Lecture 1-2 Image Denoising

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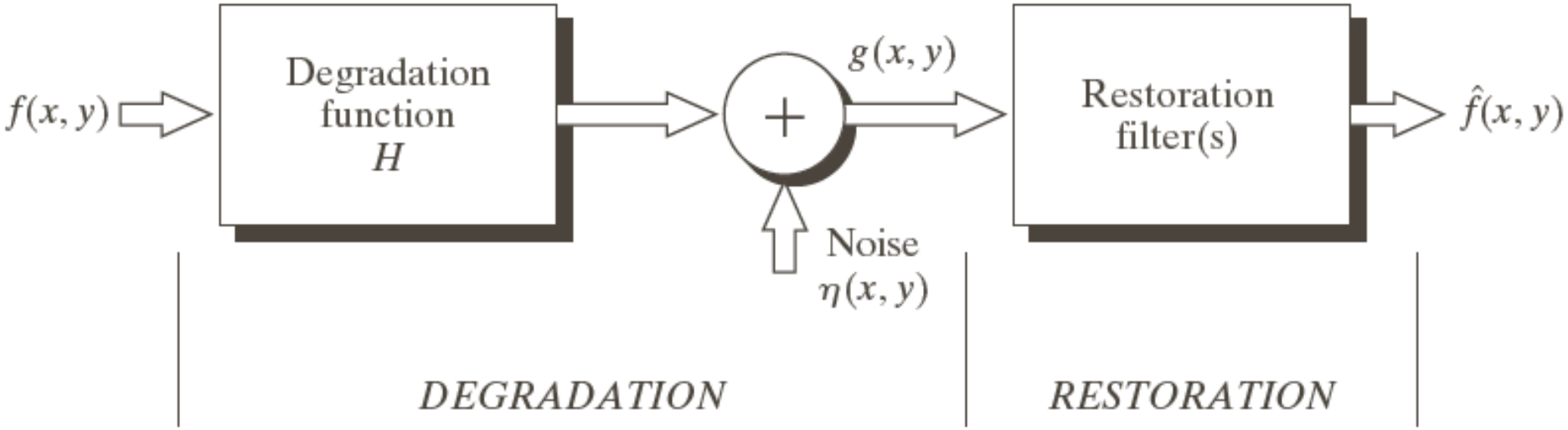
Model of Image Degradation



In Spatial domain: $g(x, y) = h\,(x, y) \star f(x, y) + \eta(x, y)$

In Frequency domain: $G(u, v) = H\,(u, v)F(u, v) + N(u, v)$

H is a linear, position-invariant process

$g(x, y)$: a degraded image $f(x, y)$: input image

$h(x, y)$: degradation function $\eta(x, y)$: additive noise term

Task for restoration: objective methods for undoing corruption.

When only noise

- For easier case: when H is identity (no blur). Degraded image contain only additive noise.

$$g(x,y) = f(x,y) + \eta(x,y) \text{ or } \mathbf{G}(x,y) = F(x,y) + N(x,y)$$

- Noise is often described by Probability Density Function (PDF).
- Noise may be due to：
  - Non-ideal sensor elements.
  - Environmental conditions (light level, temperature…).
  - Corruption during transmission/ compression.

Denoising Outline

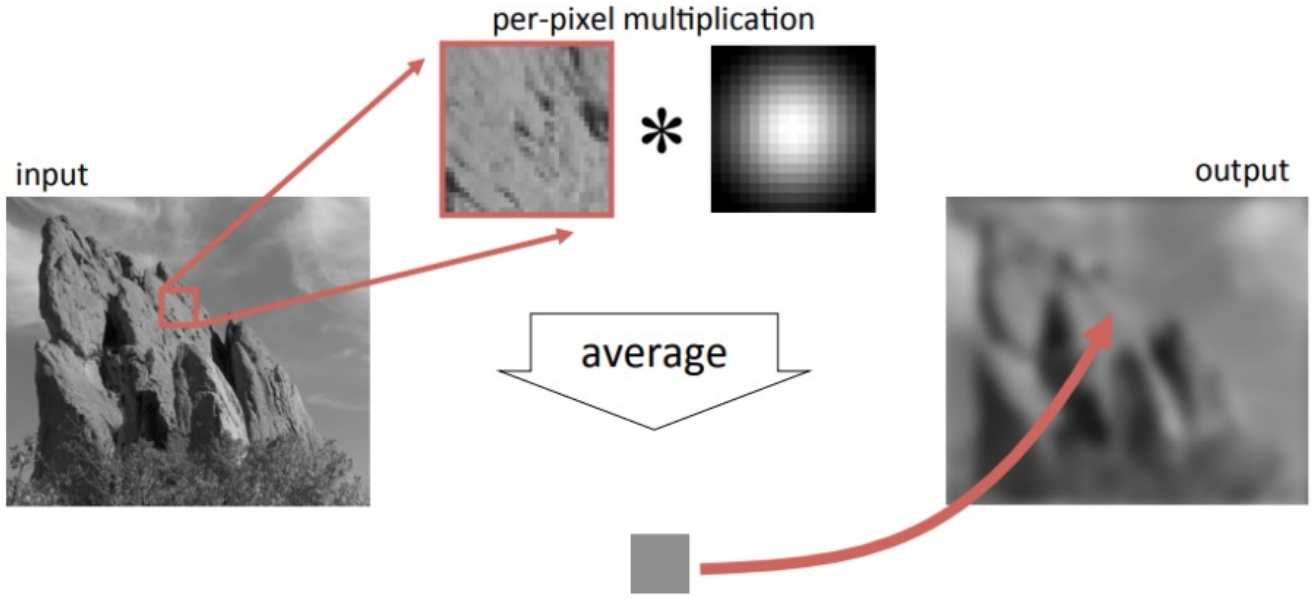
- Gaussian Filter
- Bilateral Filter
- Guided Filter
- Non Local Means
- Wavelet Denoising
- Block Matching and 3D Filtering （BM3D）
- Anisotropic diffusion
- Markov Random Field
- New Deep Learning Approaches, still emerging

