Robust Minutiae Extractor: Integrating Deep Networks and Fingerprint Domain Knowledge

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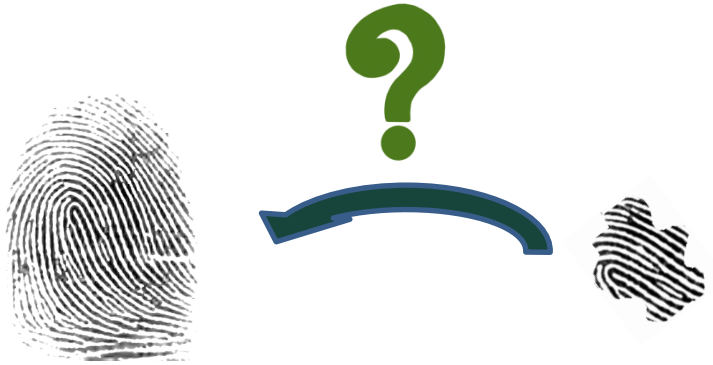
Introduction

Latent fingerprint recognition is not a new area **BUT** challenging

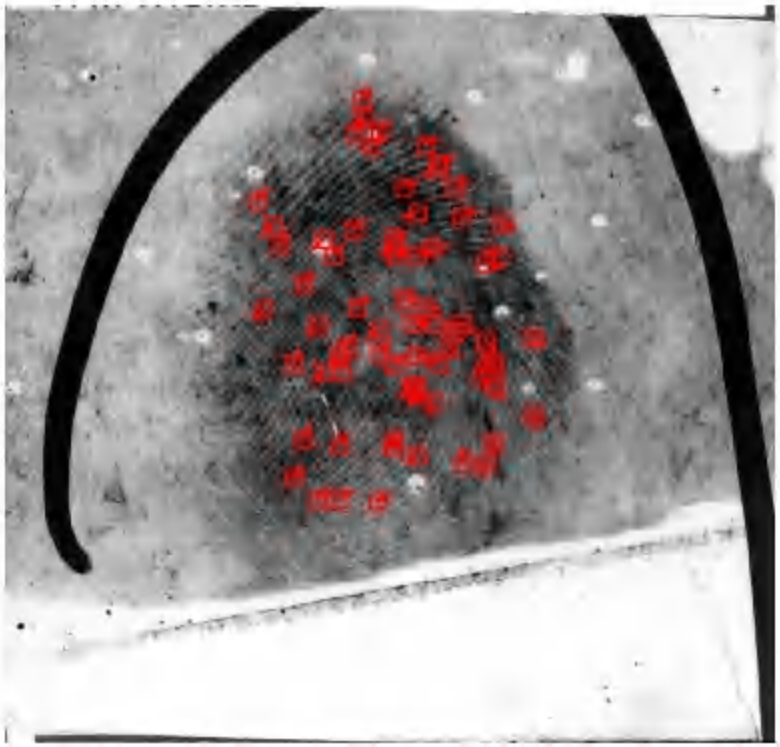
- *Noise* and *low quality* in Latent fingerprint
- *No end-to-end system* has been proposed to solve completely
- Trade off between *speed* and *accuracy* is still a bottleneck



Rolled/Slap **Latent**

Why minutiae?

- Crucial for fingerprint recognition
- Key element in traditional approach



Deep networks
Fingerprint domain knowledge

What is deep network?

A type of learning with layers

+ meaningful features

- does not provide explicit relationship between features

What is fingerprint domain knowledge?

A series of small modules: segmentation, enhancement, orientation, etc.

