Question 8

CS663 (Digital Image Processing) Assignment 2

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Problem 1
Consider the two images in the homework folder 'barbara256.png' and 'kodak24.png'. Add zero-mean Gaussian noise with standard deviation $\sigma = 5$ to both of them. Implement a bilateral filter and show the outputs of the bilateral filter on both images for the following parameter configurations: $(\sigma_s = 2, \sigma_r = 2); (\sigma_s = 0.1, \sigma_r = 0.1); (\sigma_s = 3, \sigma_r = 15)$. Comment on your results in your report. Repeat when the image is corrupted with zero-mean Gaussian noise of $\sigma = 10$ (with the same bilaterial filter parameters). Comment on your results in your report. For the bilateral filter implementation, write a MATLAB function `mybilateralfilter.m` which takes as input an image and parameters σ_r, σ_s. Implement your filter using at the most two nested for-loops for traversing the image indices. For creating the filter, use functions like meshgrid and vectorization for more efficient implementation. Include all image ouputs as well as noisy images in the report. [15 points]

SECTION 1

Barbara256 with Gaussian Noise ($\sigma = 5$)

(a) Original Barbara Image   (b) Noisy Barbara Image
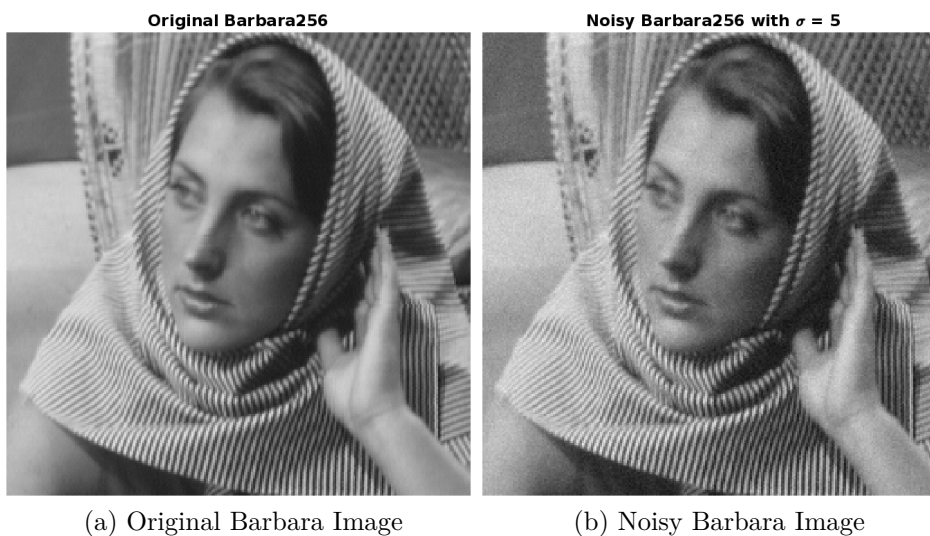
Figure 1. (b) shows Noisy Barbara with Gaussian Noise ($\mu = 0, \sigma = 5$)

(a) $\sigma = 5, \sigma_s = 2, \sigma_r = 2$

(b) $\sigma = 5, \sigma_s = 0.1, \sigma_r = 0.1$

(c) $\sigma = 5, \sigma_s = 3, \sigma_r = 15$

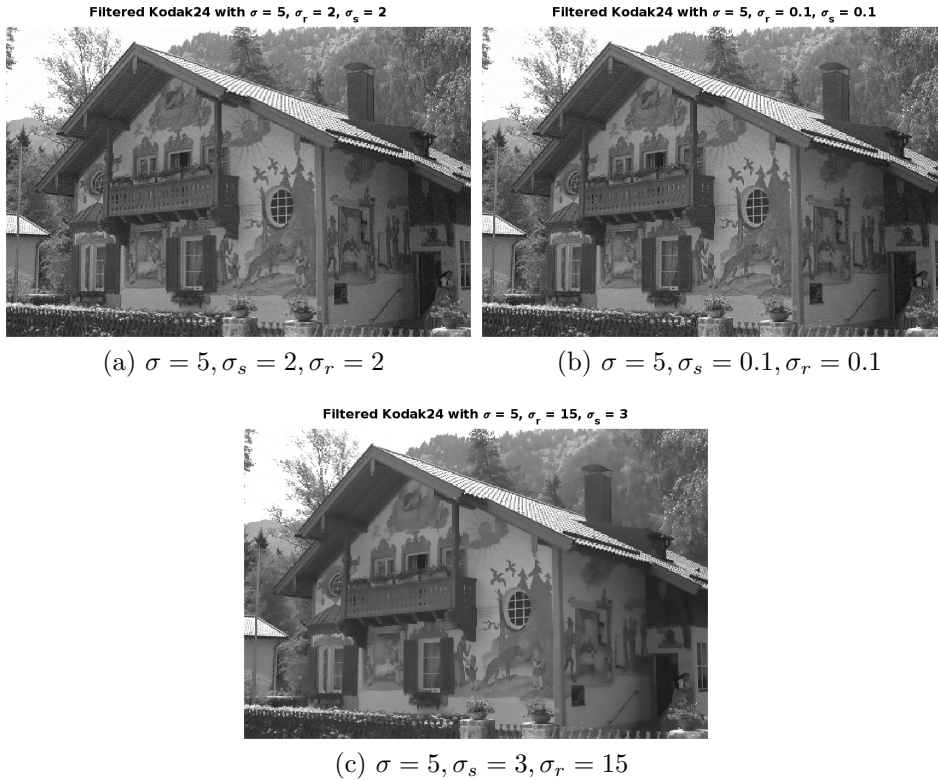**Figure 2**. Barbara Images after applying Bilateral Filter

