UNIVERSITÀ DEGLI STUDI DI PADOVA

The bilateral filter

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Bilateral filter

- Very commonly used
- A spatial filtering!
- Recent method
  - Carlo Tomasi, Roberto Manduchi, “Bilateral Filtering for Gray and Color Images”, Proceedings of the ICCV 1998
- Many applications with high quality results
- Based on the gaussian filter
  - But: edge-preserving filter

Gaussian filter example

- What is left behind when we use a gaussian filter?

input

smoothed

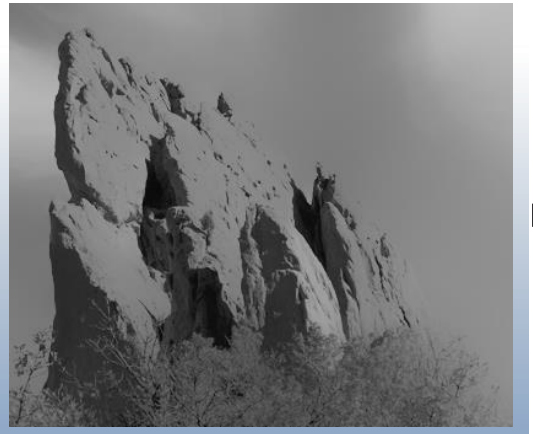
residual

Gaussian Convolution

Bilateral filter example

- What is left behind when we use a bilateral filter?