+ proved advantages in fingerprint problem

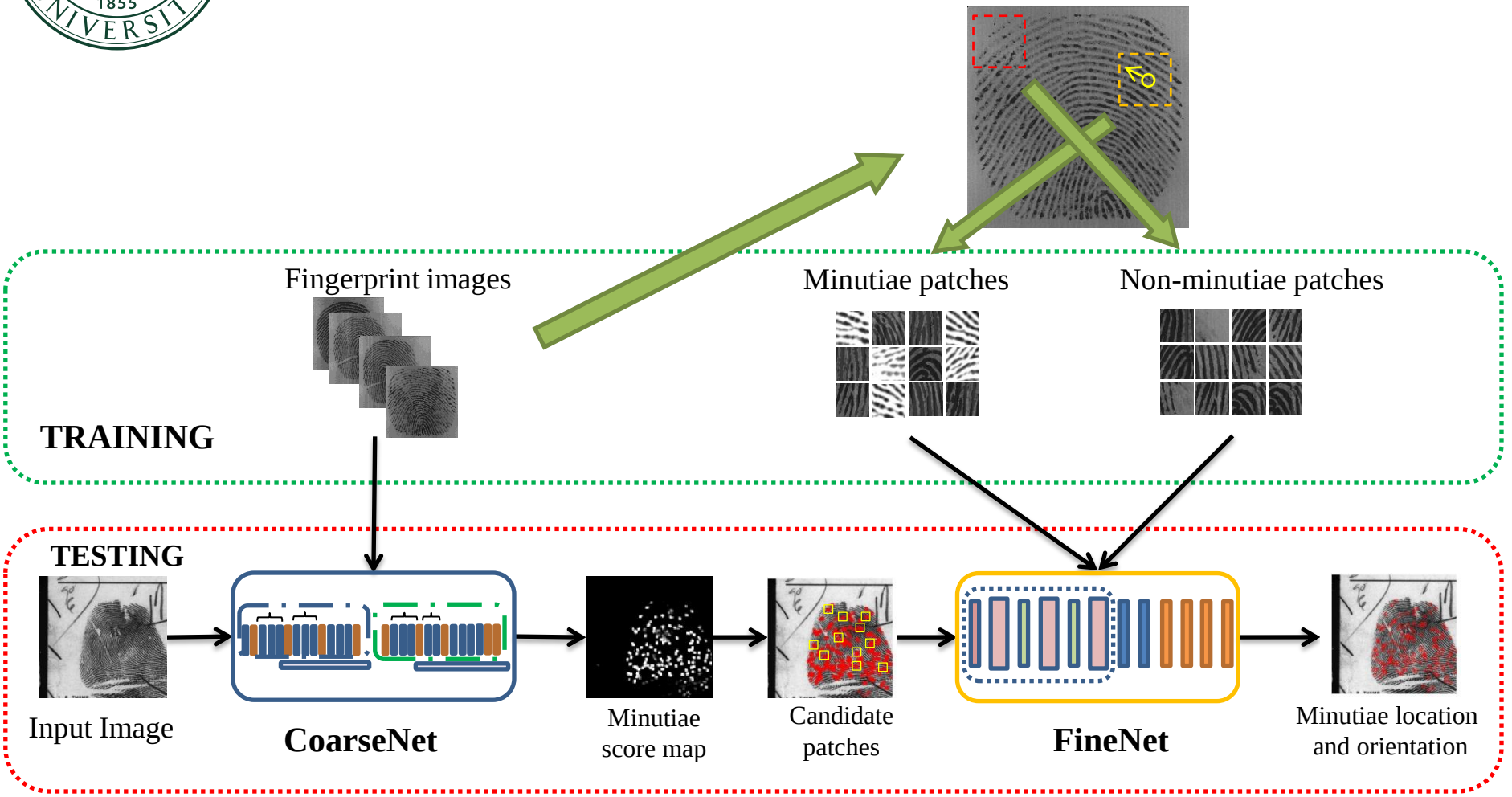
- mainly based on handcrafted approaches

