Generative Adversarial Network for Denoising Medical Images

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Outline

- Introduction
- Context
- Methods
- Experiment & Result
- Conclusion

Introduction

- **Name**

  DOAN Tien Tai

- **From**

  Hanoi, Vietnam

- **Education**

  Master student in Information and Communication Technology (ICT)

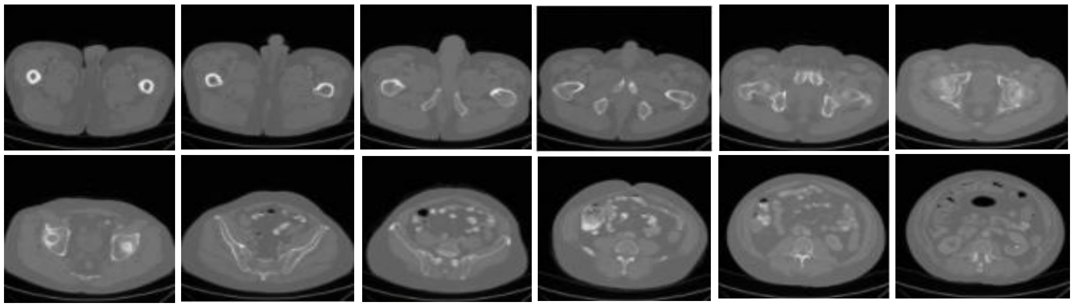
  University of Science and Technology of Hanoi *(USTH, or Vietnam France University)*

- **Currently work at L2TI & LIPN**

  M2 Internship *(5 months)* of *Deep Learning for Image Classification and Restoration*

Why denoising?

- Computed tomography (CT) scan images [*]:
  - Uses low-radiation X-ray to avoid harmful effects
  - Noisy images: difficult for diagnosing diseases
  - Effective denoising methods are needed



Example of abdominal CT scanned images

[*] Provided by Asso. Prof. Marie LUONG at L2TI, Paris 13 University

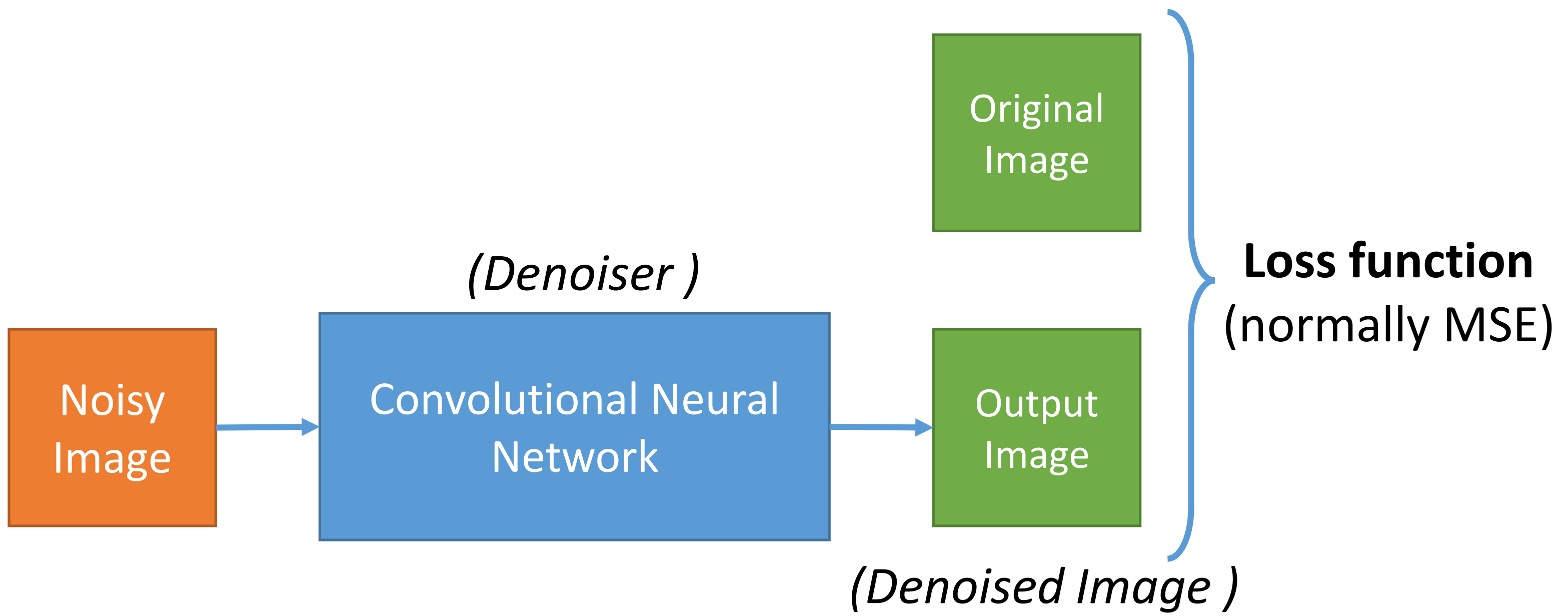
Methods

- A popular approach: Sparse-coding based
  - × Mean Square Error (MSE) based
  - × Slow

