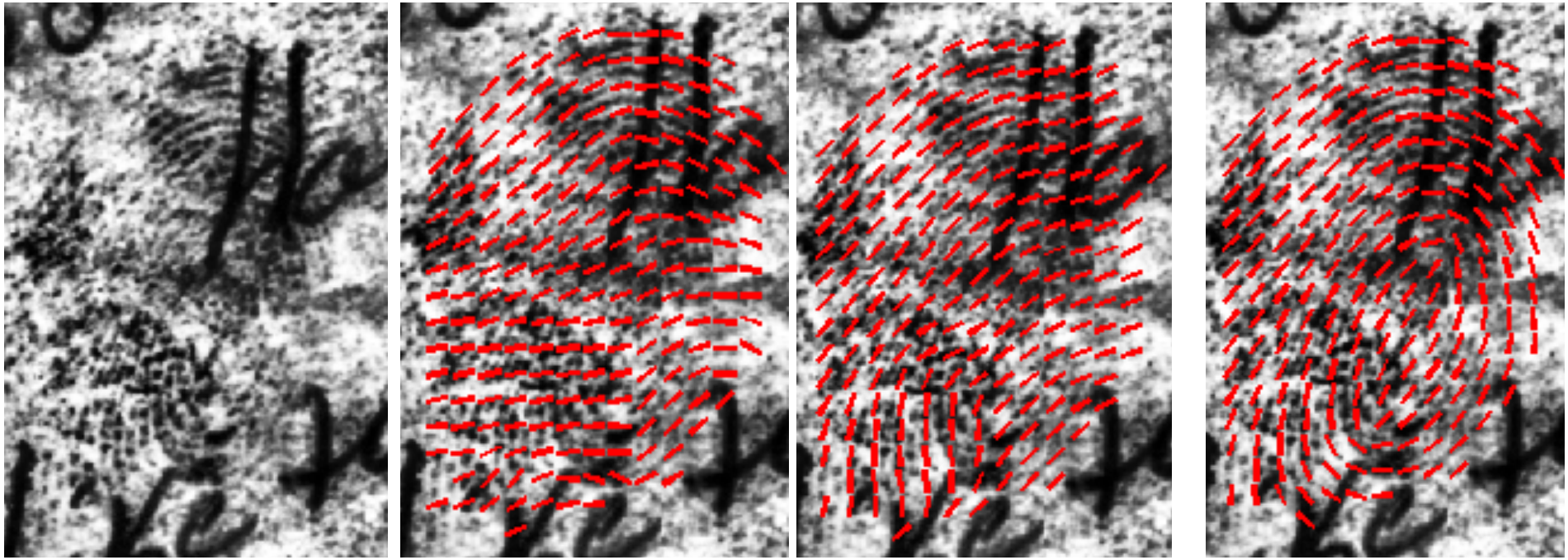


1) ReLU activation function ($f(x) = max(0, x)$) is used at the convolutional layers and the fully connected layer.
2) Dropout regularization for the fully connected layer: 50% neurons are randomly selected with their output set as 0
3) *N*-way softmax is used at output layer

Experimental Setup

- Database for evaluation
  - NIST SD27 (258 latents and their rolled mates)
- Evaluation
  - Accuracy of estimated OF
    - Compared to manually marked orientation field
  - Identification performance
    - Matching enhanced latents against 100K reference prints including mated rolled prints in NIST SD27

Latent Orientation Field Comparison

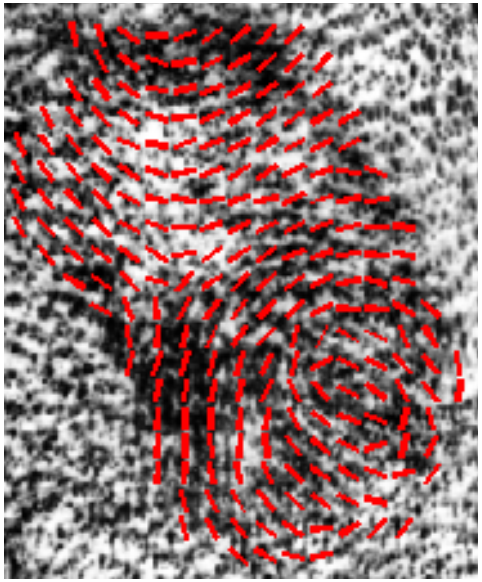


Original latent | Orientation patch dictionary | Ridge structure dictionary | Proposed method

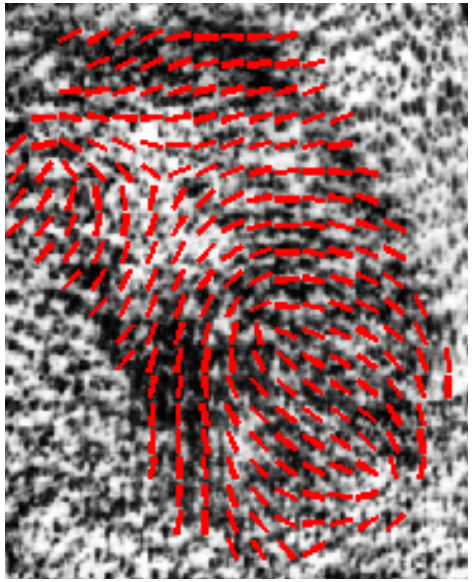
Feng et al.. Orientation field estimation for latent fingerprint enhancement. *TPAMI,* 2013.
Cao et al., Segmentation and enhancement of latent fingerprints: A coarse to fine ridge structure dictionary. *TPAMI, 2014.*