From the above results, we observe that the image gets more blurred when σ_s and σ_r are increased for the bilateral filter. When σ_s increases, a larger and larger neighborhood of values around a pixel (x, y) will contribute to the averaging (more noise reduction but possible contribution from dissimilar regions).

Also, when σ_r is more, then the blurring is even more because it controls the amount of different intensities taken around a pixel for averaging. Features or edges with intensity difference less than σ_r become blurred, and others remain preserved. At higher values, the bilateral filter begins to resemble a Gaussian filter.

Kodak24 with Gaussian Noise ($\sigma = 5$)

(a) Original Kodak Image   (b) Noisy Kodak Image
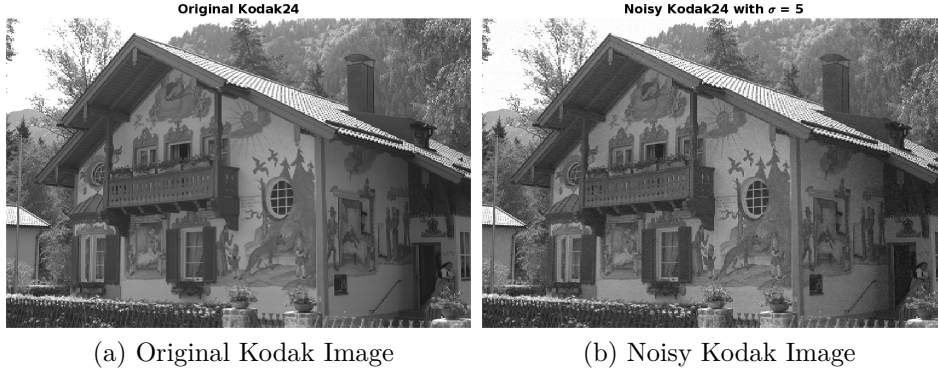
Figure 3. (b) shows Noisy Kodak with Gaussian Noise ($\mu = 0, \sigma = 5$)

(a) $\sigma = 5, \sigma_s = 2, \sigma_r = 2$ (b) $\sigma = 5, \sigma_s = 0.1, \sigma_r = 0.1$

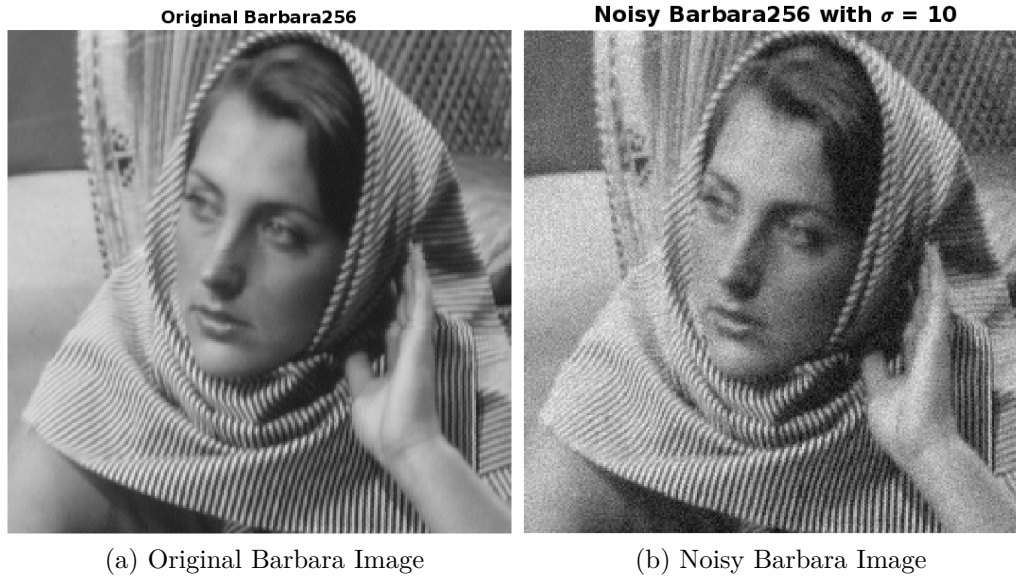(c) $\sigma = 5, \sigma_s = 3, \sigma_r = 15$