- My work
  - Convolutional Neural Networks (Deep Networks)
    - ✓ State-of-the-art results in image denoising
    - × MSE based
  - Generative Adversarial Networks [*]
    - ✓ Loss function is learned

[*] Goodfellow, Ian, et al. "Generative adversarial nets." *Advances in neural information processing systems*. 2014.

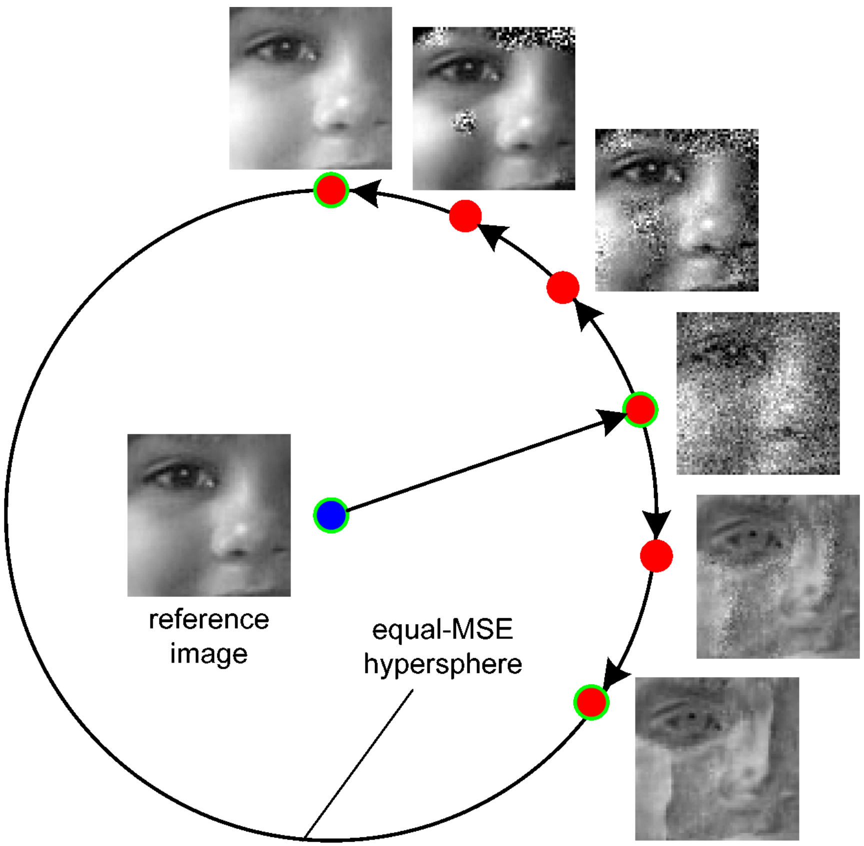
Convolutional Neural Network (CNN)