input



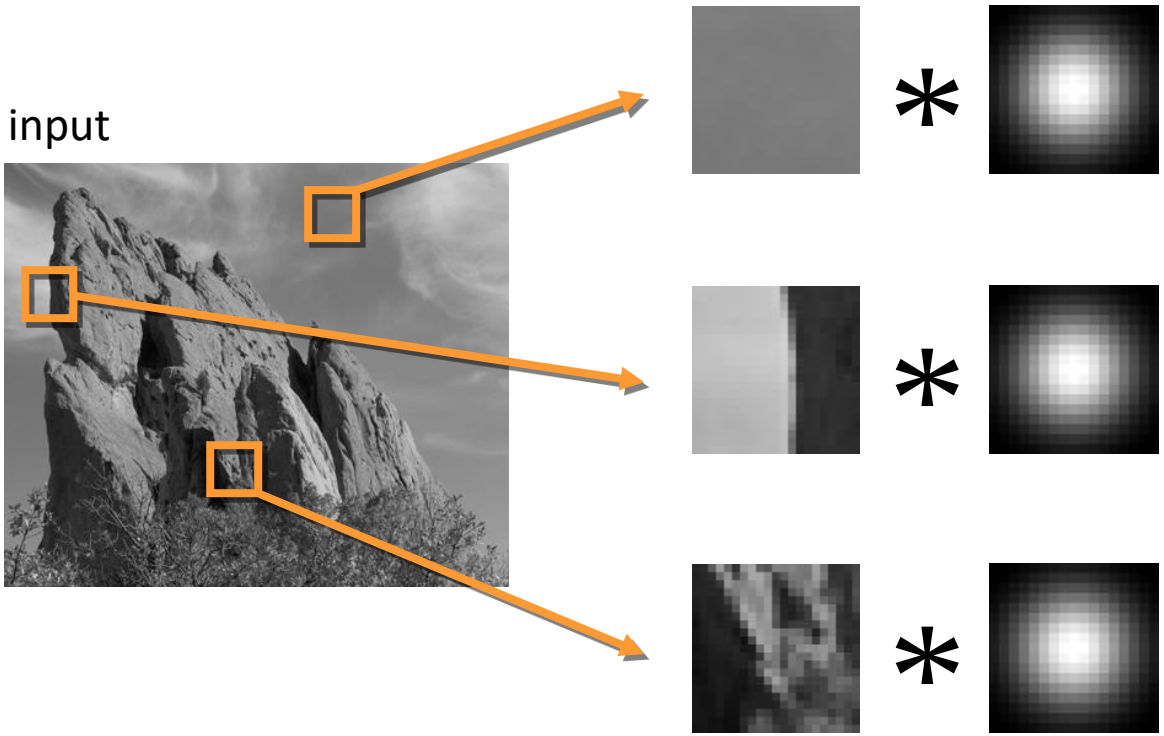
smoothed

residual

Edge-preserving: Bilateral Filter

Gaussian filter action

- Kernel with the gaussian filter

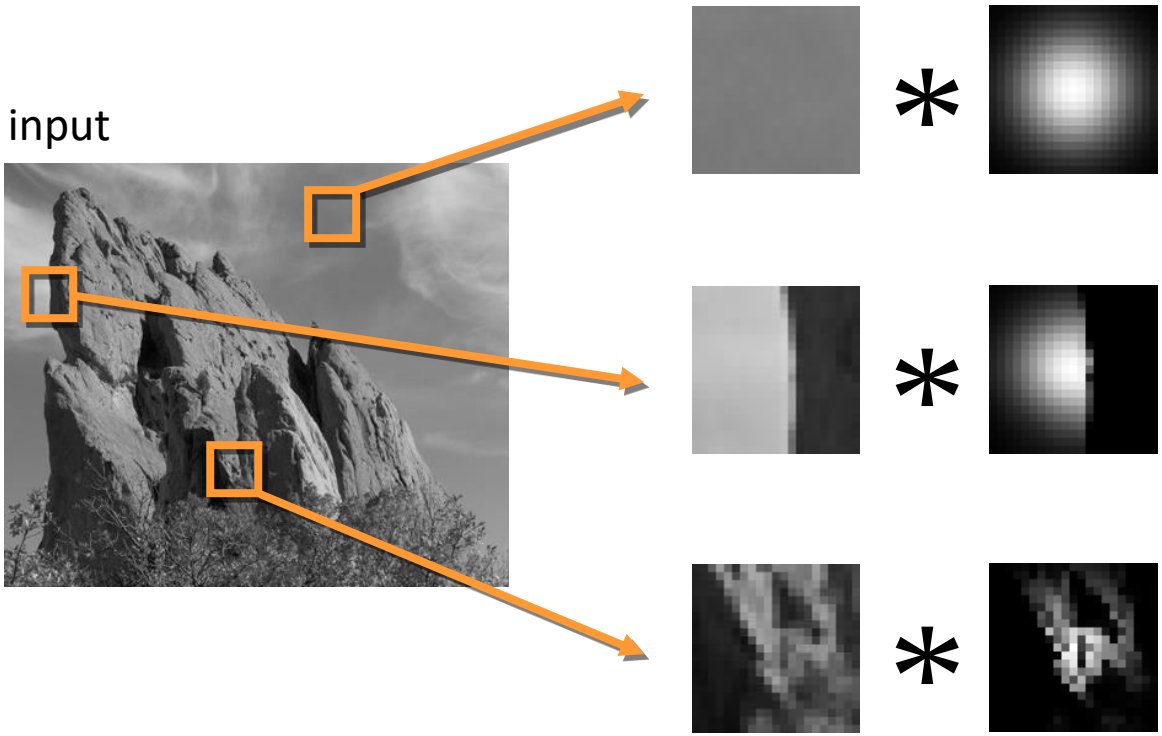


output

Same Gaussian kernel everywhere

Bilateral filter action

- Kernel with the bilateral filter



The kernel shape depends on the image content

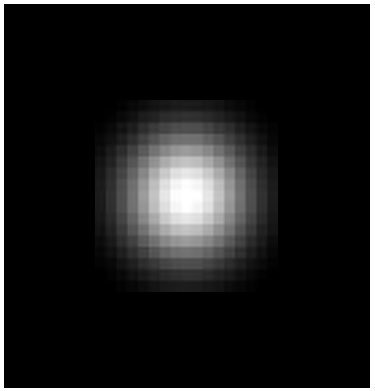
Bilateral filter function

Bilateral filter: **weighted average of pixels with a new weight**

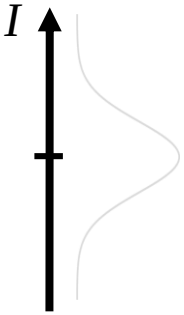
$$BF[I]_p = \frac{1}{W_p} \sum_{q \in S} G_{\sigma_s}(||p-q||) G_{\sigma_r}(|I_p - I_q|) I_q$$