Related works

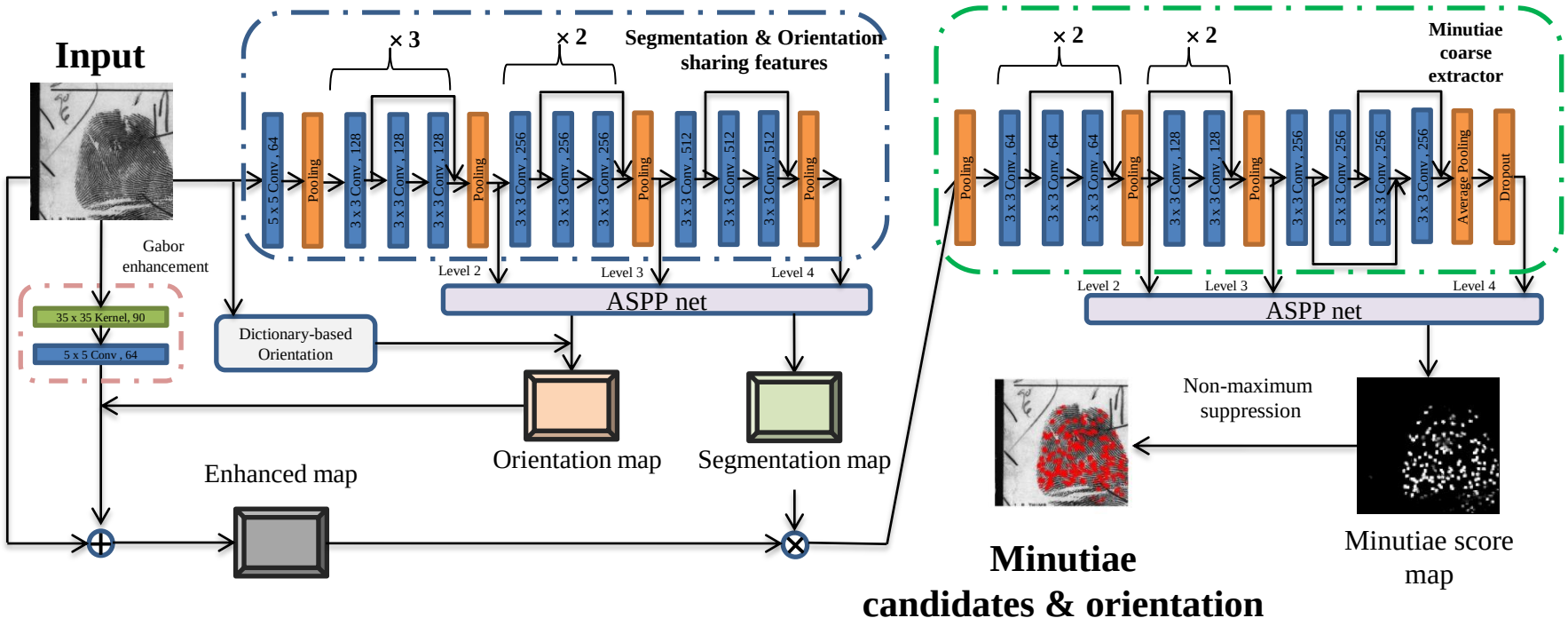
Study	Method	Comments	Evaluation
Sankaran *et al.* [1]	Sparse autoencoders for classification	Sliding window; manual segmentation of latent fingerprints	Patch-based and minutia-based metric and matching performance
Jiang *et al.* [2]	A combination of JudgeNet and LocateNet	Sliding window; hand-crafted dividing regions; no minutiae orientation information	Precision, recall, and F1 score
Tang *et al.* [3]	Fully convolutional neural network	Hard thresholds to cut off candidate regions; plain network	Precision, recall, F1 score, and matching performance
Darlow *et al.* [4]	Convolutional network classifier	Sliding window; hard threshold for candidate regions (minutiae); separately estimated minutiae orientation	Equal error rate and matching performance
Tang *et al.* [5]	Unified network with domain knowledge	Plain network; depends largely on the quality of the enhancement and segmentation stages	Precision, recall, and matching performance
Proposed approach	***Domain knowledge with Residual learning based CoarseNet and inception-resnet based FineNet***	***Residual network; automatic minutiae extractor utilizing domain knowledge; robust patch based minutiae classifier***	***Precision, recall, and F1 score under different location and orientation thresholds***