Figure 4. kodak Images after applying Bilateral Filter

Similar results as explained before in barbara image are obtained for kodak image also in terms of varying σ_r and σ_s
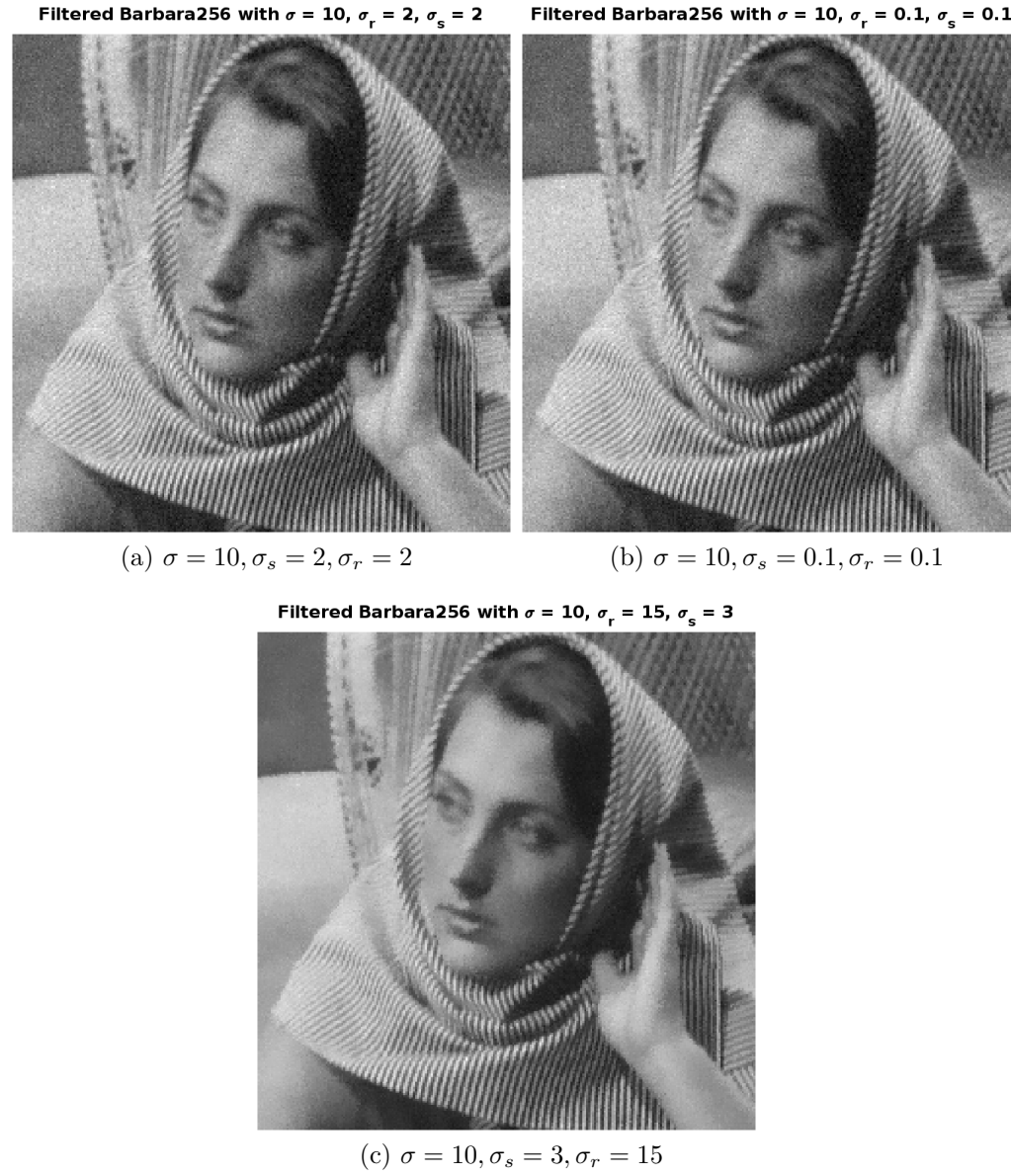
Barbara256 with Gaussian Noise ($\sigma = 10$)