normalization factor

space gaussian



range gaussian

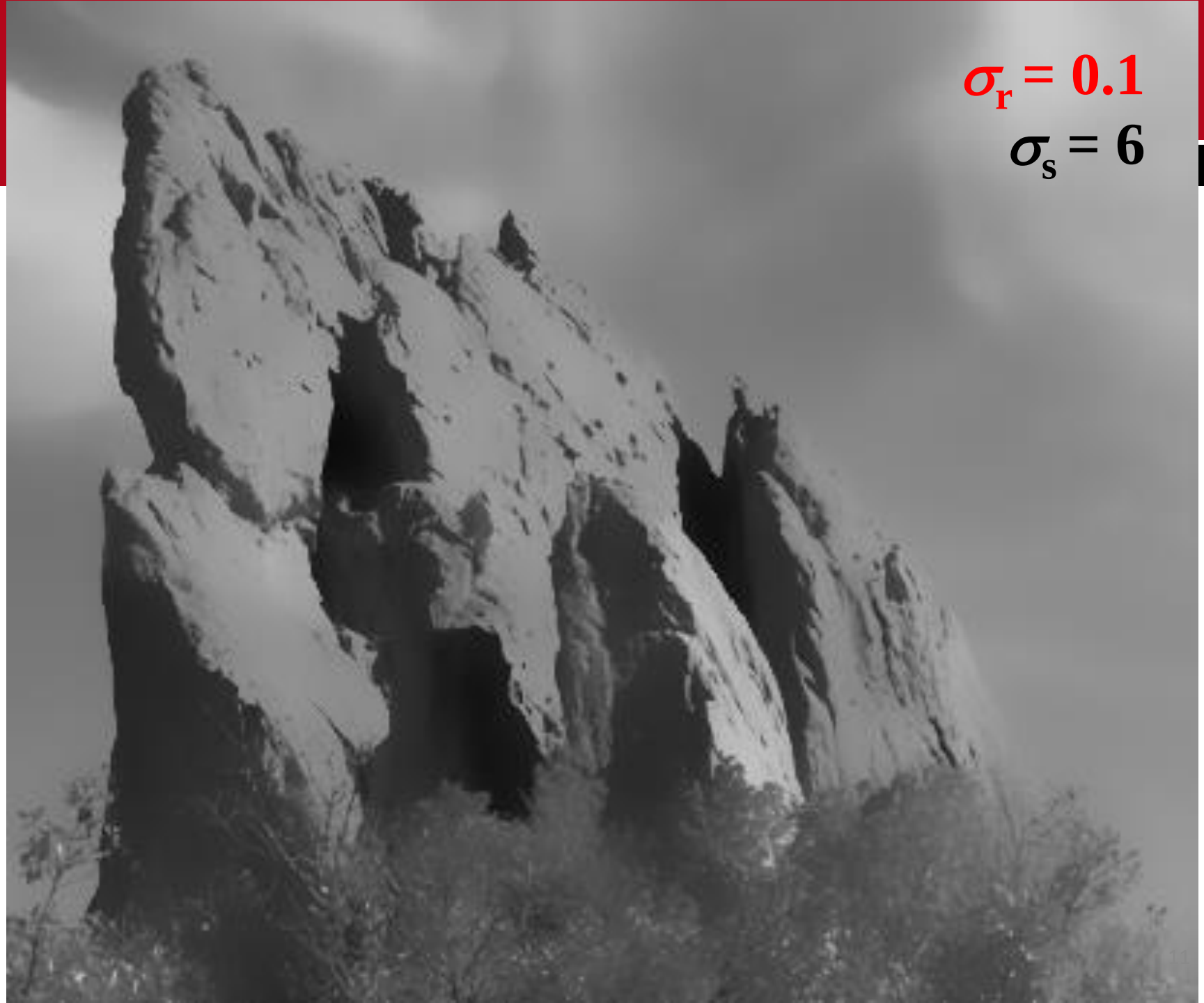


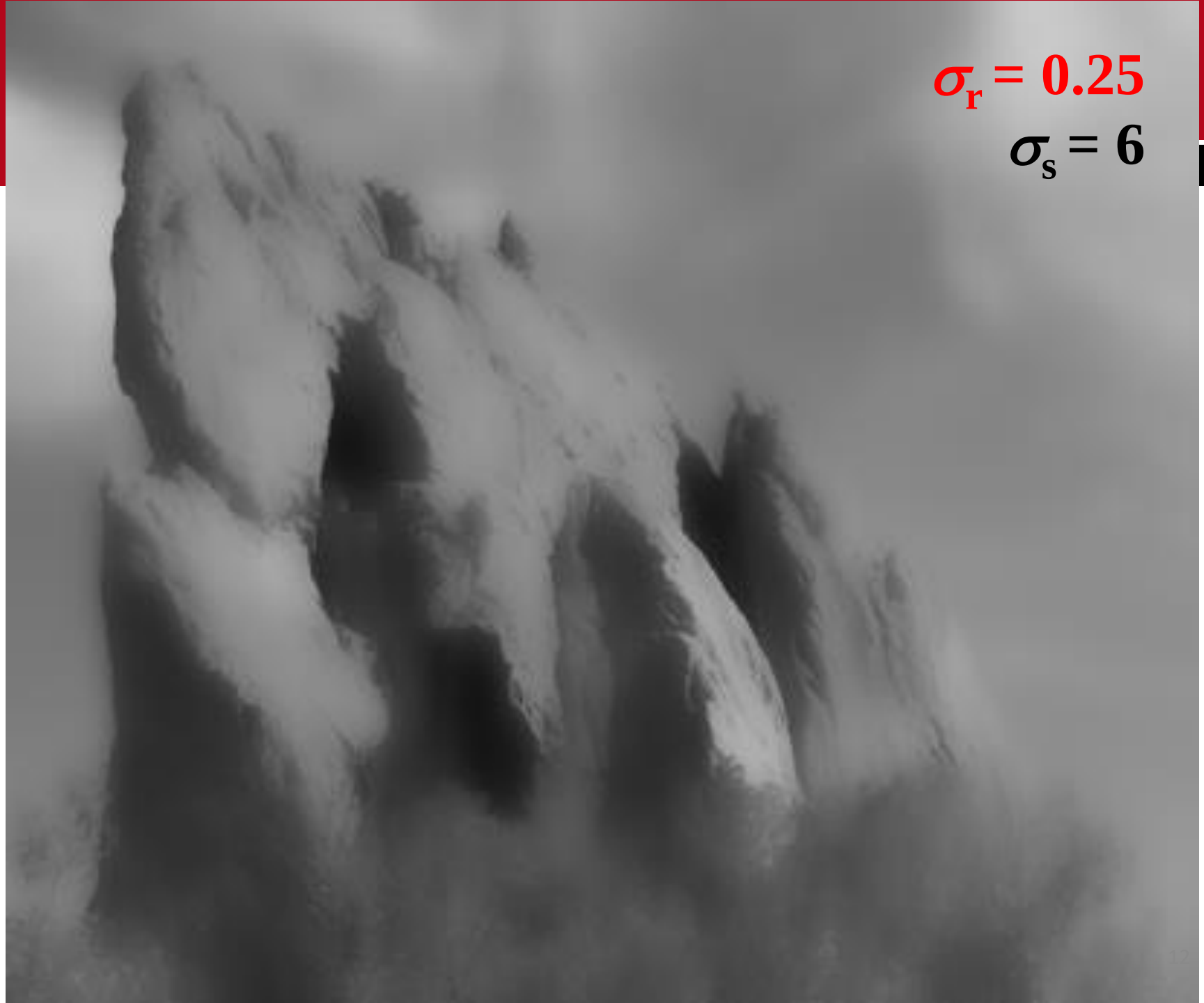
- The factor G_{σ_s} depends on geometrical distance
  - Decreases the influence of distant pixels
- The factor G_{σ_r} depends on the gray level distance
  - Decreases the influence of pixels with different intensity values