[1] A. Sankaran, P. Pandey, M. Vatsa, and R. Singh. On latent fingerprint minutiae extraction using stacked denoising sparse autoencoders. In Proc. IEEE IJCB, pages 1–7, 2014
[2] L. Jiang, T. Zhao, C. Bai, A. Yong, and M. Wu. A direct finger-print minutiae extraction approach based on convolutional neural net-works. In Proc. IEEE IJCNN, pages 571–578, 2016
[3] Y. Tang, F. Gao, and J. Feng. Latent fingerprint minutia extraction using fully convolutional network. In Proc. IEEE IJCB, 2017
[4] L. Darlow and B. Rosman. Fingerprint minutiae extraction using deep learning. In Proc. IEEE IJCB, 2017
[5] Y. Tang, F. Gao, J. Feng, and Y. Liu. Fingernet: An unified deep network for fingerprint minutiae extraction. In Proc. IEEE IJCB, 2017

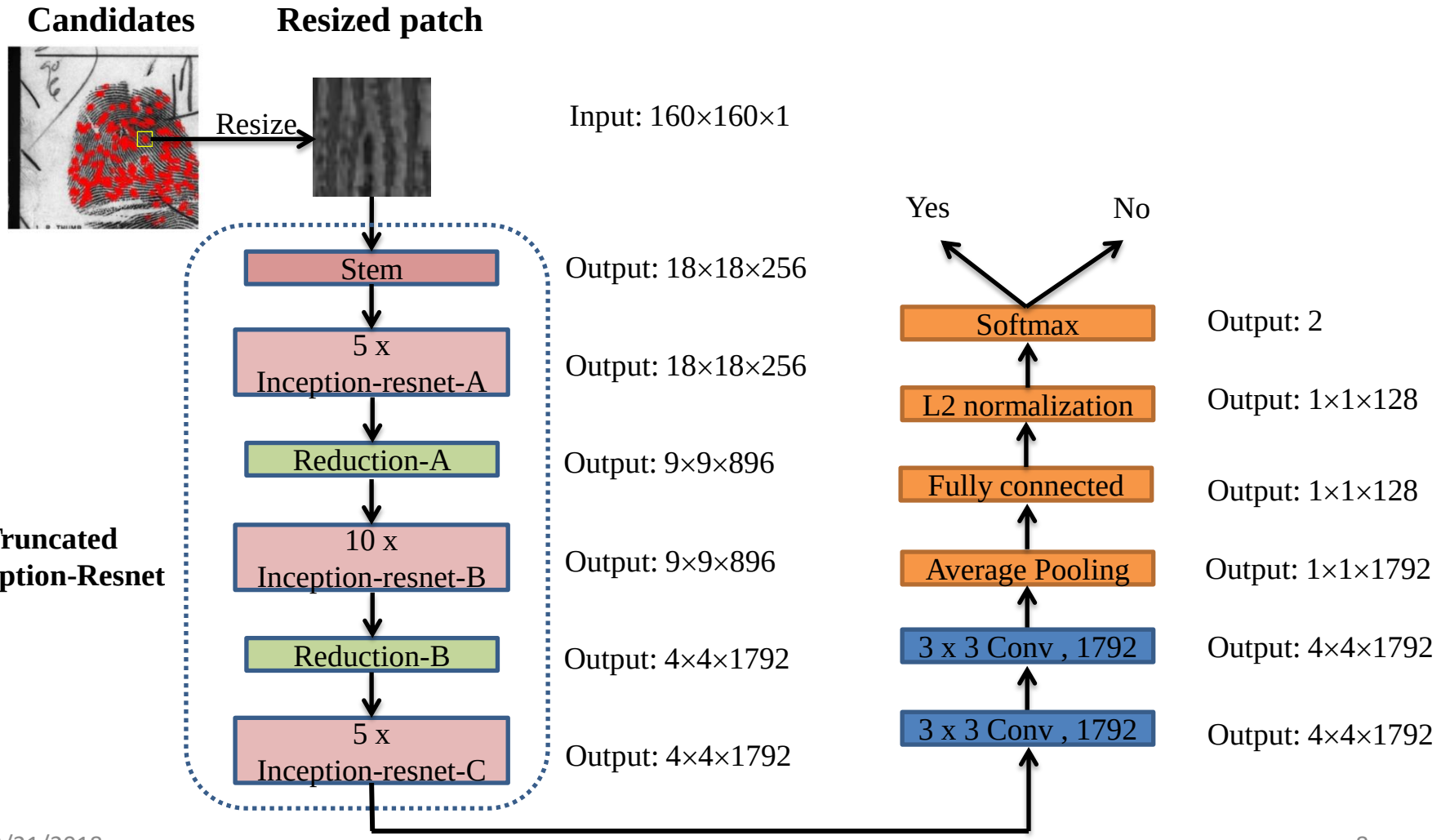
MinutiaeNet



CoarseNet


Input
Gabor enhancement
35 x 35 Kernel, 90
5 x 5 Conv , 64
Dictionary-based Orientation
× 3
× 2
Segmentation & Orientation sharing features
5 x 5 Conv , 64
Pooling
3 x 3 Conv , 128
3 x 3 Conv , 256
3 x 3 Conv , 512
Level 2
Level 3
Level 4
ASPP net
Orientation map
Segmentation map
Enhanced map
Minutiae coarse extractor
Average Pooling
Dropout
Non-maximum suppression
