Computational Photography
Project 2, Fall 2014

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October 16, 2014

1 Tone Mapping using the Bilateral Filter

The Bilateral Filter and its Parameters

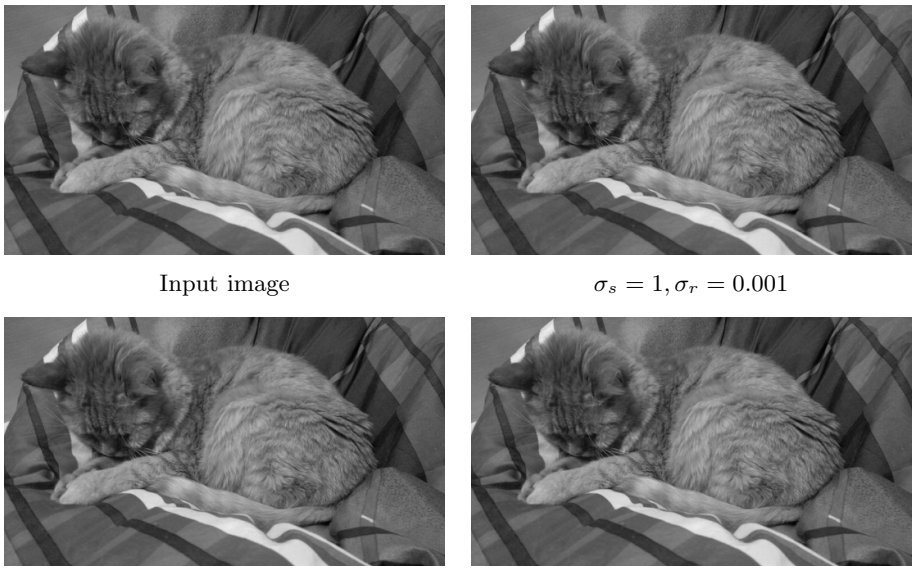
The main parameters that a user can set for the bilateral filter are the standard deviations σ_s for the spatial and σ_r for the range kernel. Both kernels are usually chosen to be Gaussians. Intuitively, σ_s controls the *amount* of blurring, and σ_r controls *what* is blurred. A small value of σ_r means that already very small difference in intensity stop the averaging process. In this case, no matter how large σ_s is, the image won't be smoothed because every little change in intensity will be interpreted as an edge and smoothing will be stopped by the edge-stopping function (range kernel). For an example, see Figure 1. Higher values for σ_r allow the filter to average pixels that are less similar to each other (see Figure 2). However, in the case of a too high value for the standard deviation of the range filter kernel σ_r, the bilateral filter performs like a usual low-pass Gaussian filter (see Figure 3). By finding appropriate values for the standard deviations, one can achieve smoothing of the image while preserving edges (see Figure 4).

Examples

In Figure 5 there are several output exmaples of tonemapping using bilateral filtering. Whereas the images "Bench" and "Church" are good results, one can see that even small changes in scenes may cause the whole procedure to fail because we didn't use any alignment while producing the hdr images. Therefore, you can see a ghost-motorcycle on the "Münster" image and "Stairs" seems to be blurry/shaky.

Bilateral vs. Gaussian Filter

Because the Gaussian domain filter is not edge-aware, smoothing with this filter causes large differences to the original image at edges. Therefore, the detail layer contains mostly the edges in the image. Since this layer is not further processed



Input image $\sigma_s = 1, \sigma_r = 0.001$

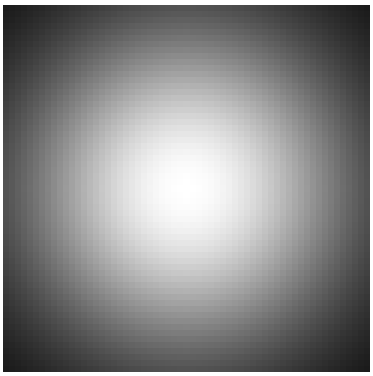
$\sigma_s = 10, \sigma_r = 0.001$ $\sigma_s = 20, \sigma_r = 0.001$

Figure 1: An image of Jerry. Applying the bilateral filter with a very small range value σ_r does not have any effect.