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

Effect of σ_r


input


$\sigma_r = 0.1$
$\sigma_s = 6$

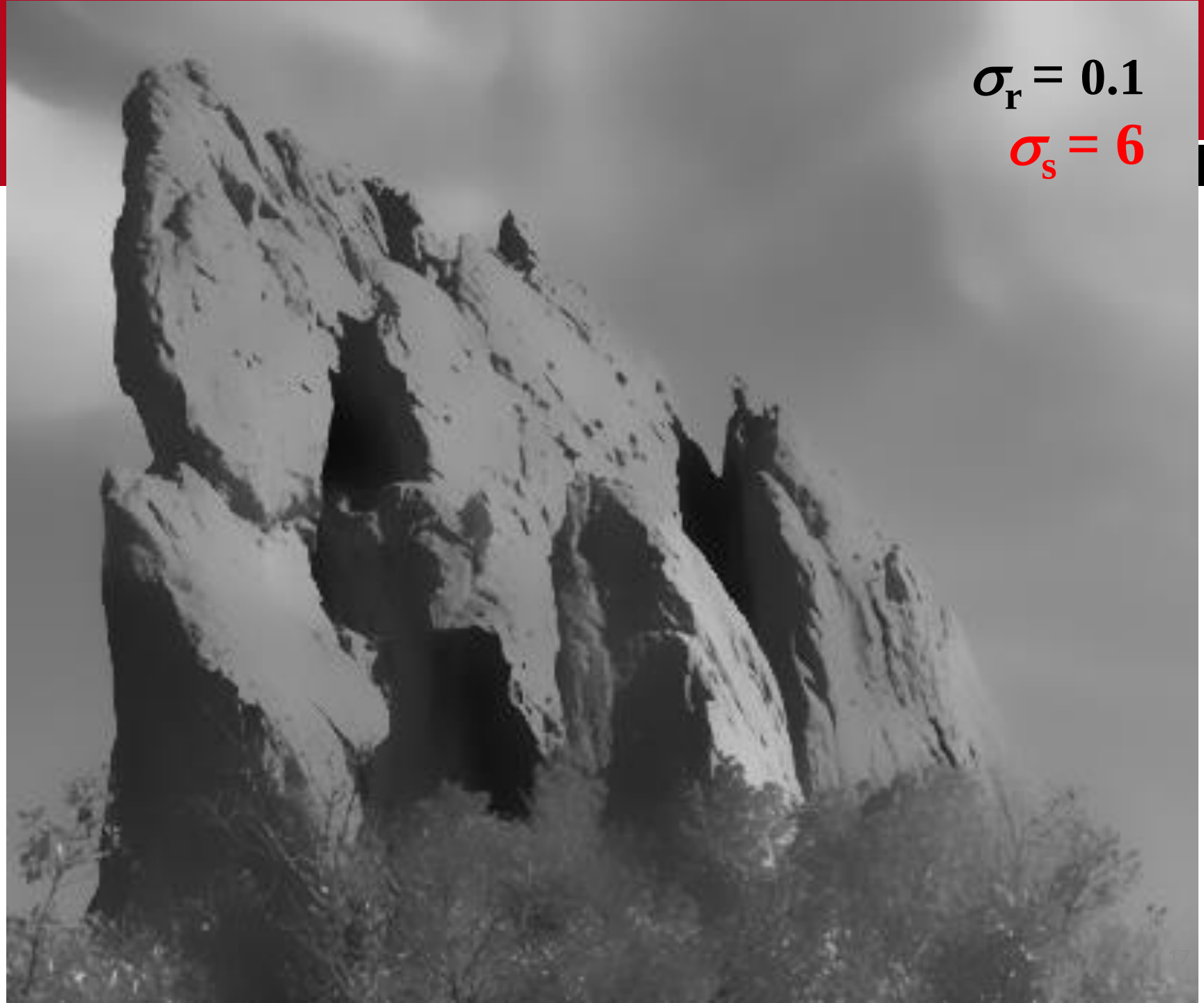

$\sigma_r = 0.25$
$\sigma_s = 6$

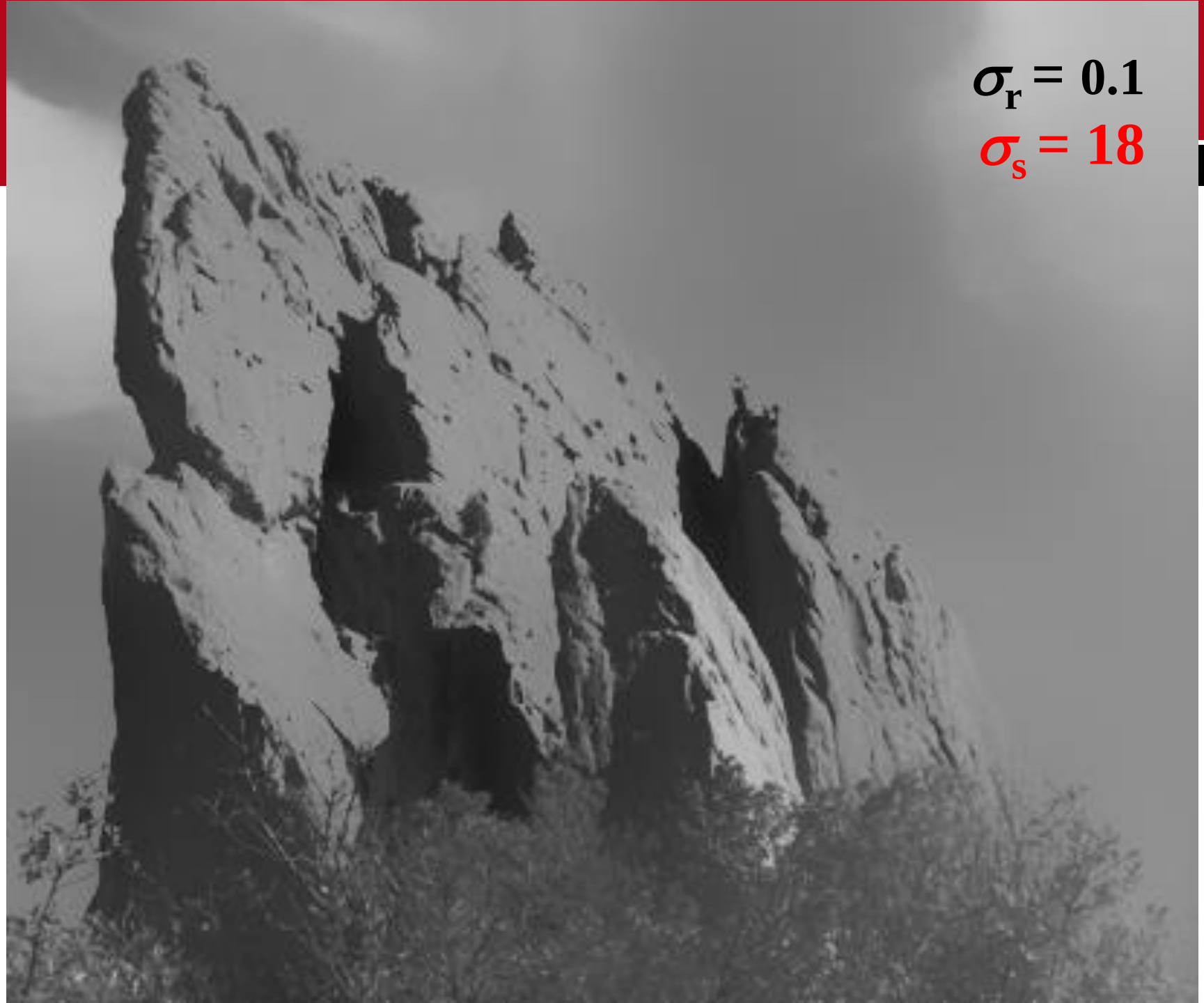

