



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

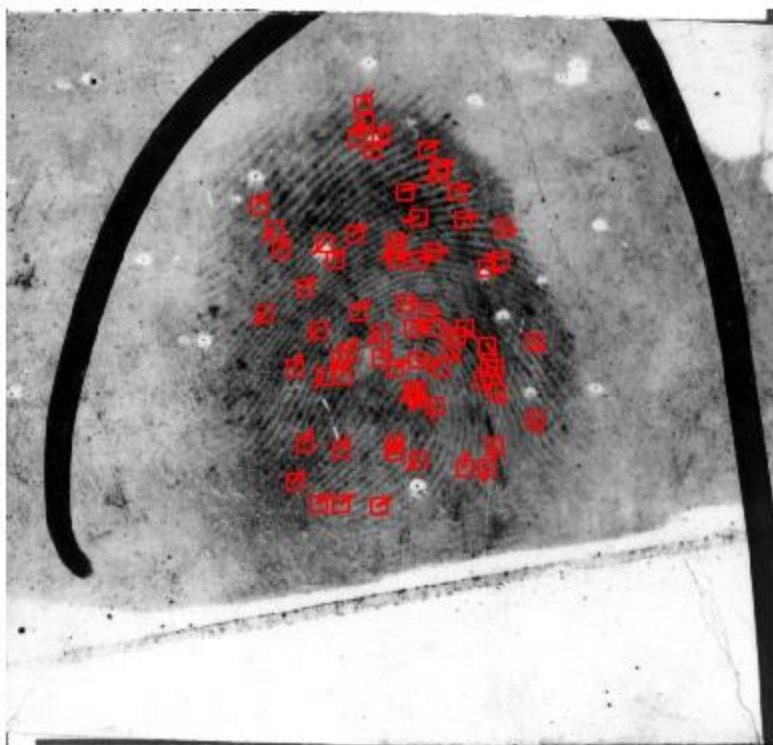
- *Noise and low quality* in Latent fingerprint
- *No end-to-end system* has been proposed to solve completely
- Trade off between *speed* and *accuracy* is still a bottleneck





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



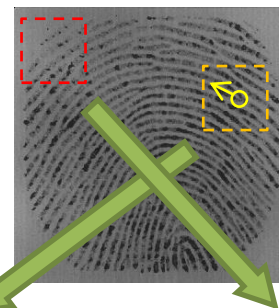
Related works

Study	Method	Comments	Evaluation
Sankaran <i>et al.</i> [1]	Sparse autoencoders for classification	Sliding window; manual segmentation of latent fingerprints	Patch-based and minutia-based metric and matching performance
Jiang <i>et al.</i> [2]	A combination of JudgeNet and LocateNet	Sliding window; hand-crafted dividing regions; no minutiae orientation information	Precision, recall, and F1 score
Tang <i>et al.</i> [3]	Fully convolutional neural network	Hard thresholds to cut off candidate regions; plain network	Precision, recall, F1 score, and matching performance
Darlow <i>et al.</i> [4]	Convolutional network classifier	Sliding window; hard threshold for candidate regions (minutiae); separately estimated minutiae orientation	Equal error rate and matching performance
Tang <i>et al.</i> [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