Loss function: $L = \frac{1}{N}\sum_{i=1}^{N} | Y_i' - Y_i|^2$

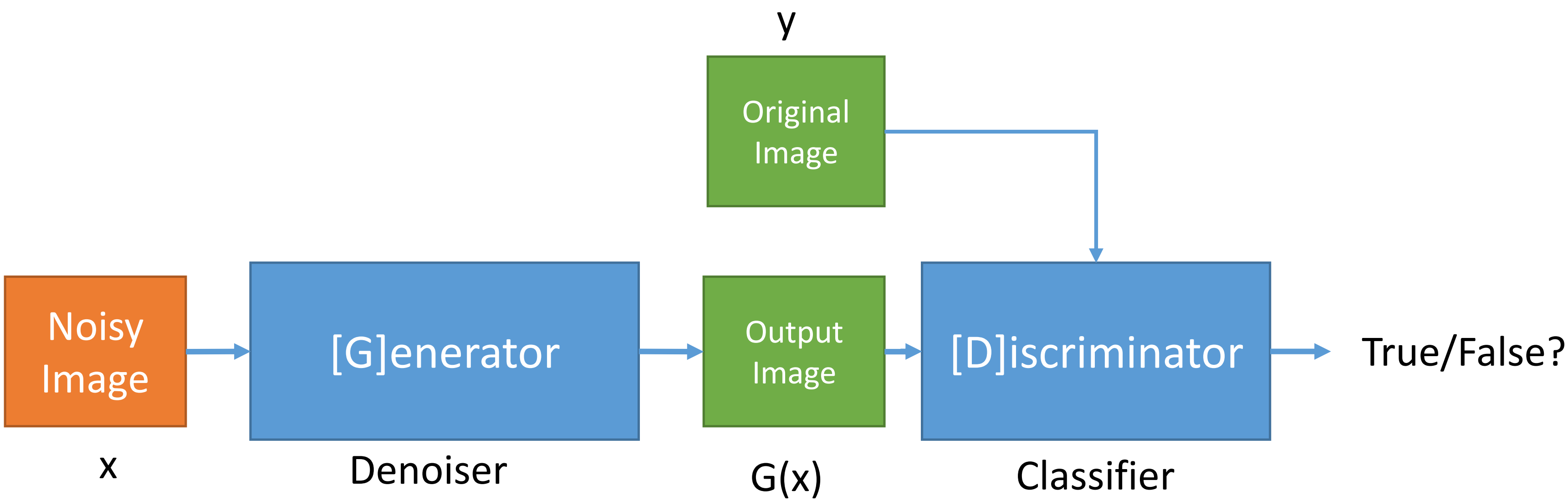
Objective: Minimize the loss function

Low MSE ≠ High Quality



Source: The SSIM Index for Image Quality Assessment
http://www.cns.nyu.edu/~lcv/ssim/

Generative Adversarial Network (GAN)



- New loss function:

$$L_{GAN}(G, D) = E_{x,y \sim p_{data}(x,y)}[logD(G(x), y)] + E_{x,y \sim p_{data}(x,y)}[\log(1 - D(y, G(x)))]$$

- Objective:

$$G^* = \arg\min_G \max_D \mathcal{L}_{cGAN}(G, D).$$

Generative Adversarial Network (GAN)

- MSE Loss

$$L_{MSE}(G) = E_{x,y\sim p_{data}(x,y)}[||y - G(x)||]$$

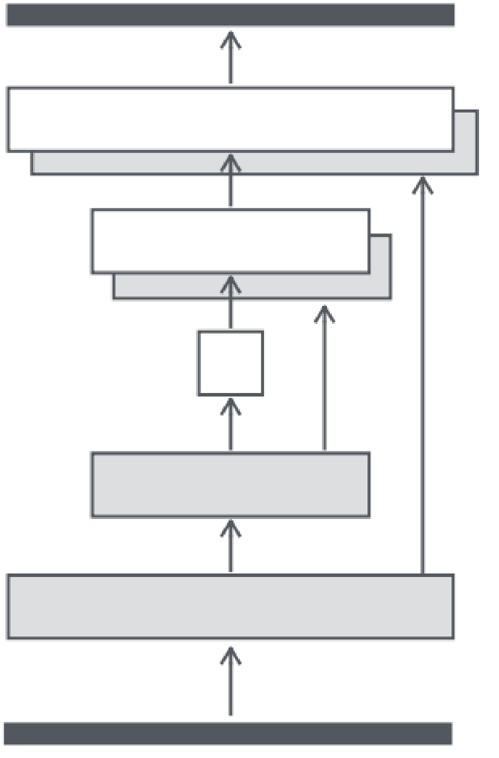
- Final Objective:

$$G^* = \arg\min_G \max_D L_{cGAN}(G,D) + \lambda L_{MSE}(G)$$

This method is developed from: Isola, Phillip, et al. "Image-to-image translation with conditional adversarial networks." *arXiv preprint arXiv:1611.07004* (2016).

Network structure

- Generator:
  - 7 layers encoder & 7 layers decoder
  - Skip connections
  - Total 54 millions of parameters
- Discriminator:
  - A simple 3-layers convolutional neural network
  - Total 2,7 millions of parameters



An example of a simple auto-encoder with skip connections [*]