$\sigma_r = \infty$
(Gaussian blur)
$\sigma_s = 6$

Effect of σ_s


input


$\sigma_r = 0.1$
$\sigma_s = 2$

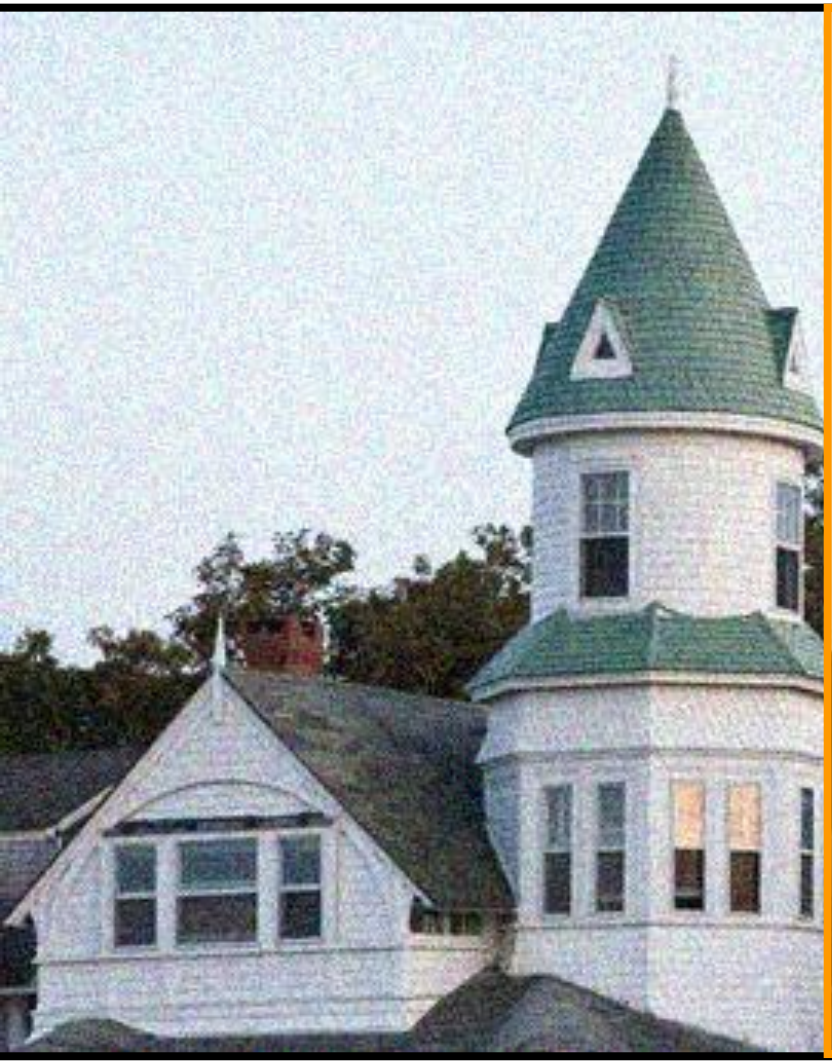

$\sigma_r = 0.1$
$\sigma_s = 6$


$\sigma_r = 0.1$
$\sigma_s = 18$

Denoising: an example