Fingerprint images

Minutiae patches

Non-minutiae patches

TRAINING

TESTING

Input Image

CoarseNet

Minutiae
score map

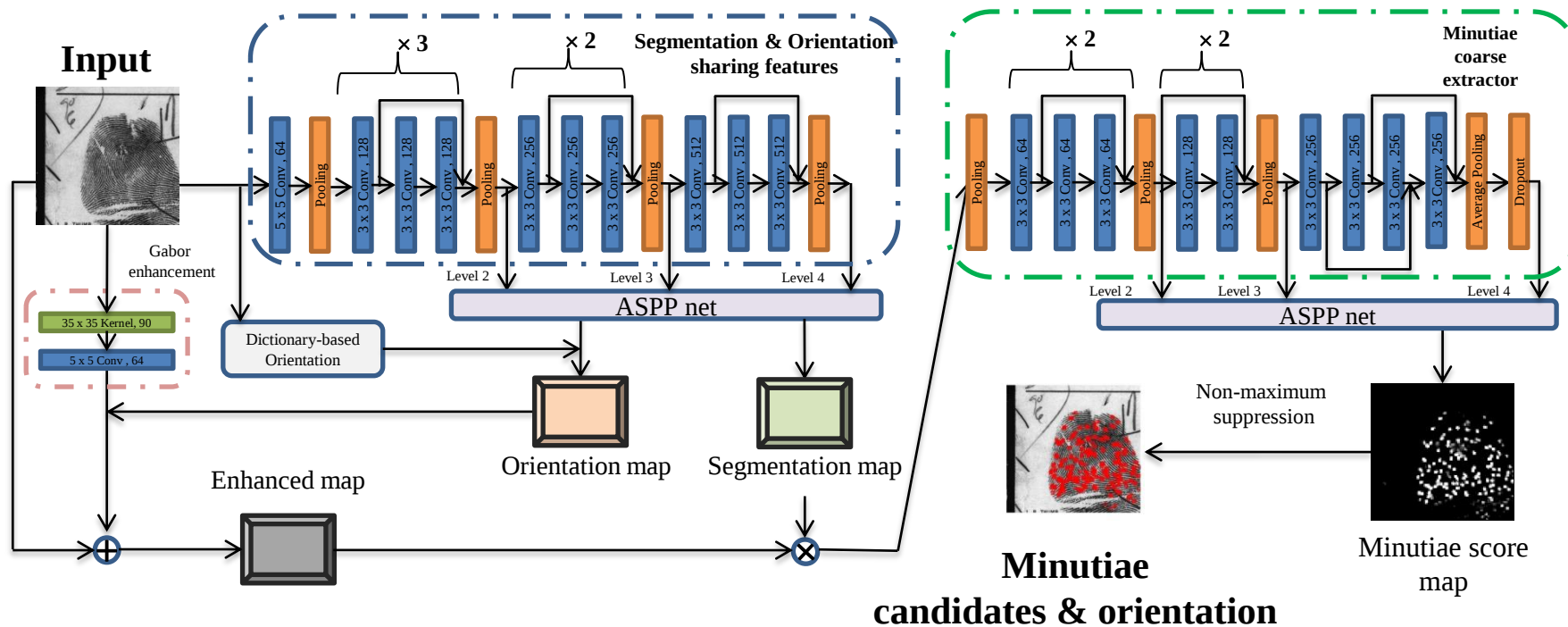
Candidate
patches

FineNet

Minutiae location
and orientation

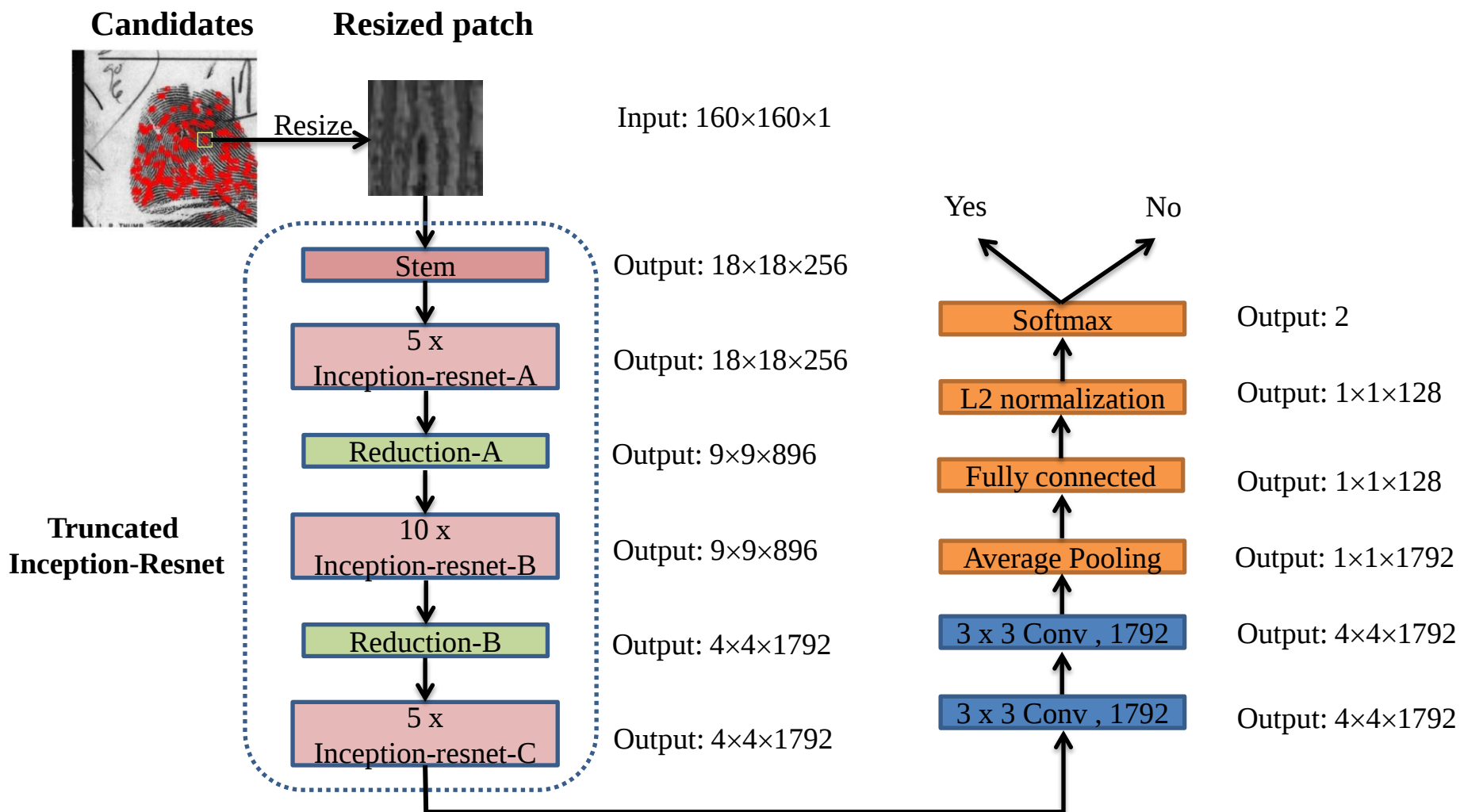


CoarseNet





FineNet





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/slapped 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. Garriss and R. M. McCabe. NIST special database 27: Fingerprint minutiae from latent and matching tenprint images. NIST Technical Report NISTIR, 6534, 2000