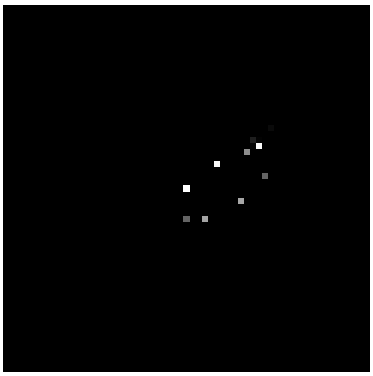
but instead only re-added at the end, tonemapping using a simple Gaussian results in visible halo artifacts. They are clearly visible in the example from Figure 7.

Tone adjustment

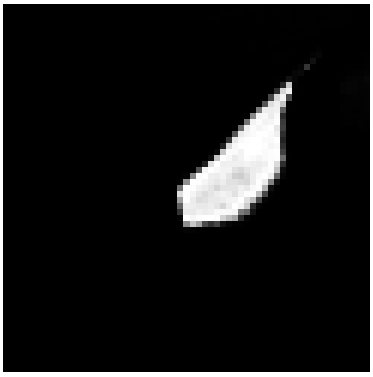
Input image. Red: the pixel for which the filter kernels are visualized.



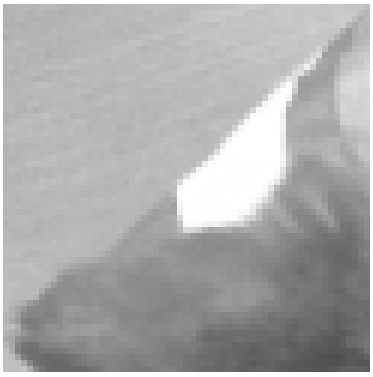
Spatial filter kernel, $\sigma_s = 20$



Range filter kernel, $\sigma_r = 0.001$

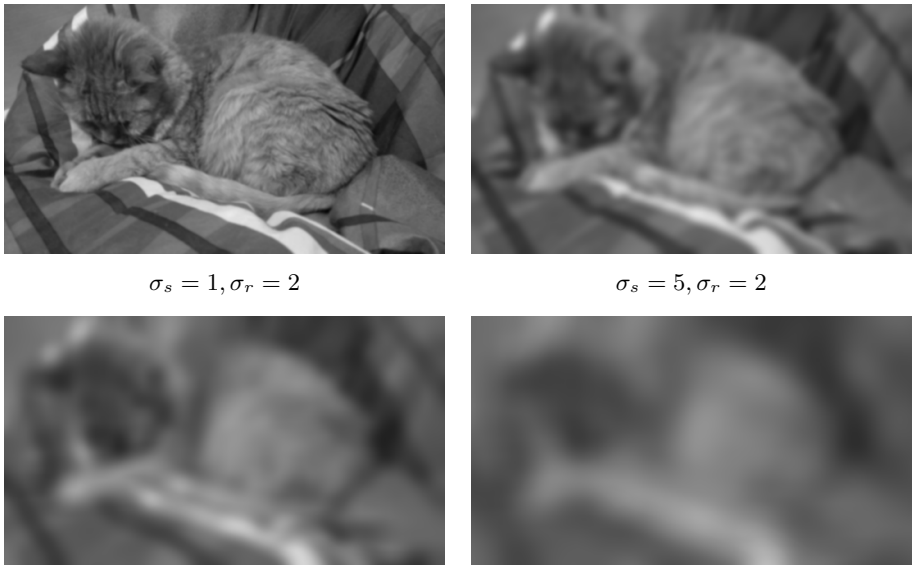


Range filter kernel, $\sigma_r = 0.1$



Range filter kernel, $\sigma_r = 0.5$

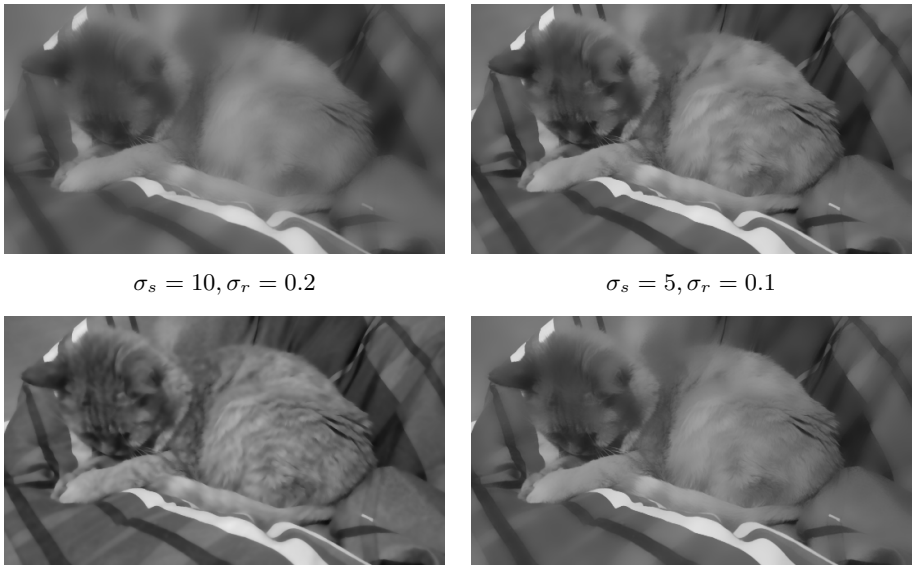
Figure 2: Visualized filter kernels for the pixel marked in red. A very low value for σ_r causes the values of the range filter kernel to be very low almost everywhere – higher values allow averaging of pixels that are less similar.



$\sigma_s = 1, \sigma_r = 2$ $\sigma_s = 5, \sigma_r = 2$

$\sigma_s = 10, \sigma_r = 2$ $\sigma_s = 20, \sigma_r = 2$

Figure 3: With a large value of $\sigma_r = 2$, the bilateral filter is pretty much just a Gaussian filter.

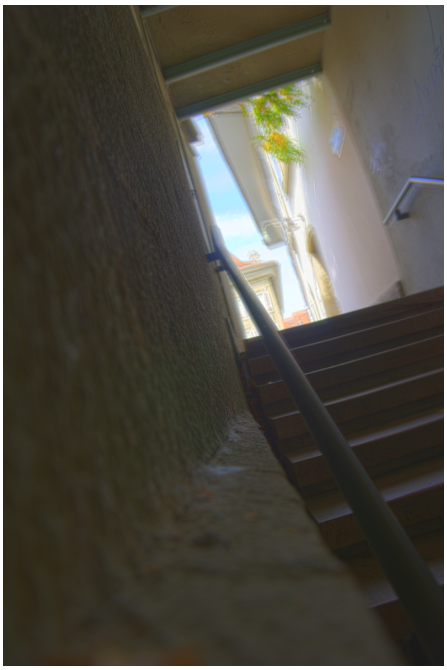