Minutiae score map
Minutiae candidates & orientation

FineNet


Candidates
Resized patch
Resize
Input: 160×160×1
Stem
Output: 18×18×256
5 x Inception-resnet-A
Output: 18×18×256
Reduction-A
Output: 9×9×896
10 x Inception-resnet-B
Output: 9×9×896
Reduction-B
Output: 4×4×1792
5 x Inception-resnet-C
Output: 4×4×1792
Truncated Inception-Resnet
Yes
No
Softmax
Output: 2
L2 normalization
Output: 1×1×128
Fully connected
Output: 1×1×128
Average Pooling
Output: 1×1×1792
3 x 3 Conv , 1792
Output: 4×4×1792
3 x 3 Conv , 1792
Output: 4×4×1792

Dataset

Training:

FVC 2002 [6] with data augmentation consisting of 3,200 plain fingerprint images

- **8K** images for *CoarseNet*
- **100K** 45×45 pixels patches for *FineNet*

Testing:

FVC 2004 [7]: rolled/slap fingerprint

NIST SD27 [8]: latent fingerprint

Criteria:

Let the tuples (l_p, o_p) and (l_{gt}, o_{gt}) be the location coordinates and orientation values of predicted and ground truth minutia.

Predicted minutia is called true if:

$$\begin{cases} \|l_p - l_{gt}\|_2 \leq D \\ \|o_p - o_{gt}\|_1 \leq O \end{cases}$$

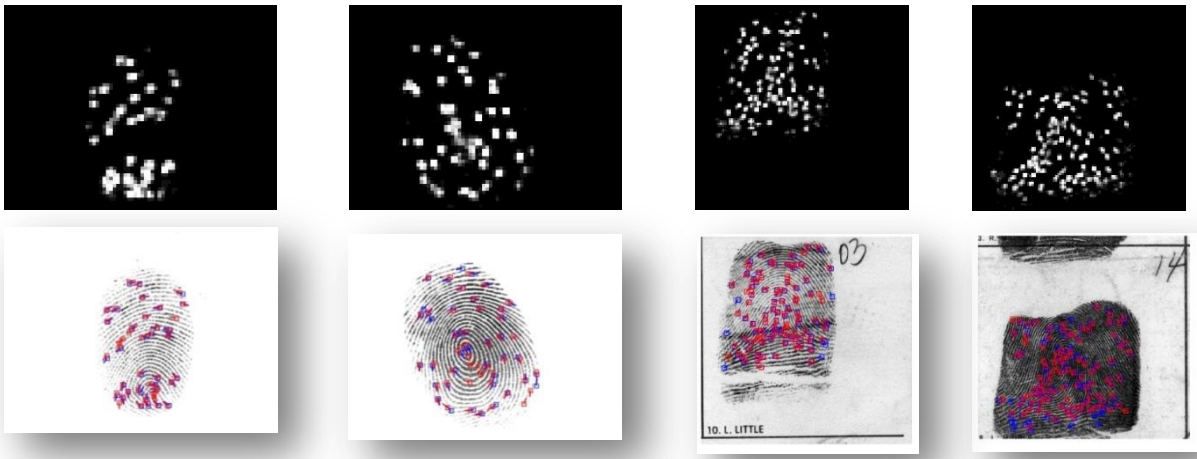
where D and O are the thresholds in pixels and degrees, respectively

