

Image Noise and Filtering (II)

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Bilateral Filter [2]

- Bilateral filtering smoothes images while preserving edges, by means of a **nonlinear combination** of nearby image values.

$$BF[I]_p = \frac{1}{W_p} \sum_{q \in S} G_{\sigma_s}(\|\mathbf{p} - \mathbf{q}\|) G_{\sigma_r}(|I_p - I_q|) I_q$$

Diagram illustrating the components of the Bilateral Filter equation:

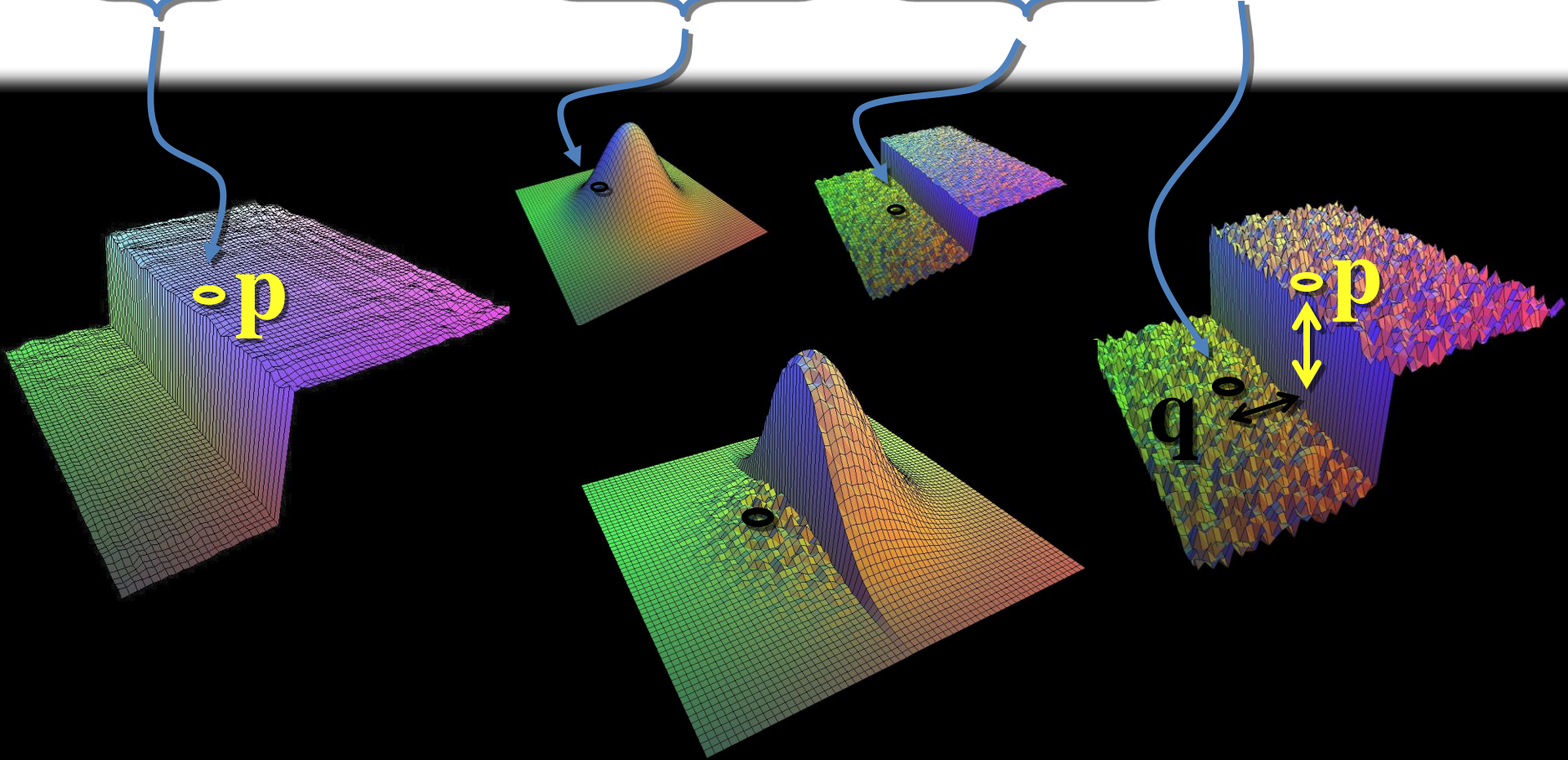
- new** (pink box): $\frac{1}{W_p}$ (normalization factor)
- not new** (orange box): $G_{\sigma_s}(\|\mathbf{p} - \mathbf{q}\|)$ (*space* weight)
- new** (blue box): $G_{\sigma_r}(|I_p - I_q|)$ (*range* weight)