Original Barbara256   Noisy Barbara256 with σ = 10

(a) Original Barbara Image   (b) Noisy Barbara Image

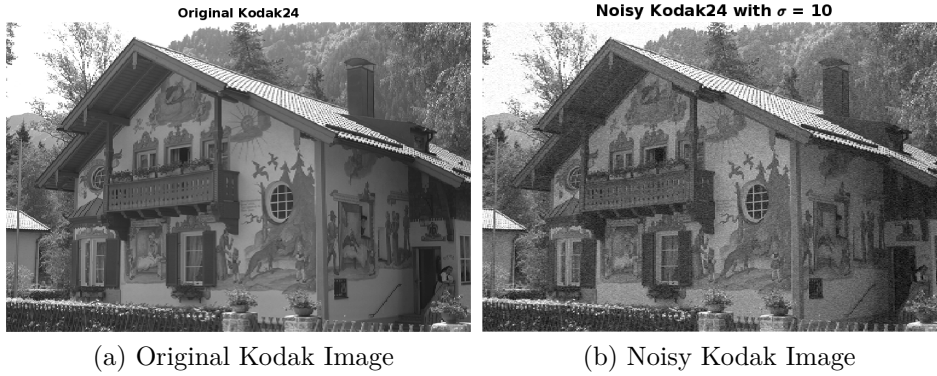**Figure 5**. (b) shows Noisy Barbara with Gaussian Noise ($\mu = 0, \sigma = 10$)

Now, the value of standard deviation of the Gaussian Noise added is increased from 5 to 10. We repeated the same processes and observed that as σ increased, the extent of noise added to the image increased because the Gaussian curve widens on increasing σ, and hence more error is added to the image intensities. The trend in filtering results were similar, that is $\sigma_r = 3$, $\sigma_s = 15$ case provided better filtering than other ones, but with some blur.
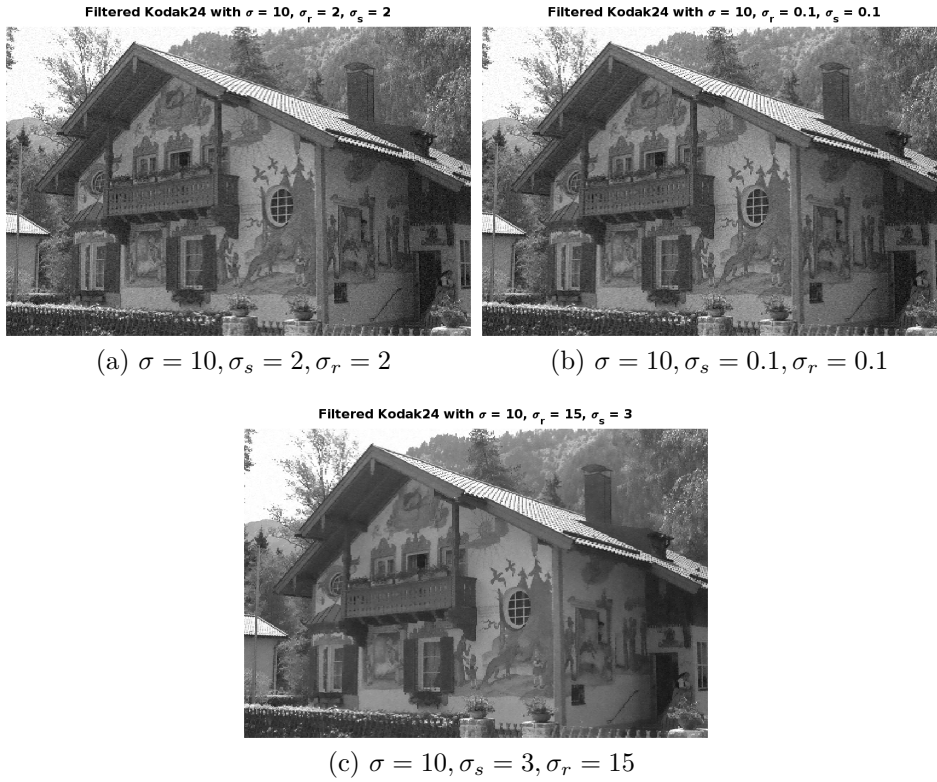
(a) $\sigma = 10, \sigma_s = 2, \sigma_r = 2$

(b) $\sigma = 10, \sigma_s = 0.1, \sigma_r = 0.1$

(c) $\sigma = 10, \sigma_s = 3, \sigma_r = 15$

Figure 6. Barbara Images after applying Bilateral Filter

Kodak24 with Gaussian Noise ($\sigma = 10$)

(a) Original Kodak Image

(b) Noisy Kodak Image

Figure 7. (b) shows Noisy Kodak with Gaussian Noise ($\mu = 0, \sigma = 10$)

(a) $\sigma = 10, \sigma_s = 2, \sigma_r = 2$

(b) $\sigma = 10, \sigma_s = 0.1, \sigma_r = 0.1$

(c) $\sigma = 10, \sigma_s = 3, \sigma_r = 15$

Figure 8. kodak Images after applying Bilateral Filter