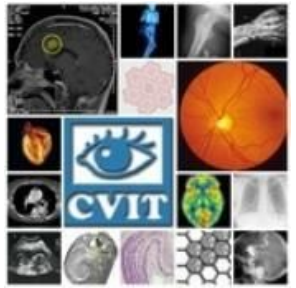
FPD-M-net: Fingerprint Image Denoising and Inpainting Using M-Net Based Convolutional Neural Networks

Sukesh Adiga V and *Jayanthi Sivaswamy*
Center for Visual Information Technology,
IIIT, Hyderabad
09-09-2018



Problems to be solved

- Degradation in fingerprint image quality
  - Example: when fingers are wet, dirty, skin dryness.
- A denoising problem with signal is fingerprint and background is noise.

- Incomplete information
  - due to the failure of sensors or wound in finger.
- An inpainting problem.

Method

Our view: The given image consists of an object of interest present in some background or clutter

- Problem to be solved is **segmentation** of the object (fingerprint).
- Hypotheses is that missing information can be handled with appropriate training, i.e. no explicit inpainting is required.

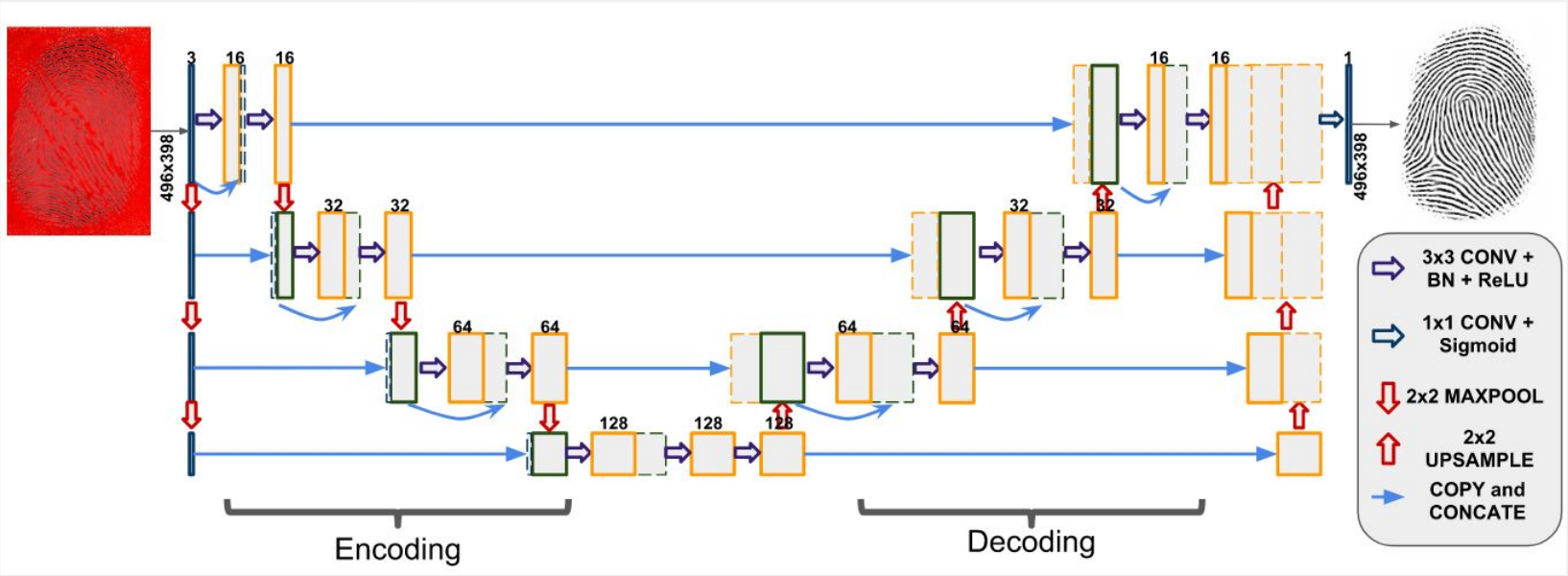
Proposed solution: An architecture called ***FPD-M-net,*** based on the *M-net**

- originally proposed for brain structure segmentation.

** Mehta et al., M-net: A convolutional neural network for deep brain structure segmentation, ISBI 2017*

FPD-M-net Architecture

- *FDP-M-net* is a encoder-decoder style of architecture with some skips connections.
- Skip connections between two convolution helps in learning better features and side skip connection helps to drive fine grain details.



What is new in FPD-M-net ?

Modifications done:

- M-net uses an initial block to convert 3D information into a 2D image.

⇒ This is dropped.

- M-net uses categorical cross entropy for the loss function.

⇒ This is replaced by a mixture of per-pixel (L1) loss and the multiscale SSIM.

- M-net does batch normalization after the activation function.

⇒ This is now done before the activation function.

Training of FPD-M-Net

- The network is trained end-to-end.
- Input and ground truth images are padded with the edge values to suit the network and normalized to the range [0, 1].
- The network is trained to minimize a combination of per-pixel (L1) loss and the MS-SSIM loss.