Basic denoising

Noisy input



Bilateral filter 7x7 window

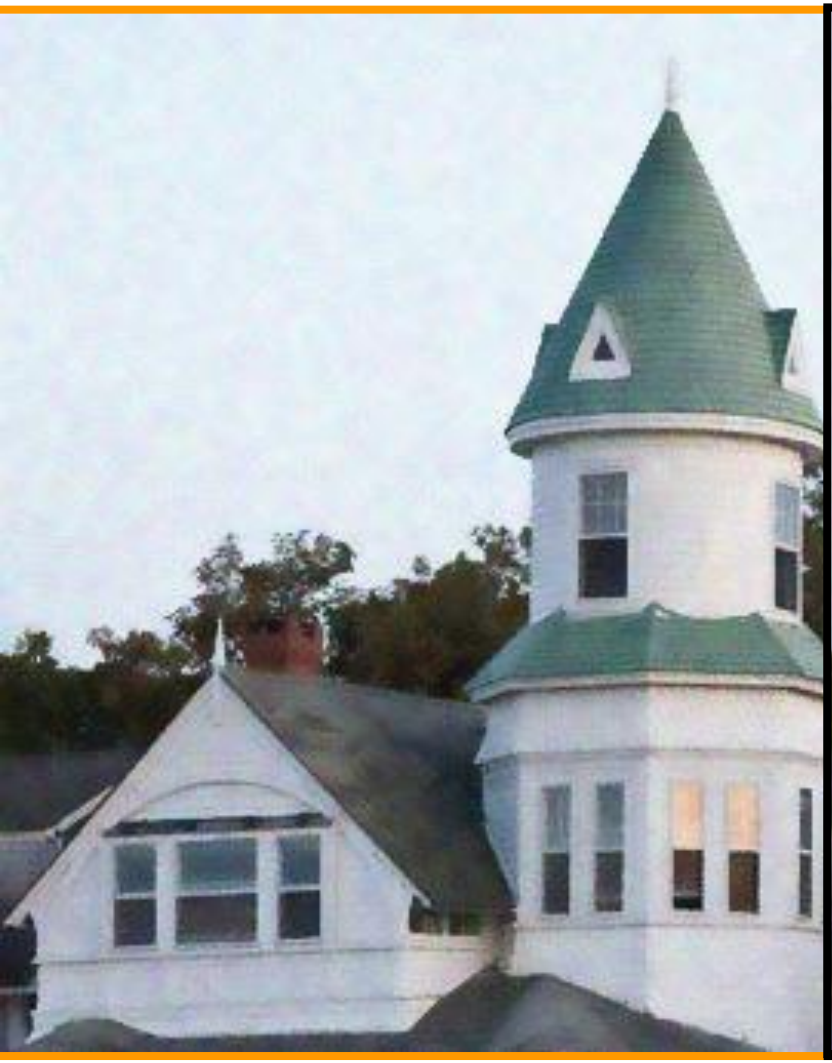
Basic denoising

Bilateral filter

Median 3x3

Basic denoising

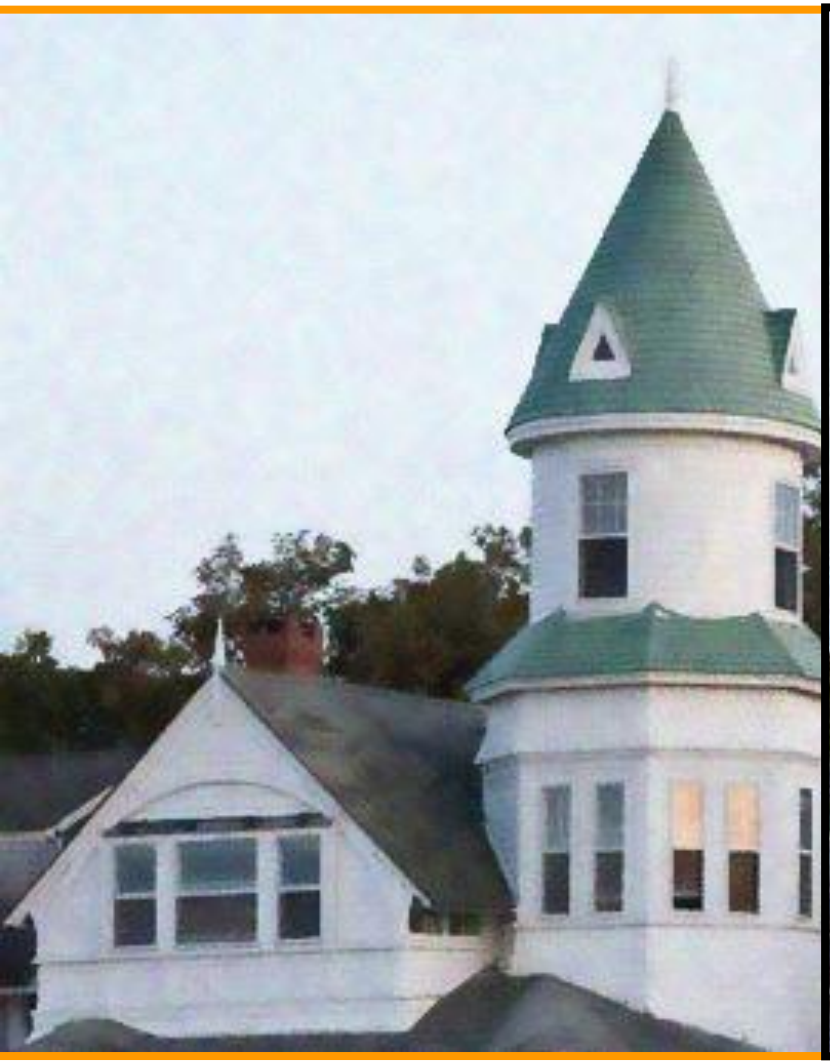
Bilateral filter