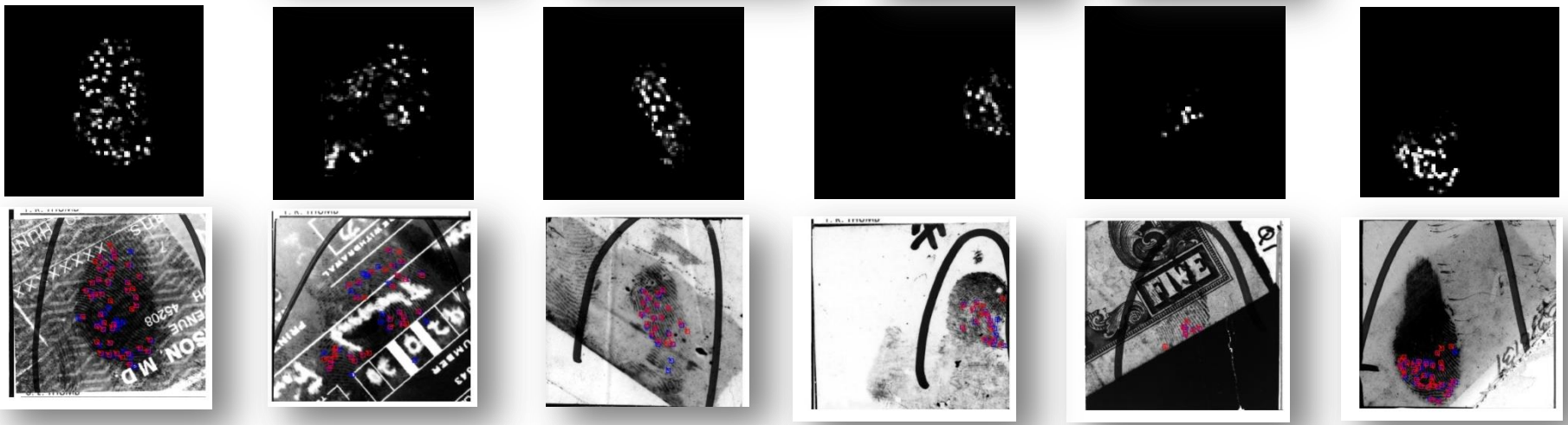
[6] D. Maio, D. Maltoni, R. Cappelli, J. L. Wayman, and A. K. Jain. FVC2002: Second fingerprint verification competition. In Proc. 16th ICPR, volume 3, pages 811–814, 2002
[7] D. Maio, D. Maltoni, R. Cappelli, J. Wayman, and A. Jain. FVC2004: Third fingerprint verification competition. In Biometric Authentication, pages 31–35. Springer, 2004
[8] M. D. Garris and R. M. McCabe. NIST special database 27: Fingerprint minutiae from latent and matching tenprint images. NIST Technical Report NISTIR, 6534, 2000

