NPTEL ONLINE CERTIFICATION COURSES

Course Name: Deep Learning

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Department : E & ECE, IIT Kharagpur

Topic

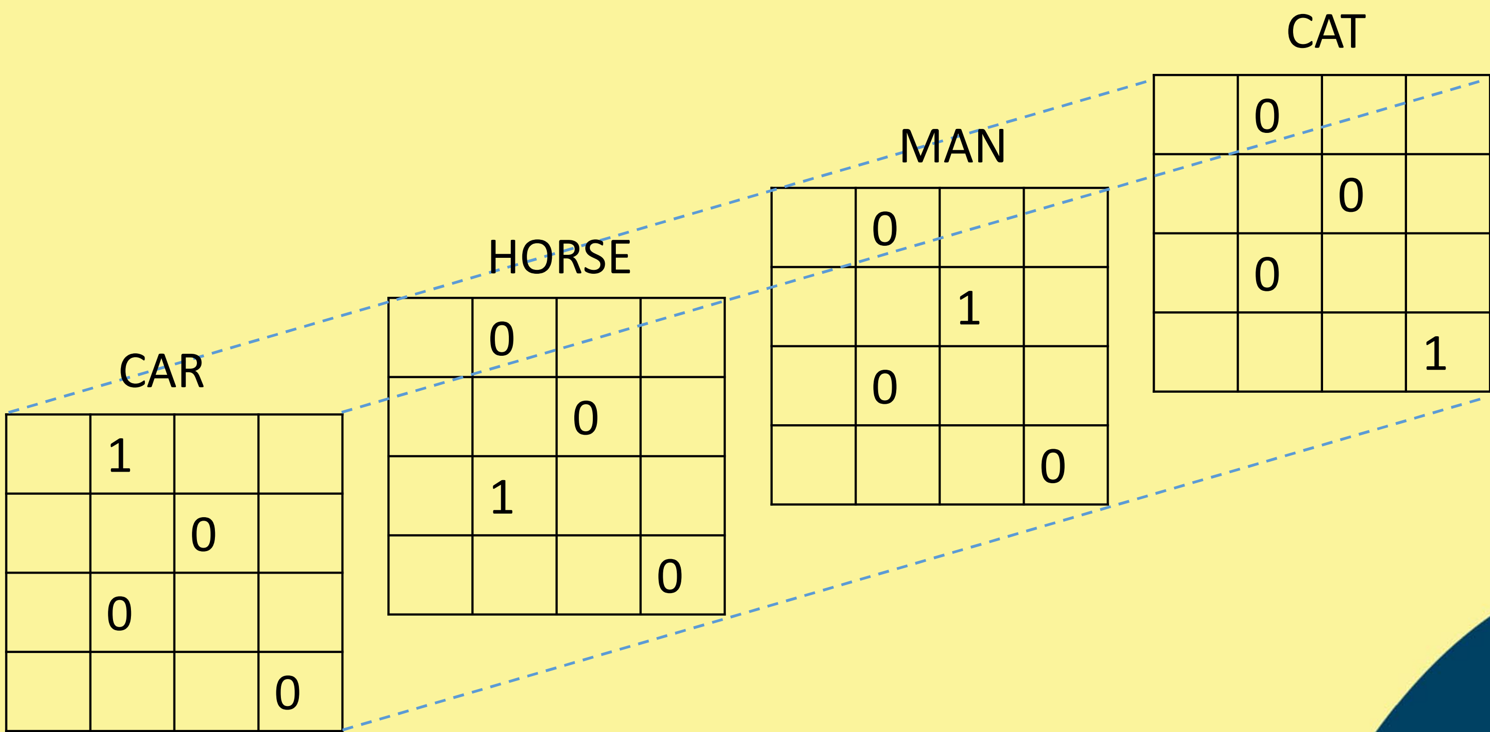
Lecture 56: Image Denoising

CONCEPTS COVERED

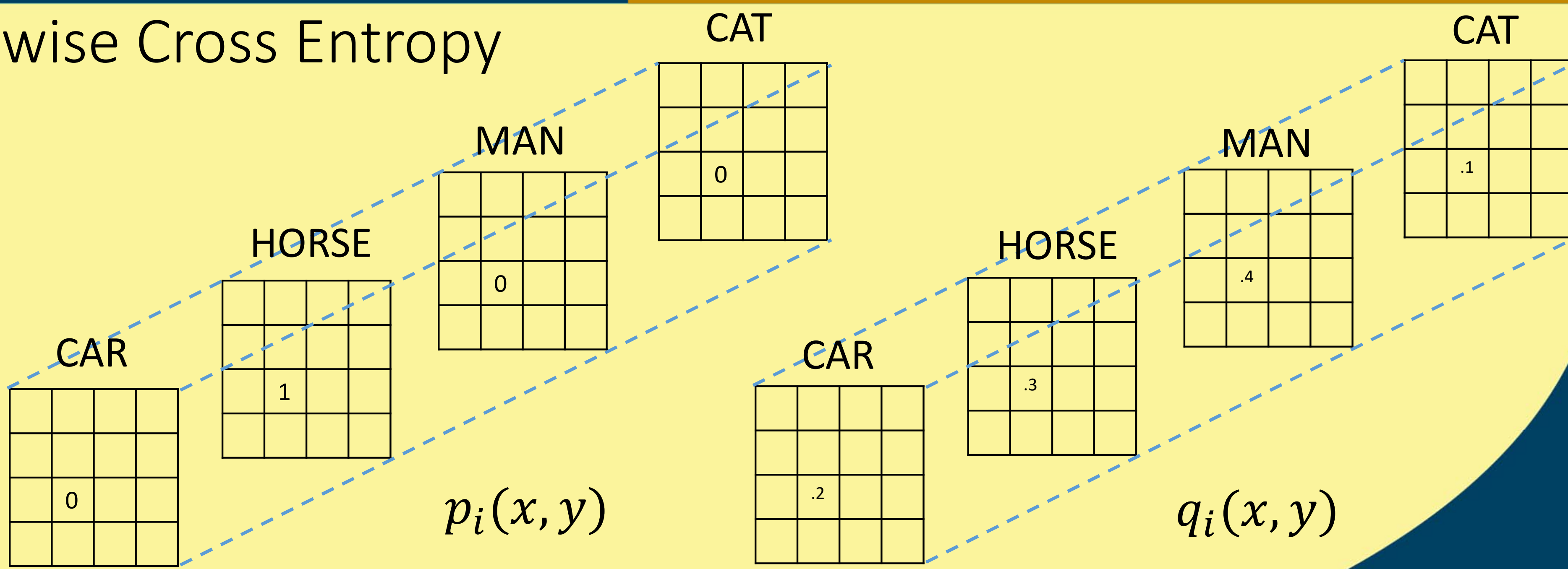
Concepts Covered:

- FCN/Deconv NN Training
- Pixelwise Entropy Loss
- Dice Loss
- Image Restoration
- Image Restoration Network
- Low dose C.T. denoising

Training for Sem Segmentation



Pixel wise Cross Entropy



$$L = -\frac{1}{N}\sum_{N}\sum_{x,y} p_i(x,y).\,log q_i(x,y)$$

Dice Loss

- Another popular loss function for image segmentation tasks is based on the Dice coefficient.
- A measure of overlap between two samples.
- This measure ranges from 0 to 1 where a Dice coefficient of 1 denotes perfect and complete overlap.