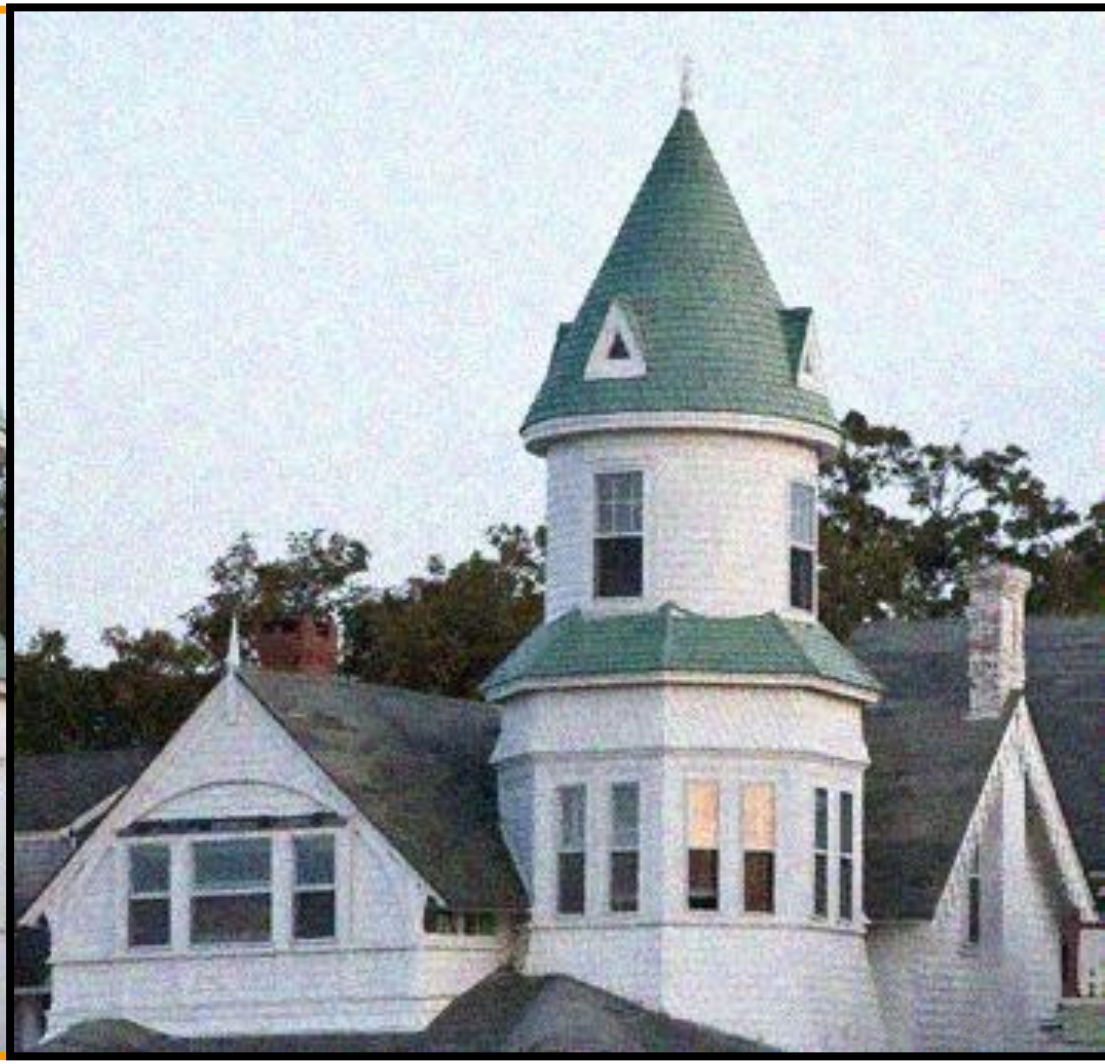
Median 5x5

Basic denoising

Bilateral filter



Bilateral filter – lower sigma



Basic denoising

Bilateral filter

Bilateral filter – higher sigma

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