Result

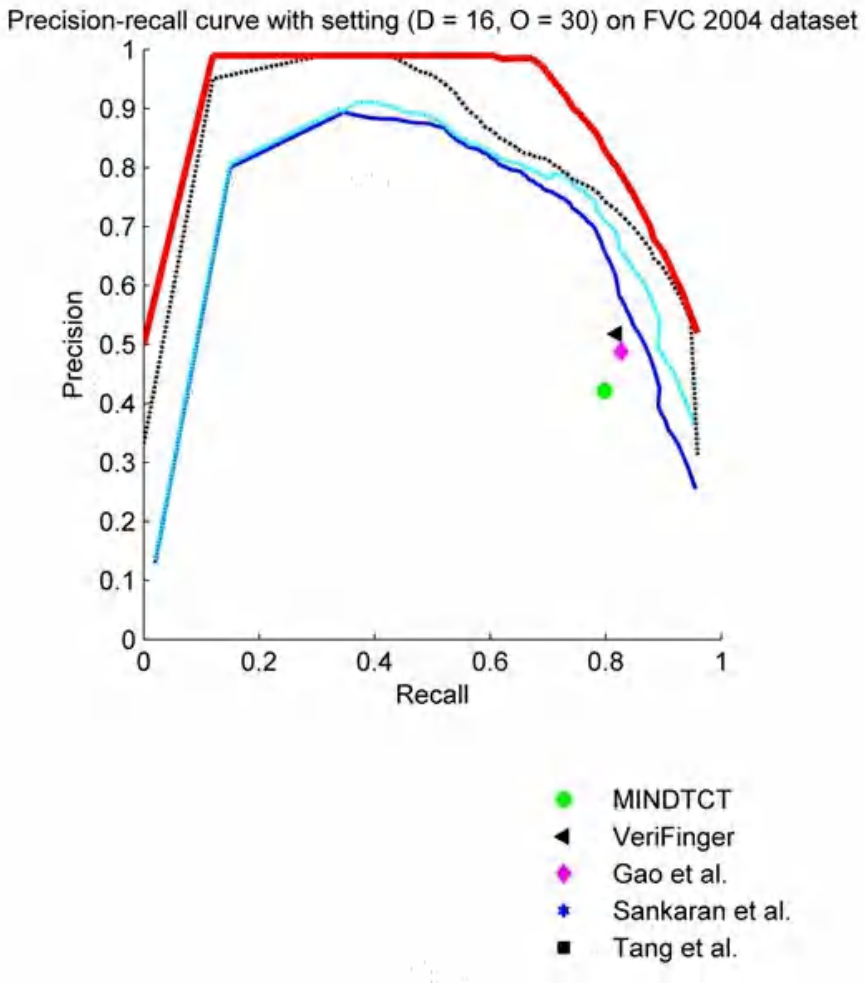
Dataset	Method	Setting 1 (*D = 8, O = 10*)			Setting 2 (*D = 12, O = 20*)			Setting 3 (*D = 16, O = 30*)		
		Precision	Recall	F1 score	Precision	Recall	F1 score	Precision	Recall	F1 score
NIST SD27	MINDTCT	8.3%	14.7%	0.106	10.0%	16.4%	0.214	11.2%	18.9%	0.141
	VeriFinger	3.6%	40.1%	0.066	5.3%	47.9%	0.095	7.6%	58.3%	0.134
	Gao *et al.*	_	_	_	_	_	_	23.5%	8.7%	0.127
	Sankaran *et al.*	_	_	_	_	_	_	26.4%	63.1%	0.372
	Tang *et al.*	_	_	_	_	_	_	53.0%	53.4%	0.532
	FingerNet	53.2%	49.5%	0.513	58.0%	58.1%	0.58	63.0%	63.2%	0.631
	Proposed method	**69.2%**	**67.7%**	**0.684**	**70.5%**	**72.3%**	**0.714**	**71.2%**	**75.7%**	**0.734**
FVC 2004	MINDTCT	30.8%	64.3%	0.416	37.7%	72.1%	0.495	42.1%	79.8%	0.551
	VeriFinger	39.8%	69.2%	0.505	45.6%	77.5%	0.574	51.8%	81.9%	0.635
	Gao *et al.*	_	_	_	_	_	_	48.8%	82.7%	0.614
	FingerNet	68.7%	62.1%	0.643	72.9%	70.4%	0.716	76.0%	80.0%	0.779
	Proposed method	**79.0%**	**80.1%**	**0.795**	**83.6%**	**83.9%**	**0.837**	**85.9%**	**84.8%**	**0.853**

