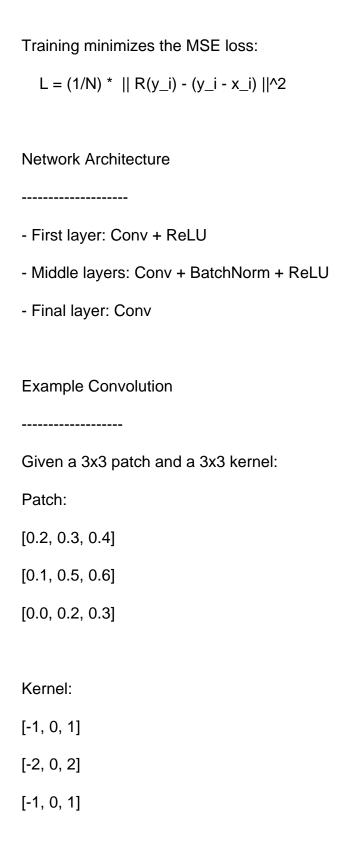# Understanding and Implementing Image Denoising with DnCNN

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Introduction

Image denoising is the process of removing noise from images while preserving important structures like edges and textures. The Deep CNN-based Denoising (DnCNN) model has shown excellent performance for this task.

Mathematical Formulation

Let:

- x be the clean image

- n be the noise

- y be the noisy image

Then, $y = x + n$

The goal is to recover x given y.

DnCNN Model

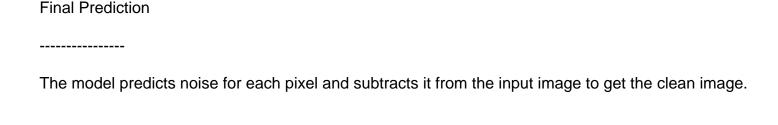DnCNN learns the residual noise $R(y)$, and recovers the image as:

$x = y - R(y)$

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Training minimizes the MSE loss:

$$L = (1/N) * \| R(y\_i) - (y\_i - x\_i) \|^2$$

Network Architecture

- First layer: Conv + ReLU

- Middle layers: Conv + BatchNorm + ReLU

- Final layer: Conv

Example Convolution

Given a 3x3 patch and a 3x3 kernel:

Patch:

[0.2, 0.3, 0.4]

[0.1, 0.5, 0.6]

[0.0, 0.2, 0.3]

Kernel:

[-1, 0, 1]

[-2, 0, 2]

[-1, 0, 1]

Output = Sum(Patch * Kernel) = 1.5

After ReLU: max(0, 1.5) = 1.5

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Final Prediction

The model predicts noise for each pixel and subtracts it from the input image to get the clean image.

Citations

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[2] Vincent, P., Larochelle, H., Lajoie, I., Bengio, Y., & Manzagol, P. A. (2010). Stacked Denoising Autoencoders: Learning Useful Representations in a Deep Network with a Local Denoising Criterion. Journal of Machine Learning Research, 11, 3371-3408.

[3] Buades, A., Coll, B., & Morel, J. M. (2005). A Non-Local Algorithm for Image Denoising. In 2005 IEEE Computer Society Conference on Computer Vision and Pattern Recognition (CVPR'05), Vol. 2, pp. 6065.

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