$\sigma_s = 10, \sigma_r = 0.2$ $\sigma_s = 5, \sigma_r = 0.1$

$\sigma_s = 2, \sigma_r = 0.12$ $\sigma_s = 8, \sigma_r = 0.12$

Figure 4: Suitable values for σ_s and σ_r allow smoothing while preserving strong edges. However, sometimes it's difficult to find appropriate values such that all the edges are captured by the range kernel. This may lead to artifacts (blurred regions even though there would be edges), which is visible above at Jerry's neck.

Bench



Stairs

Church

Münster

Figure 5: Some examples for tonemapping using Bilateral filtering. For all images, I used $\sigma_s = 2, \sigma_r = 0.12$ and an output range of 40. Note the weird transparend motorcycle on the "Münster" image.

Bilateral, $\sigma_s = 5, \sigma_r = 0.12$

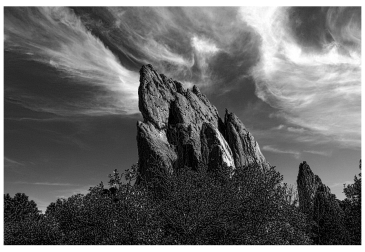
Gaussian $\sigma = 5$

Zoomed in (bilateral)

Zommed in (Gaussian)

Figure 6: Tonemapping using Bilateral and Gaussian filtering, respectively. In the image on the right side, the halo artifacts are clearly visible.

Bilateral, $\sigma_s = 5, \sigma_r = 0.12$



Gaussian $\sigma = 5$

Figure 7: Tone adjustment for a gray and an rgb image.