Visualizations of the weight functions:

- space weight**: A 2D Gaussian-like heatmap showing a bright center fading to black.
- range weight**: A 1D plot showing a bell-shaped curve (Gaussian) centered at zero, with the vertical axis labeled I .

Bilateral Filter on a Height Field

$$\underbrace{BF[I]_p}_{\text{Output}} = \frac{1}{W_p} \sum_{\mathbf{q} \in S} \underbrace{G_{\sigma_s}(\|\mathbf{p} - \mathbf{q}\|)}_{\text{Spatial Weight}} \underbrace{G_{\sigma_r}(\|I_p - I_q\|)}_{\text{Range Weight}} \underbrace{I_q}_{\text{Input}}$$



Bilateral Filter for Gray Image



Noise image (Gaussian Noise, mean =0, std = 5)



Bilateral Filtering (ISNR= 1.4211 dB, 9×9 , $\sigma_s = 5$, $\sigma_r = 10$, Time = 1.1909s)

Failed Example



Noise image (Gaussian Noise, mean = 0, std = 20)



Bilateral Filtering (ISNR= 1.0637 dB, 9×9, $\sigma_s = 5$, $\sigma_r = 10$, Time = 1.2673s)

Failed Example



Noise image (Gaussian Noise, mean = 0, std = 20)



Bilateral Filtering (ISNR= 4.0883 dB, 9×9, $\sigma_s = 5$, $\sigma_r = 50$, Time = 1.0722s)

Bilateral Filter for Color Image



Noise image (Gaussian Noise, mean =0, std = 10)



Bilateral Filtering (ISNR= 3.8447 dB, 9×9 , $\sigma_s = 5$, $\sigma_r = 10$, Time = 3.2966s)

More Examples for Color Images



(a) Input Image



(b) Bilateral Filtered Image (iter = 5, $w = 5$, $\sigma_s = 5$, $\sigma_r = 3$)

More Examples for Color Images



(b) Bilateral Filtered Image (iter = 5, w = 5, $\sigma_s = 5$, $\sigma_r = 3$)



(c) Bilateral Filtered Image (iter = 5, w = 5, $\sigma_s = 5$, $\sigma_r = 10$)

More Examples for Color Images



(c) Bilateral Filtered Image (iter = 5, $w = 5$, $\sigma_s = 5$, $\sigma_r = 10$)



(d) Bilateral Filtered Image (iter = 10, $w = 5$, $\sigma_s = 5$, $\sigma_r = 3$)

Failed Example for Texture Noise



(a) Input Image



(b) Bilateral Filtered Image (iter = 5, $w = 5$, $\sigma_s = 5$, $\sigma_r = 3$)

References

- [1] X.-Q. Lu and H. Sakaino, “A spatial adaptive filter for smoothing of non-Gaussian texture noise” in Proc. of ICASSP, 2009.
- [2] C. Tomasi and R. Manduchi, “Bilateral filtering for gray and color images,” in Proc. Of the IEEE International Conference on Computer Vision, pp.839-846, 1998.

Thank You!

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