$$Dice = \frac{2|A \cap B|}{|A| + |B|}$$

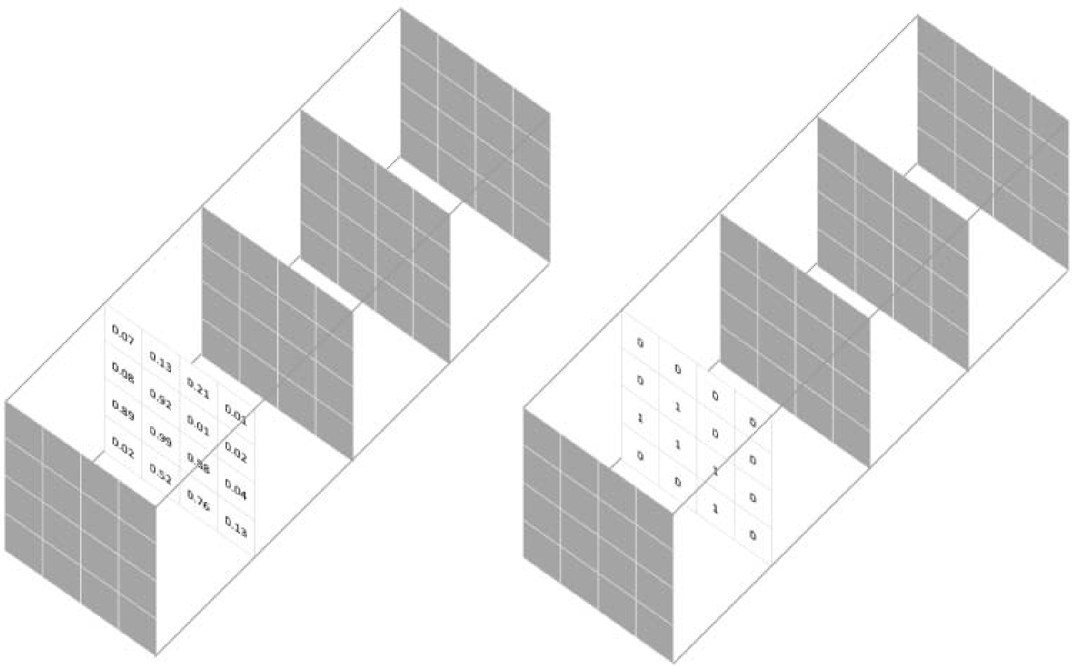
- $|A \cap B|$ represents the common elements between sets A and B
- $|A|$ represents the number of elements in set A (and likewise for set B)
- $|A \cap B|$ is the element-wise multiplication between the prediction and target mask, and then sum the resulting matrix

Dice Loss

$$|A \cap B| = \underset{\text{prediction}}{\begin{bmatrix} 0.01 & 0.03 & 0.02 & 0.02 \\ 0.05 & 0.12 & 0.09 & 0.07 \\ 0.89 & 0.85 & 0.88 & 0.91 \\ 0.99 & 0.97 & 0.95 & 0.97 \end{bmatrix}} * \underset{\text{target}}{\begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 \end{bmatrix}} \xrightarrow{\text{element-wise multiply}} \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0.89 & 0.85 & 0.88 & 0.91 \\ 0.99 & 0.97 & 0.95 & 0.97 \end{bmatrix}$$

Image Source : https://www.jeremyjordan.me/semantic-segmentation/

Dice Loss



Prediction for a selected class

Target for the corresponding class

$$L(class) = 1 - \frac{2\sum_{\forall x,y} t(x,y).\,p(x,y)}{\sum_{\forall x,y} t(x,y)^2 + \sum_{\forall x,y} p(x,y)^2}$$

$$L = \sum_{\forall class} L(class)$$

Image Source : https://www.jeremyjordan.me/semantic-segmentation/

Image Restoration

- A general Image degradation operation consists of a degradation operator followed by additive noise.
- Image restoration is fundamental problem in image processing research.
- There are different type of restoration process like: deblurring, denoising, super resolution, inpainting etc depending on the degradation function H.
- Image restoration becomes a problem of image denoising if degradation operator is an identity matrix.