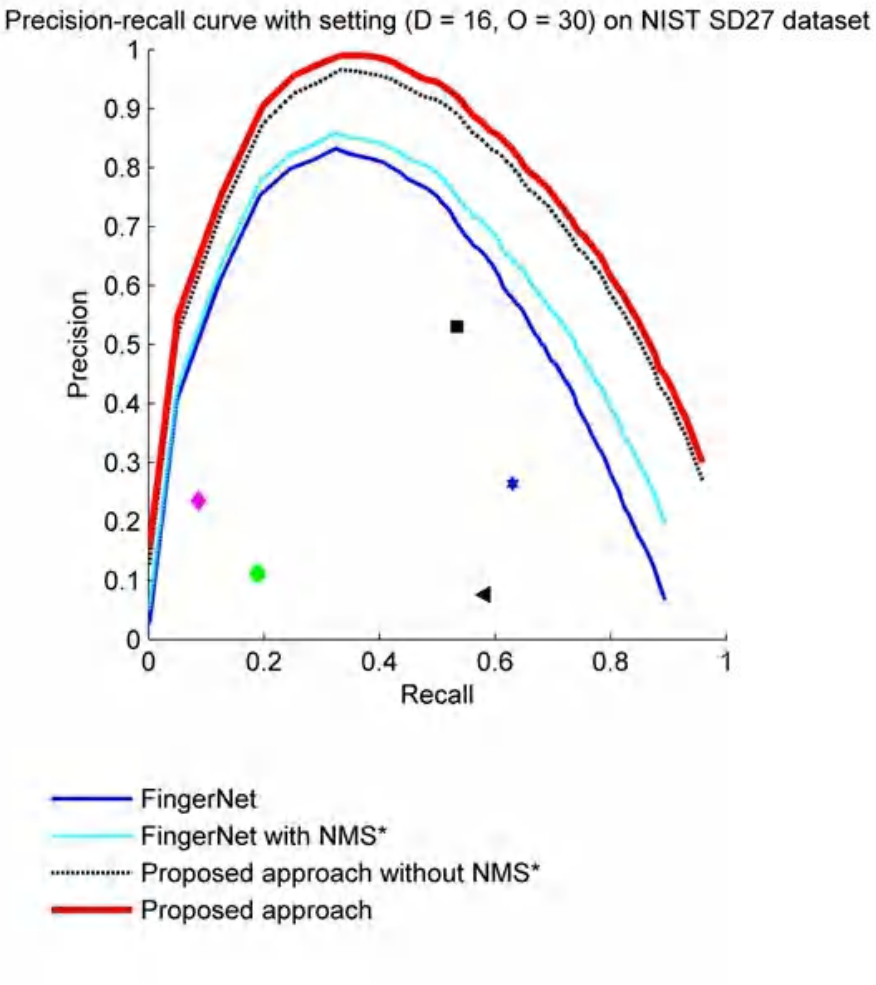
Visualization





Curves


Precision-recall curve with setting (D = 16, O = 30) on FVC 2004 dataset
Precision
Recall
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0.2
0.4
0.6
0.8
MINDTCT
VeriFinger
Gao et al.
Sankaran et al.
Tang et al.
FingerNet
FingerNet with NMS*
Proposed approach without NMS*
Proposed approach


Precision-recall curve with setting (D = 16, O = 30) on NIST SD27 dataset
Precision
Recall
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0.2
0.4
0.6
0.8

Conclusion & Future work

- **CoarseNet:** an automatic robust minutiae extractor that provides candidate minutiae location and orientation without a hard threshold or fine tuning.
- **FineNet:** a strong patch based classifier that accelerates the reliability of candidates from CoarseNet to get final results.

- Fingerprint recognition without minutiae?
- End-to-end matching system?
- Speed increment?

Thank you for your attention

Q&A

Scan me for code!