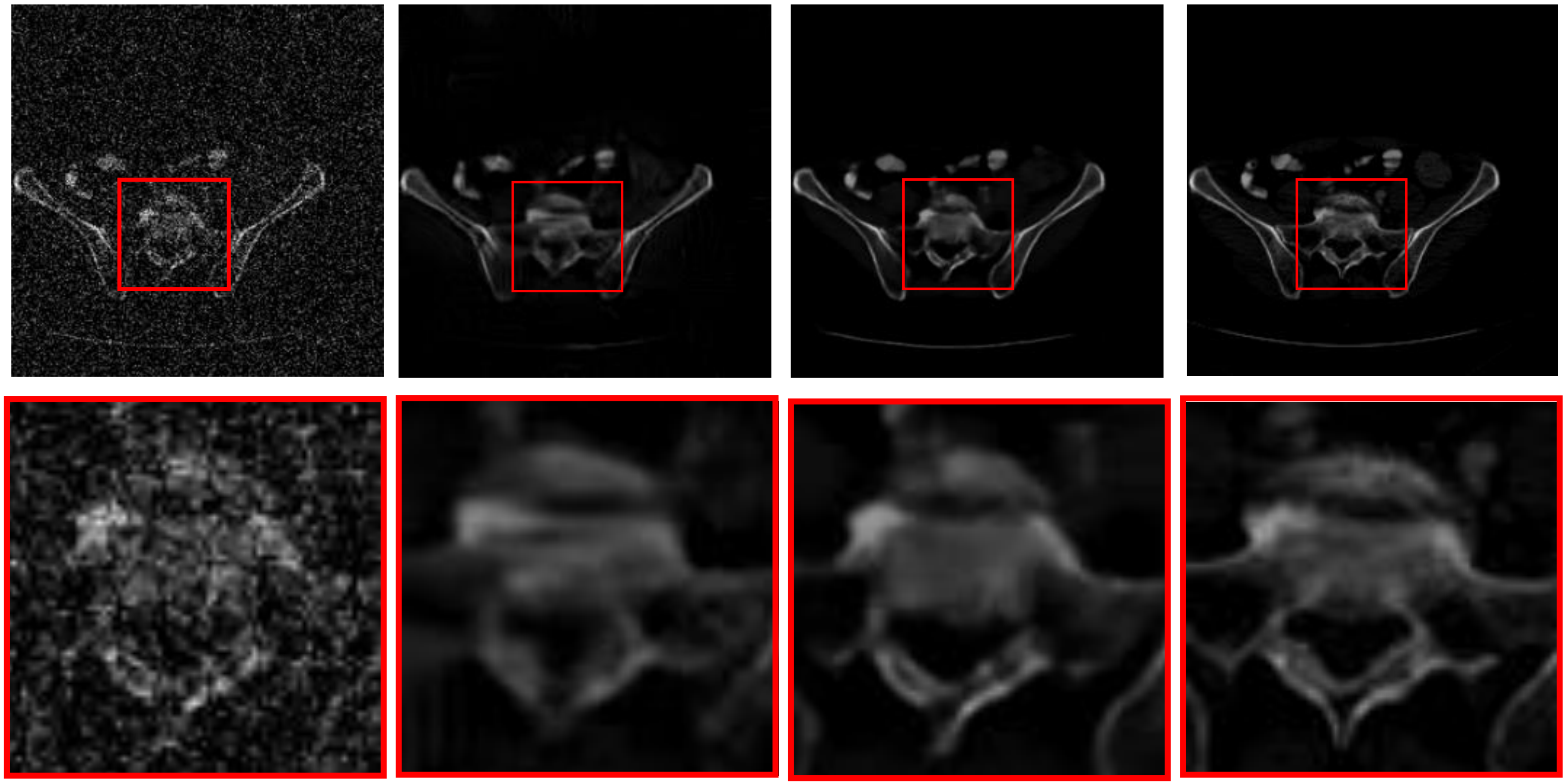
[*] Isola, Phillip, et al. "Image-to-image translation with conditional adversarial networks." *arXiv preprint arXiv:1611.07004* (2016).

Experiment

- Dataset:
  - 100,000 images (50% train, 25% validate and 25% test)
  - Adding Gaussian noise $\sigma = 50$
- Training:
  - 20 epochs (took 2 days)
  - Learning rate 0.0001, batch-size 5
- Machine: cluster GAIA gpucreos1
  - Duo GeForce GTX TITAN Black
- Deep learning framework: PyTorch

Results

Noisy image σ = 50 (PSNR = 19.49 dB) | BM3D [*] (PSNR = 31.93dB) | Proposed GAN (PSNR **33.31**dB) | Original image



Performance evaluation of denoising on an image of pelvis bone

[*] Block-matching and 3D filtering (BM3D) algorithm and its extensions http://www.cs.tut.fi/~foi/GCF-BM3D/

Conclusion and future works

- GAN is a very promising approach in image denoising
- In some situations, GAN may generate little wrong details
- Need more research on image denoising using GAN (Eg. take into account of structure-based metrics in the loss function)

Thank you!

Questions & Discussion