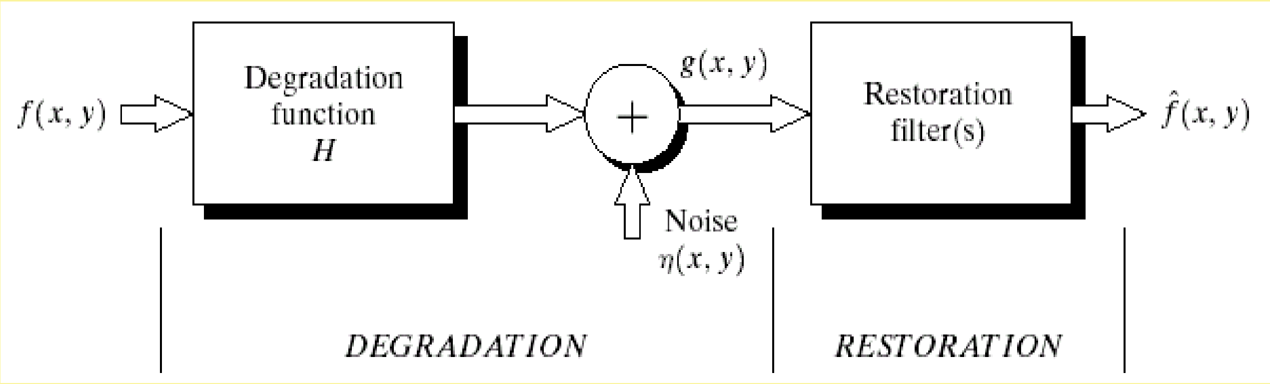
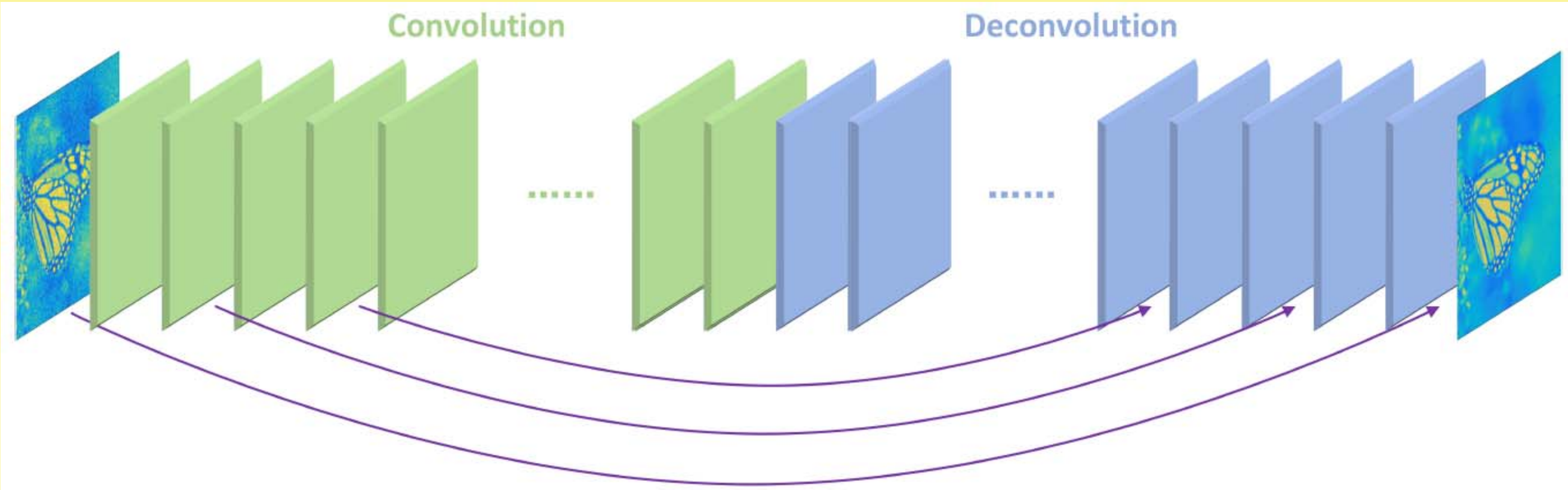