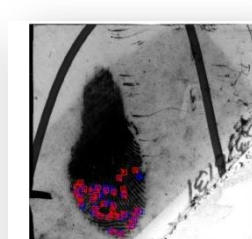
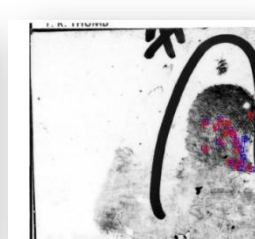
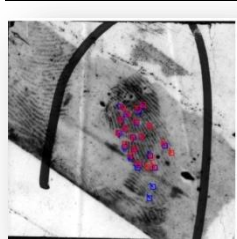
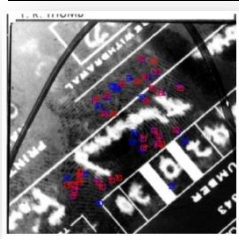
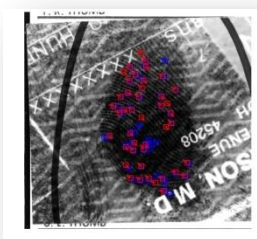
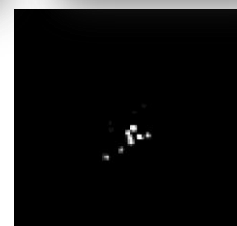
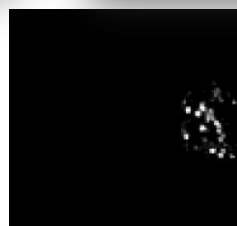
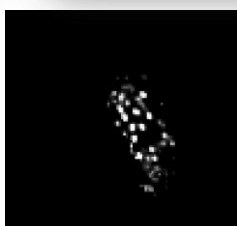
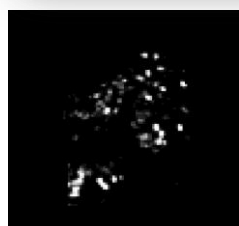
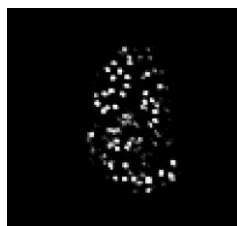
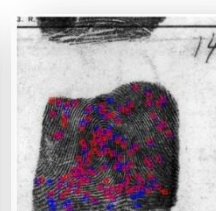
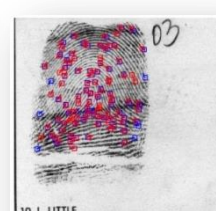
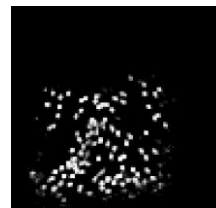
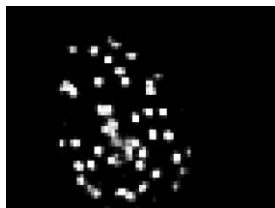


