Image denoising with multi-layer perceptrons

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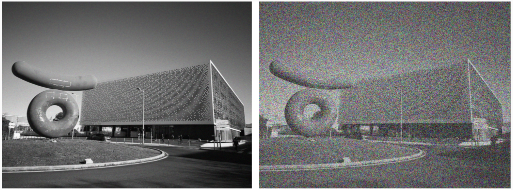


Clean image Noisy image

Sommaire

Context

***Image denoising with multi-layer perceptrons, part 1: comparison with existing algorithms and with bounds*, H. C. Burger, C. J. Schuler, S. Harmeling (2012)**

Image denoising

Image denoising seeks to find a clean image given only its noisy version.

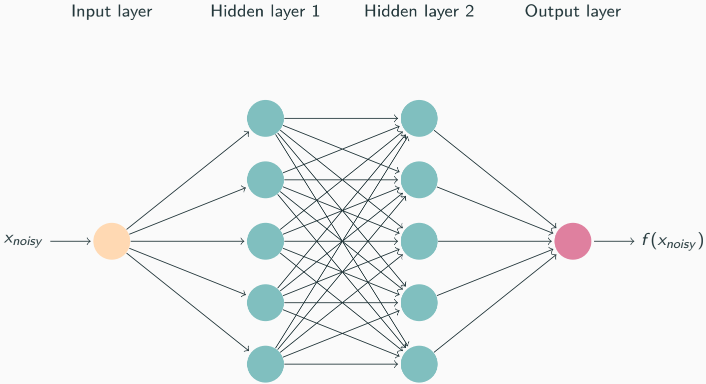
Trade-off

Image denoising requires to denoise patches separately:

- very small patches lead to a function that is easily modeled, but to bad denoising results;
- very large patches potentially lead to better denoising results, but the function might be difficult to model.

MLP-based method

A multi-layer perceptron is a fully connected neural network.



x_{noisy} is a noisy version of a clean patch x; $f(x_{noisy})$ represents an estimate of x.

Weight initialization for MLP-based method

Weights w are sampled from an uniform distribution :

$$w \sim \left[-\frac{\sqrt{6}}{\sqrt{n_j + n_{j+1}}}, \frac{\sqrt{6}}{\sqrt{n_j + n_{j+1}}} \right]$$

n_j and n_{j+1} are the number of neurons in the input and output sides of the layer.

Loss function

The loss function used is the MSE :

$$MSE = \frac{1}{n} \sum_{i=1}^{n} (f(x_i) - x_i)^2,$$

where $f(x)$ the estimation x and x is a clean patch.

Peak Signal-To-Noise Ratio (PSNR)

$\text{PSNR} = 20 \times \log_{10} \left(\frac{m}{\sqrt{\mathrm{MSE}}} \right)$ (dB), where m is the maximum possible pixel value of a given image.

Definition

Additive white Gaussian noise (AWG) : Mimics the effect of many random processes that occur in nature.

Figure 1: Comparaison BM3D and MLP (AWG noise $\sigma = 25$)

We begin by Strip noise, see result of denoising with BM3D and MLP.

Figure 2: MLP and BM3D denoising strip noise

Other type of noise

For Salt and pepper noise, we compare MLP with median filtering methode. This method was the stat-of-the-art for this type of noise.

Figure 3: MLP and median filtering denoising salt and pepper noise

Other type of noise

For JPEG articact, we compare MLP againt the state-of-the-art.

Figure 4: MLP JPEG Artifact

Bounds

Clustering-based bounds

There exist inherent limit on denoising quality for images with rich geometric structure.

Bayesian framework

How well any denoising algorithm can perform, which depends on the patch size.

Block-matching

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Idea: Find the patches most similar to a reference patch.

Combine MLP and block-matching

Train MLPs that take as input a reference patch and its nearest neighbors (similar patches).

Results

Block-matching MLPs provides better results on images with repeating structure than plain MLPs.

However, BM3D and NLSC still provide better results on this kind of images.

Conclusion