Image Denoising

Image effected with white Gaussian noise

Clean Image

Image Restoration Network



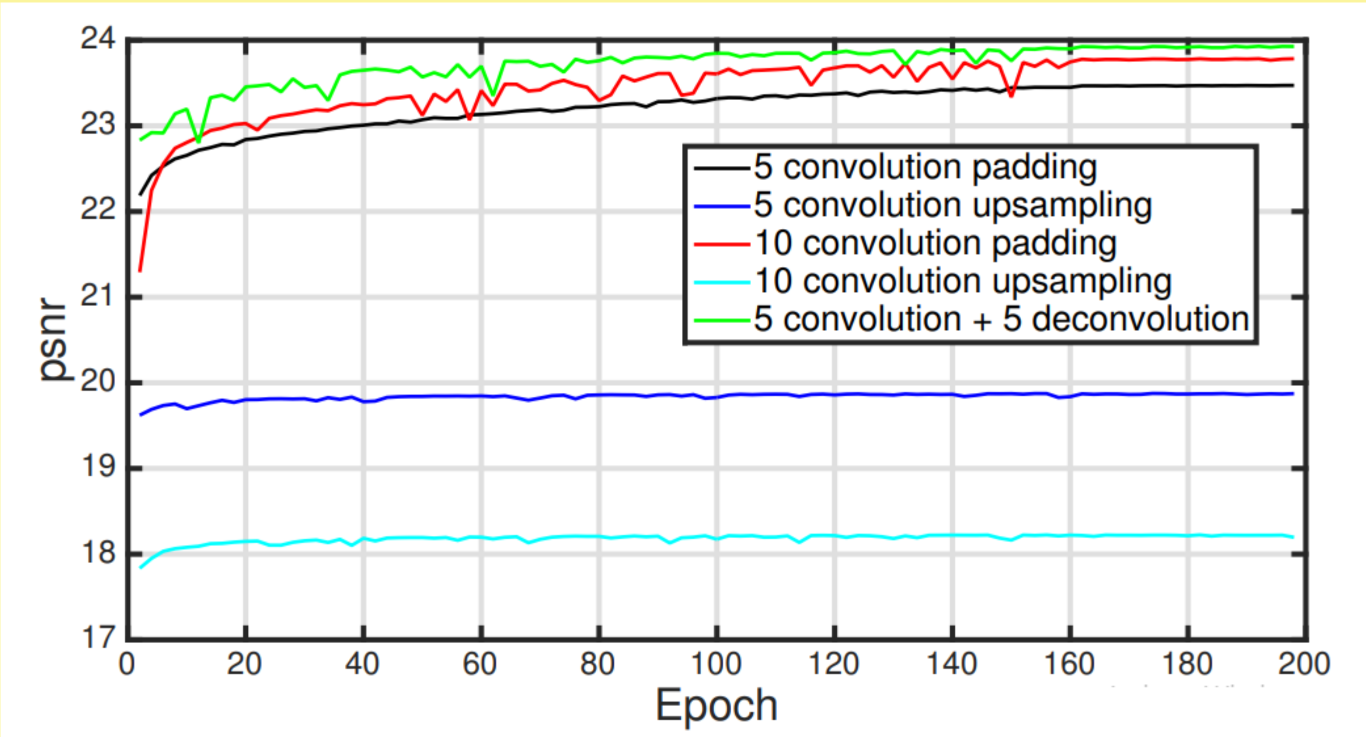
Source : Mao, Xiao-Jiao, Chunhua Shen, and Yu-Bin Yang. "Image restoration using convolutional auto-encoders with symmetric skip connections." *arXiv preprint arXiv:1606.08921* (2016).

Image Restoration Network

- The network contains layers of symmetric convolution (encoder) and deconvolution (decoder).
- Convolutional layers successively down-sample the input image content into a small size abstraction.
- Deconvolutional layers then up-sample the abstraction back into its original resolution.
- The convolutional layers act as the feature extractor, which capture the abstraction of image contents while eliminating noises/corruptions
- The deconvolutional layers are then combined to recover the details of image contents.
- Deconvolutional layers associate a single input activation with multiple outputs.
- Deconvolution is usually used as learnable up-sampling layers.

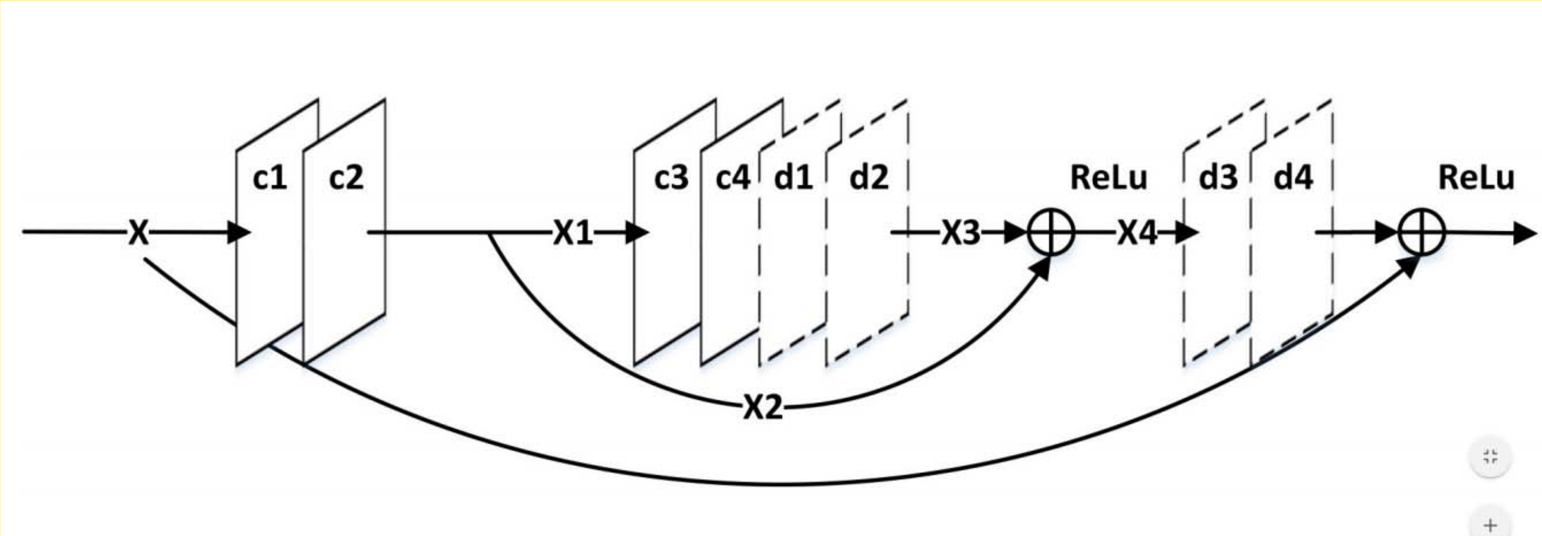
Source : Mao, Xiao-Jiao, Chunhua Shen, and Yu-Bin Yang. "Image restoration using convolutional auto-encoders with symmetric skip connections." *arXiv preprint arXiv:1606.08921* (2016).