Choice of loss function

- In reconstruction of image, loss function should preserve intensity, luminance and these should be perceptually correlated.
- The L1/L2 loss is popular but it does not correlate well with human perception.
- Structure similarity index (SSIM) metric is a better alternative.
  - the multi-scale SSIM, addresses scale issue well.
- Proposed loss function:

$$L(\theta) = \delta \cdot L_{\text{MS-SSIM}}(\theta) + (1 - \delta) \cdot L_{l_1}(\theta)$$

where δ is weight parameter and is set to 0.85*.

** Zhao et al., Loss functions for image restoration with neural networks. IEEE Transactions on Computational Imaging (2017).*

Dataset

- The dataset* consists of a pair of degraded and ground-truth fingerprint images generated by using the software: ***Anguli: Synthetic Fingerprint Generator***.

Dataset	Number of images
Training	75,600
Validation	8,400
Test	8,400

** Dataset is provided by the ChaLearn competition, ECCV 2018.*

FPD-M-Net network parameters

- The FPD-M-Net was trained for 75 epochs using SGD optimizer. The network parameter is tabulated below:

Parameter	First 50 epoch	After 50 epoch
Learning Rate	0.1	0.01
Nesterov momentum	0.75	0.95
Decay rate	0.00001	0.00001
Batch size	8	8

- Network was implemented* in Keras using Theano backend and trained for a week using NVIDIA GTX 1080 GPU.

* Code: https://github.com/adigasu/FDPMNet

Results

- Quantitative of performance:

Set	MSE ↓	PSNR ↑	SSIM ↑
validation	0.0270	16.5149	0.8255
test	0.0268	16.5534	0.8261

- Our method achieves the overall *3rd rank* in the Chalearn Inpainting Competition Track 3-Fingerprint Denoising and Inpainting.
- Final results:

Team	MSE ↓	PSNR ↑	SSIM ↑
CVxTz	0.0189 (1)	17.6968 (1)	0.8427 (1)
rgsl888	0.0231 (2)	16.9688 (2)	0.8093 (3)
hcilab	0.0238 (3)	16.6465 (3)	0.8033 (4)
FPD-M-Net	0.0268 (4)	16.5534 (4)	0.8261 (2)

Results

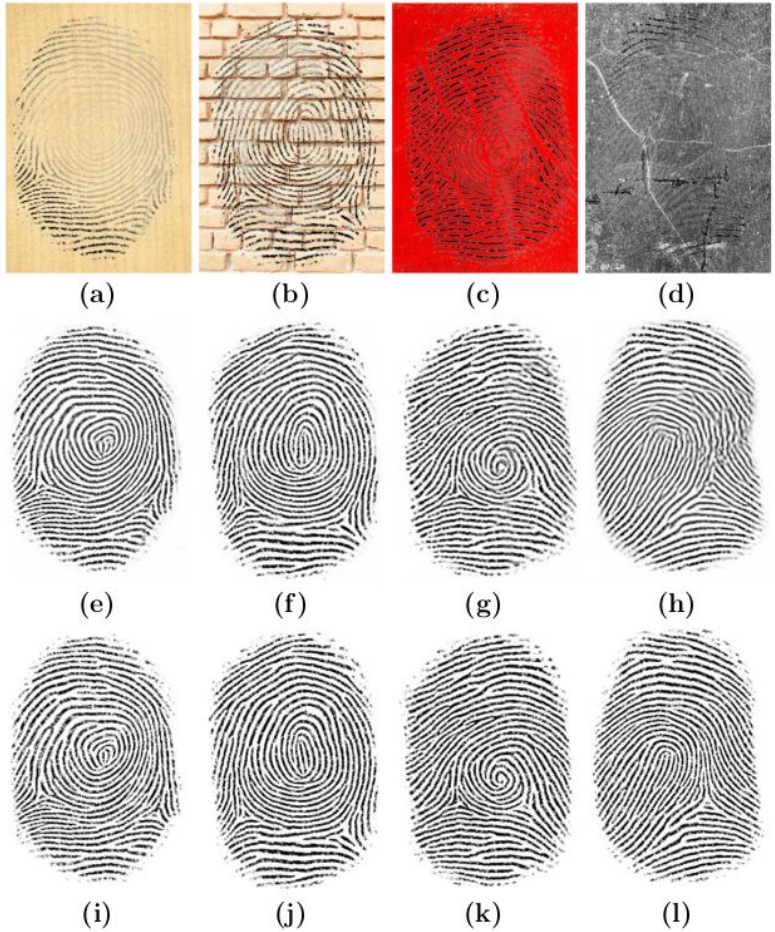
Row 1: Input image of degraded fingerprint

Row 2: Results of segmentation (output of *FPD-M-Net*)

Row 3: Ground-truth

Note:

- Automatic filling is successful
  - (c) and (d) versus (g) and (h)
- Weak prints are also recovered
  - (a) and (e)
- Robust to even strong background clutter
  - (b) and (f)



Summary and Conclusion

- A segmentation formulation was shown to handle both denoising and inpainting of fingerprint images, simultaneously.
- FPD-M-Net is robust to strong background clutter, weak signal and performs automatic filling effectively.
- Good perceptual results for both qualitatively and quantitatively indicate the effectiveness of the MS-SSIM loss function.

Any questions?

E-mail: sukesh.adigav@research.iiit.ac.in

sukesh.adiga@gmail.com

Phone Number: +91 9743493614

THANK YOU