Lecture 1 Outline

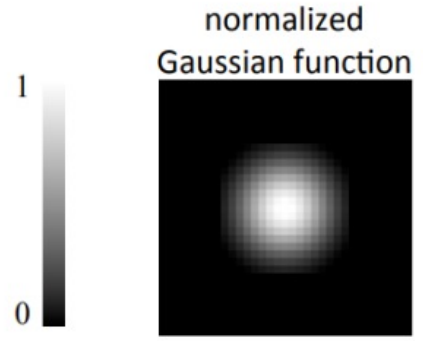
- Gaussian Filter
- Bilateral Filter
- Guided Filter

Gausssian Filter

Gaussian Filter



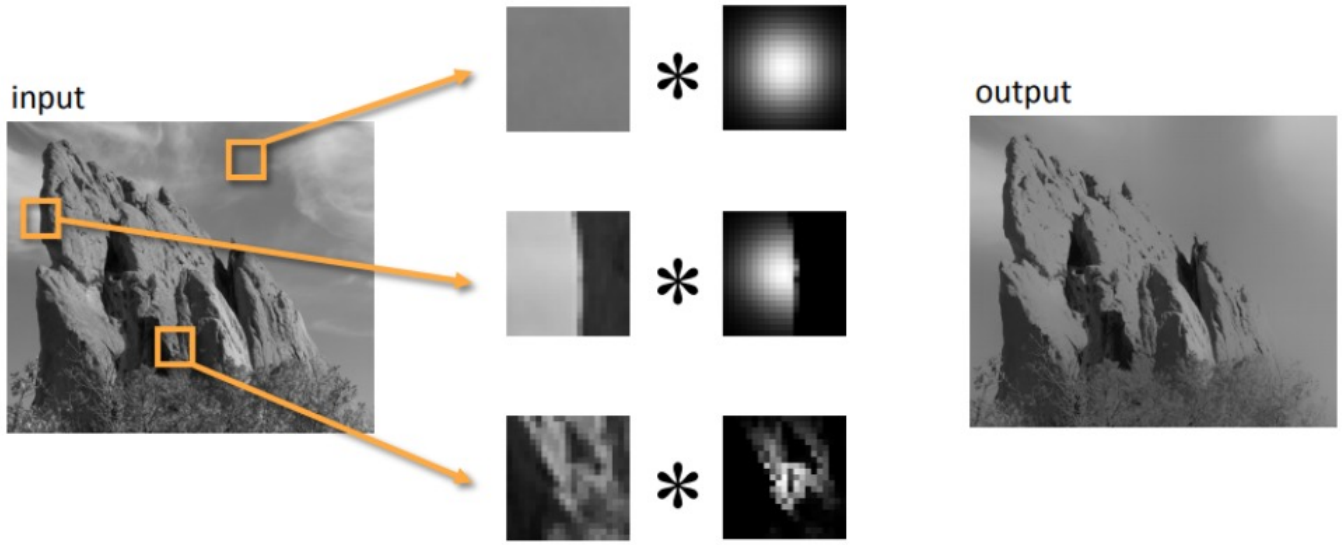
$$GB[I]_{\mathbf{p}} = \sum_{\mathbf{q} \in S} G_{\sigma}(\|\mathbf{p}-\mathbf{q}\|) I_{\mathbf{q}}$$



Bilateral Filter

Reference :
[1] Tomasi, C; Manduchi, R (1998). Bilateral filtering for gray and color images. Sixth International Conference on Computer Vision. Bombay. pp. 839–846. doi:10.1109/ICCV.1998.710815.
[2] Kornprobst, Pierre (2007). "Limitations? - A Gentle Introductionto Bilateral Filteringand its Applications".

Bilateral Filter



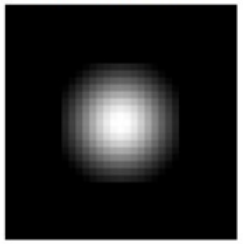
The kernel shape depends on the image content.

$$BF[I]_{\mathbf{p}} = \frac{1}{W_{\mathbf{p}}} \sum_{\mathbf{q} \in S} G_{\sigma_s}(\|\mathbf{p}-\mathbf{q}\|)\, G_{\sigma_r}(|I_{\mathbf{p}}-I_{\mathbf{q}}|)\, I_{\mathbf{q}}$$

not new — new

normalization factor

space weight



range weight

Bilateral Filter: Result

Bilateral Filter: Advantage

- Obtain cartoon-like pictures

Guided Filter

reference :
[1] K. He, J. Sun, and X. Tang. Guided image filtering. In ECCV, pages 1–14. 2010.
[2] K. He, J. Sun, and X. Tang. Guided image filtering. TPAMI, 35(6):1397–1409, 2013
[3] He K, Sun J. Fast Guided Filter[J]. Computer Science, 2015.

Take home massage

- Image denoising is to recover signals hidden in a noisy background. Since noise is a statistical fluctuation governed by quantum mechanics, denoising is generally achieved by an mean/averaging operation.
- The key idea behind early denoising methods is to avoid smoothing on image edges.