Result

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 <i>et al.</i>	—	—	—	—	—	—	23.5%	8.7%	0.127
	Sankaran <i>et al.</i>	—	—	—	—	—	—	26.4%	63.1%	0.372
	Tang <i>et al.</i>	—	—	—	—	—	—	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 <i>et al.</i>	—	—	—	—	—	—	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



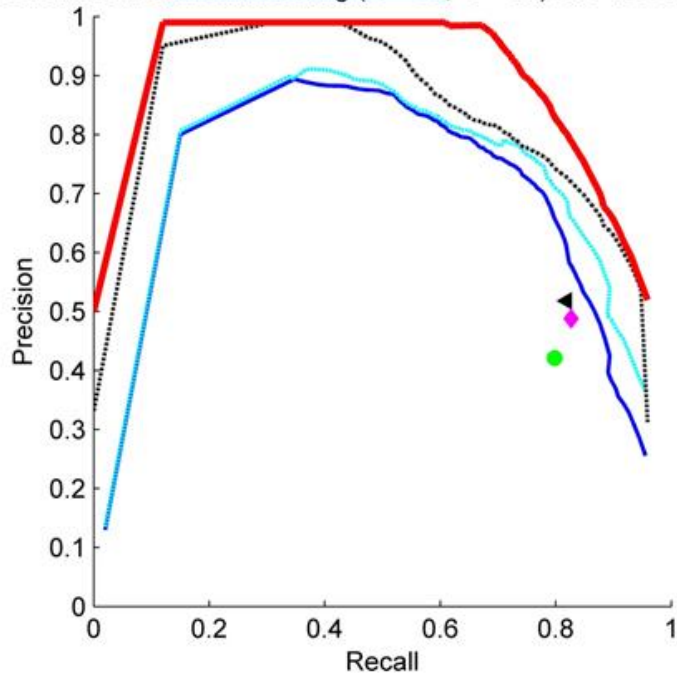
Visualization





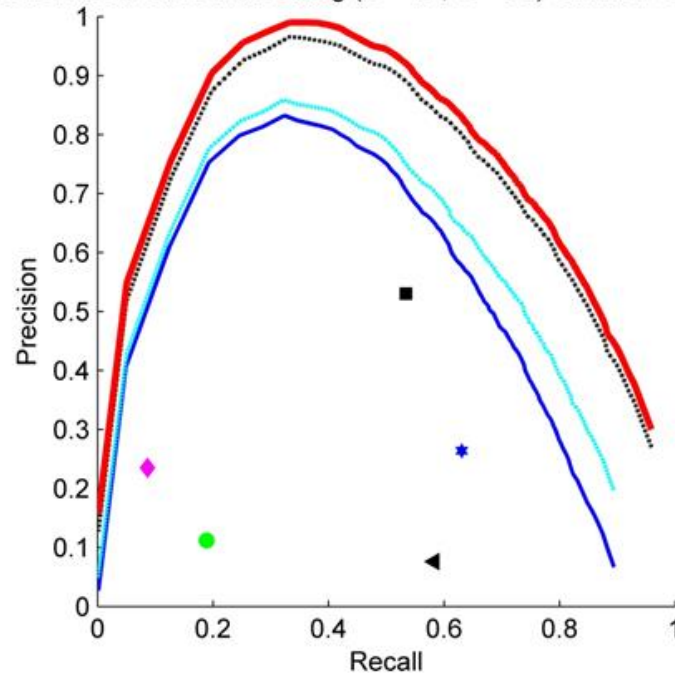
Curves

Precision-recall curve with setting ($D = 16$, $O = 30$) on FVC 2004 dataset



- MINDTCT
- ◄ VeriFinger
- ◆ Gao et al.
- ★ Sankaran et al.
- Tang et al.

Precision-recall curve with setting ($D = 16$, $O = 30$) on NIST SD27 dataset



- FingerNet
- FingerNet with NMS*
- Proposed approach without NMS*
- Proposed approach



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!