Comparison with Fully Convolutional Network



Source : Mao, Xiao-Jiao, Chunhua Shen, and Yu-Bin Yang. "Image restoration using convolutional auto-encoders with symmetric skip connections." *arXiv preprint arXiv:1606.08921* (2016).

Image Restoration Network



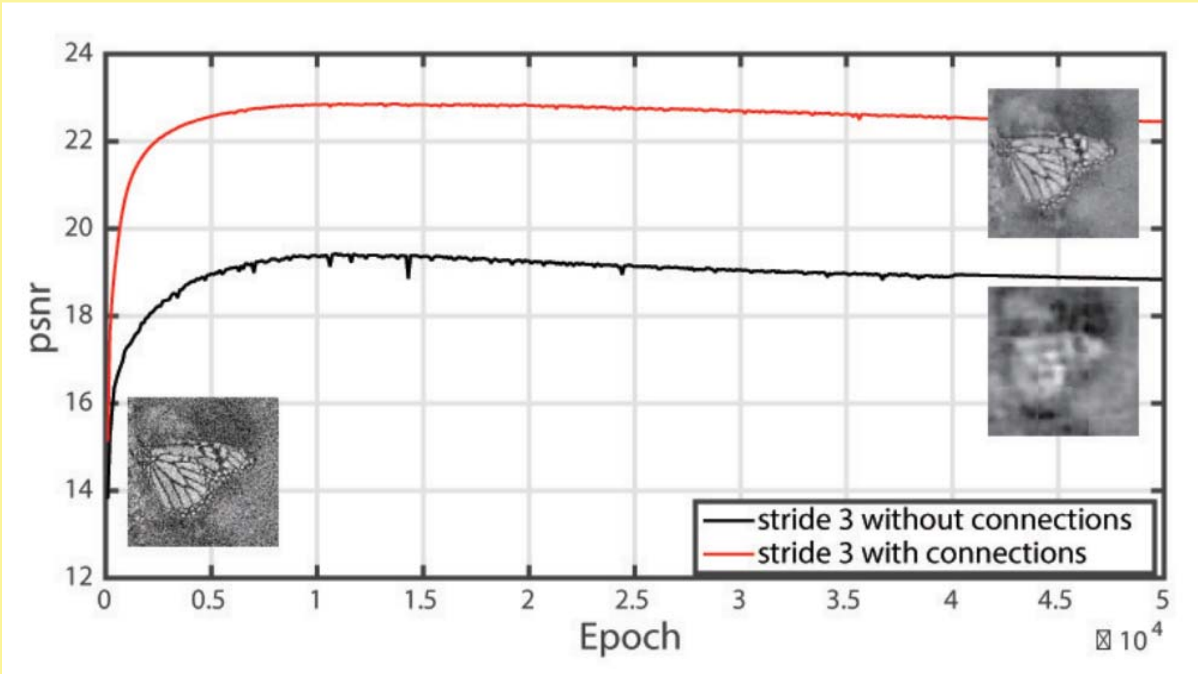
Source : Mao, Xiao-Jiao, Chunhua Shen, and Yu-Bin Yang. "Image restoration using convolutional auto-encoders with symmetric skip connections." *arXiv preprint arXiv:1606.08921* (2016).