Latent Orientation Field Comparison

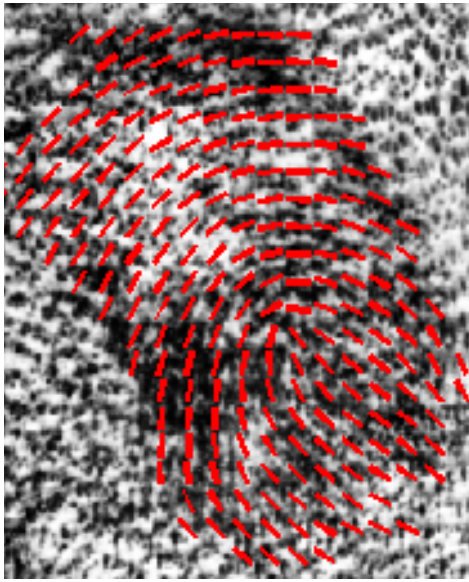
Original latent



Orientation patch dictionary



Ridge structure dictionary



Proposed method

Feng et al.. Orientation field estimation for latent fingerprint enhancement. *TPAMI,* 2013.
Cao et al., Segmentation and enhancement of latent fingerprints: A coarse to fine ridge structure dictionary. *TPAMI, 2014.*

Orientation Field Estimation Accuracy

Average estimation error (in degrees) of different orientation field estimation

Algorithm	All	Good	Bad	Ugly
LocalizedDic [3] Manually marked pose	13.76	10.87	14.12	16.40
LocalizedDic [3]	14.35	11.15	15.15	16.85
GlobalDic [1]	18.44	14.40	19.18	21.88
RidgeDic [2]	19.35	15.34	20.70	22.68
Proposed	13.51	10.76	13.41	16.00

[1] Feng et al., Orientation field estimation for latent fingerprint enhancement. *TPAMI,* 2013.
[2] Cao et al., Segmentation and enhancement of latent fingerprints: A coarse to fine ridge structure dictionary. *TPAMI, 2014.*
[3] Yang et al., Localized dictionaries based orientation field estimation for latent fingerprints. *TPAMI, 2014.*

Identification Experiments

Database

Latent database: NIST SD27

Background database: 100,000 reference prints including mates

Matcher:

A state of the art latent matcher

Input

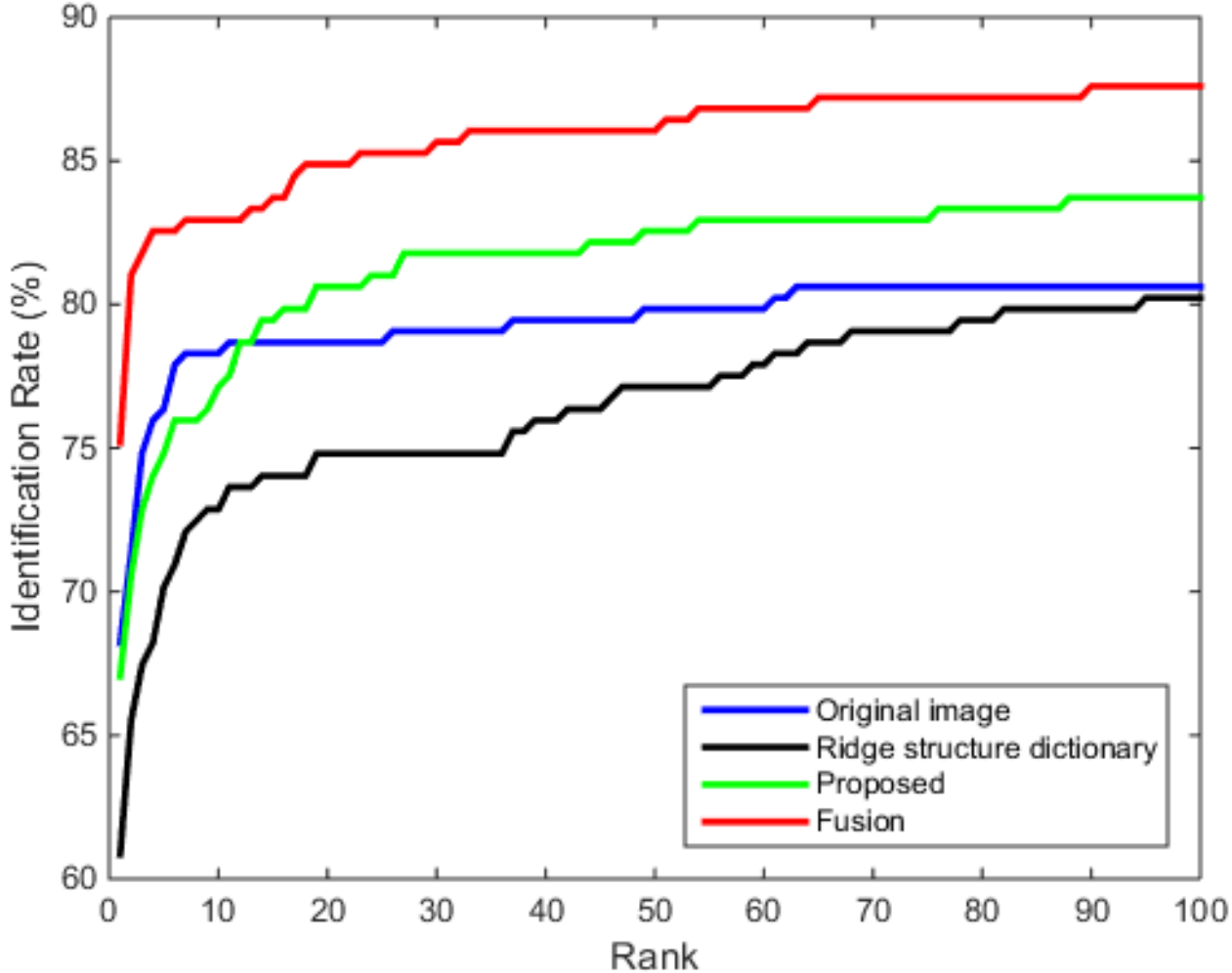
Original latent

Enhanced by [2]

Enhanced by proposed OF and fixed frequency

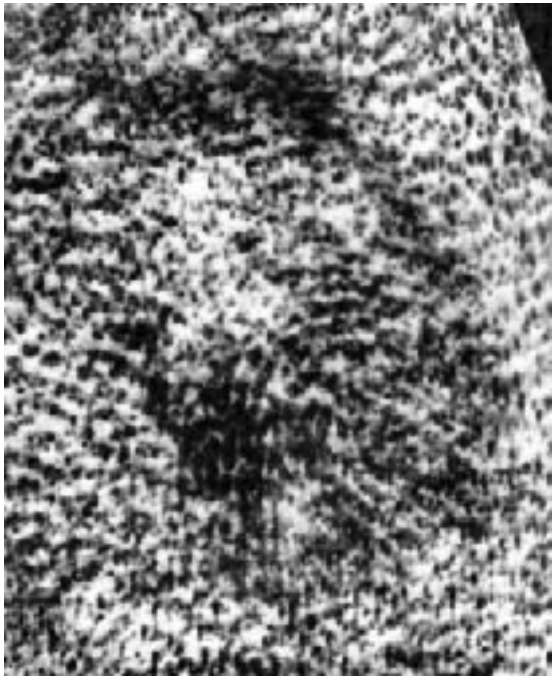
[2] Cao et al., Segmentation and enhancement of latent fingerprints: A coarse to fine ridge structure dictionary. *TPAMI, 2014.*

Identification Evaluation



7.36% rank-1 improvement after fusion

Successful Example

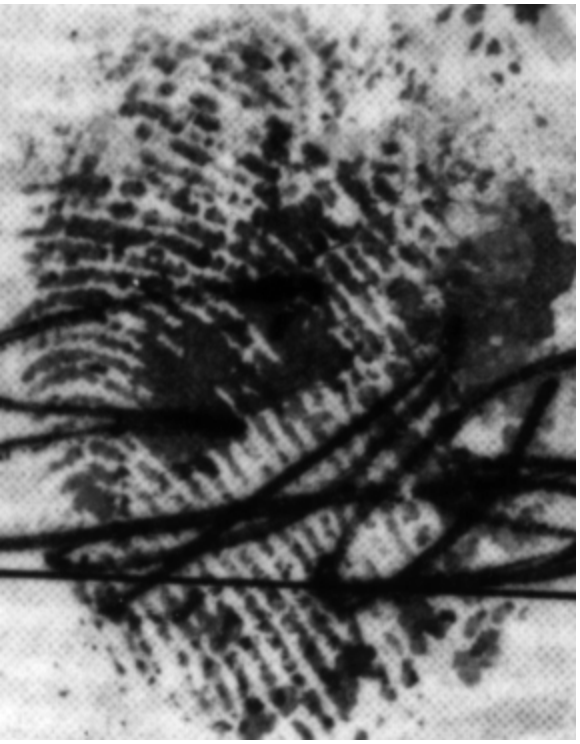


Original latent
(Failed to match)

Enhanced by ridge structure dictionary
(Rank 61)

Enhanced by proposed
(Rank 1)

Failed Example



Original latent
(Rank 4)

Adaptive ridge frequency

Enhanced by ridge structure dictionary
(Rank 528)

Fixed ridge frequency

Enhanced by proposed
(Failed to match)

Conclusion and Future Work

- Proposed orientation field estimation method via convolutional neural network
- Improved the rank-1 performance of a COTS matcher by 7.36% on NIST SD27
- Future work:
  - Effect of No. of orientation pattern classes
  - Noise level added to the training patches
  - Estimate ridge frequency field using ConvNet

Thanks