Why Skip Connections?

- As the network goes deeper image details are lost, making it difficult for deconvolution recovering them.
- The feature maps passed by skip connections carry much image detail, which helps deconvolution to recover an improved clean version of the image.
- The skip connections also achieve benefits on back-propagating the gradient to bottom layers, which makes training deeper network much easier.

Source : Mao, Xiao-Jiao, Chunhua Shen, and Yu-Bin Yang. "Image restoration using convolutional auto-encoders with symmetric skip connections." *arXiv preprint arXiv:1606.08921* (2016).

Why Skip Connections?



Source : Mao, Xiao-Jiao, Chunhua Shen, and Yu-Bin Yang. "Image restoration using convolutional auto-encoders with symmetric skip connections." *arXiv preprint arXiv:1606.08921* (2016).

Training the Restoration Network

- Learning the end-to-end mapping from corrupted images to clean images needs to estimate the weights Θ represented by the convolutional and deconvolutional kernels.
- Specifically, given a collection of N training sample pairs $\{Xi , Y_i\}$, where X_i is a noisy image and Y_i is the clean version as the ground truth. We can minimize the following Mean Squared Error (MSE):

$$L(\Theta) = \frac{1}{N}\sum_{i=1}^{N} \|F(X_i;\Theta) - Y_i\|_F^2$$

- Traditionally, a network can learn the mapping from the corrupted image to the clean version directly.
- However, it has been reported the if the network learns for the additive corruption from the input image then the network converges fast to a minima.

Low Dose CT denoising

- X-RAY computed tomography (CT) has been widely utilized in clinical, industrial and other applications.
- Due to the increasing use of medical CT, concerns have been expressed on the overall radiation dose to a patient.
- We can lower the radiation dose of a CT image by lowering the operating current, or shortening the exposure time.
- This type of lower dose CT image is known as Low dose CT images.
- However doing so results in distorting the image.
- A example of low dose CT image distorted with photon noise is given.

Image Source:
https://www.aapm.org/GrandChallenge/LowDoseCT/

Low Dose CT Denoising

Low dose CT image

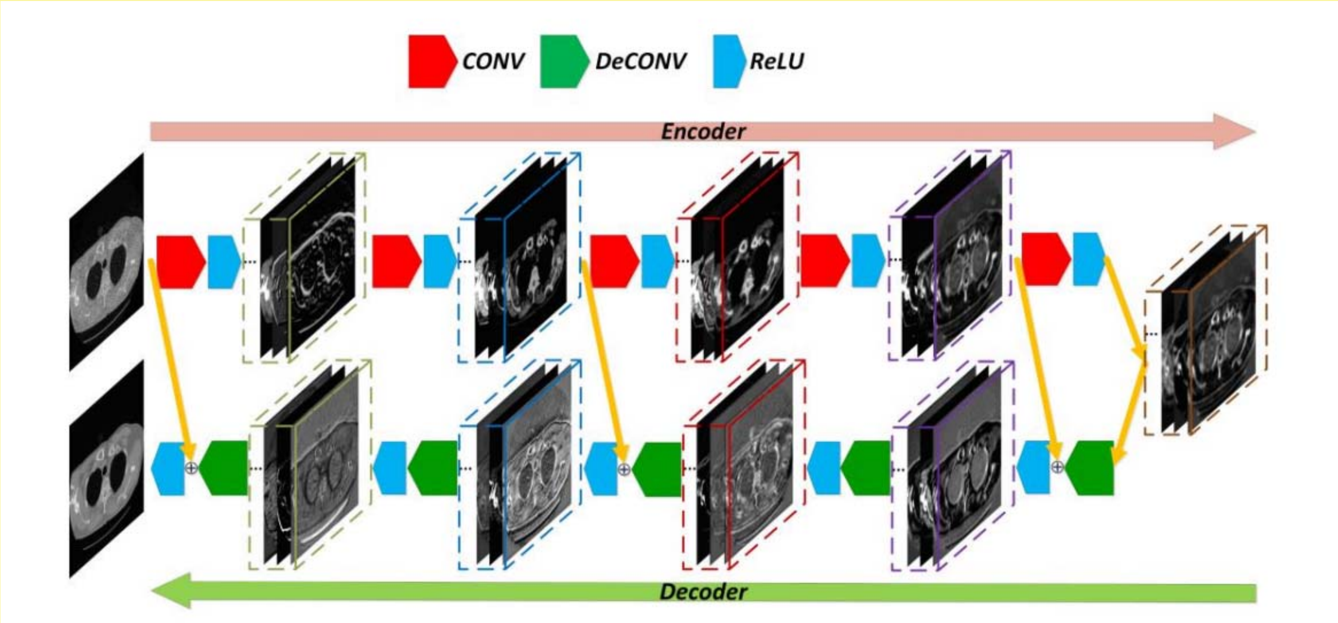
Normal dose CT image

- Due to presence of noise low dose CT images some time loose their diagnosis value
- Many important nodules are no more visible in Low dose CT image.

Image Source:
https://www.aapm.org/GrandChallenge/LowDoseCT/

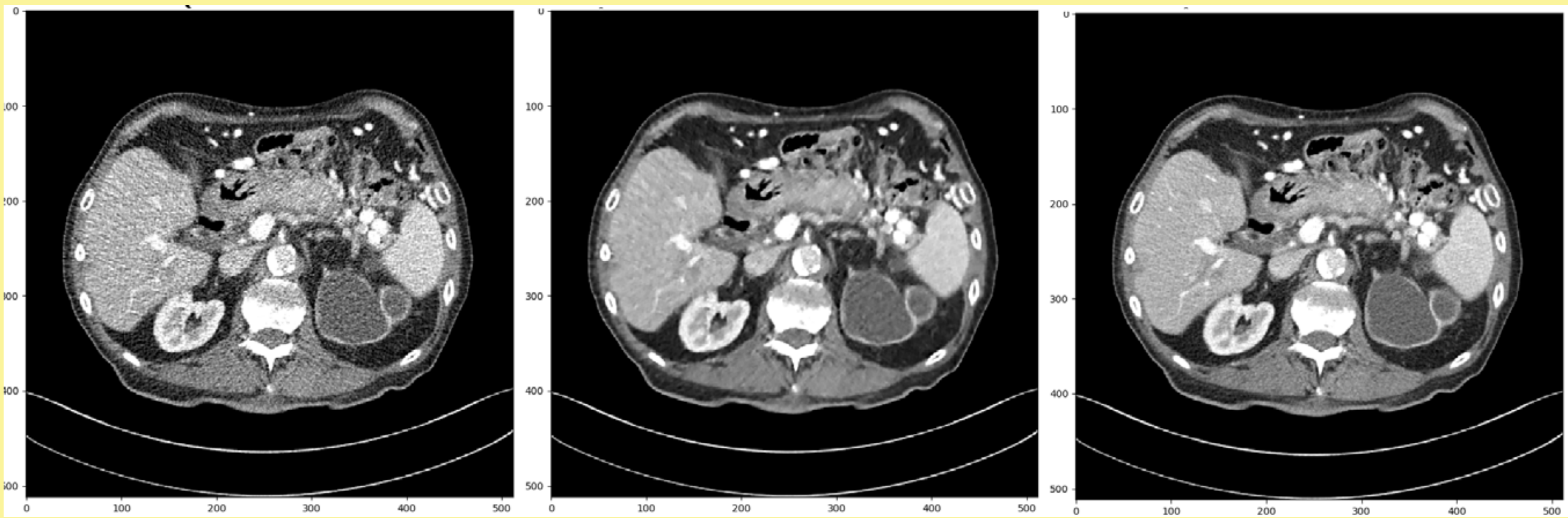
Low Dose CT Denoising

Deep Learning network can be applied to solve this real life crucial problem. A network with architecture of previous network can effectively remove noise from this low dose CT images and can recover the visibility.



Source : Chen, Hu, Yi Zhang, Mannudeep K. Kalra, Feng Lin, Yang Chen, Peixi Liao, Jiliu Zhou, and Ge Wang. "Low-dose CT with a residual encoder-decoder convolutional neural network." *IEEE transactions on medical imaging* 36, no. 12 (2017): 2524-2535.

Low Dose CT Denoising



Low Dose

Restored

Normal Dose

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Thank you