Question 1

CS663 (Digital Image Processing) Assignment 3

Atishay Jain (210050026)
Cheshta Damor (210050040)
Kanad Shende (210050078)

210050026@iitb.ac.in
210050040@iitb.ac.in
210050078@iitb.ac.in

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PART

I

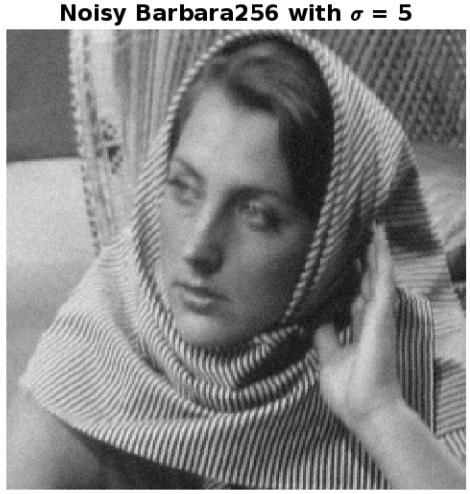
Question 1

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 mean shift based filter and show the outputs of the mean shift 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. Include all image ouputs as well as noisy images in the report. [20 points]

Section 1

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

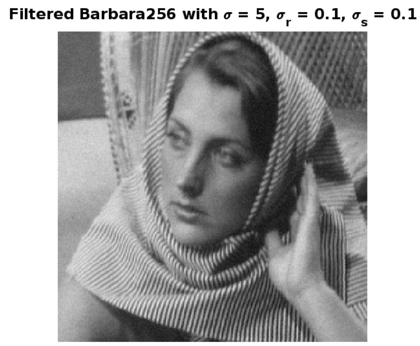
(a) Original Barbara Image



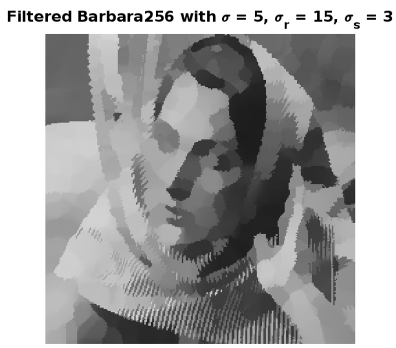
(b) Noisy Barbara Image

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

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



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



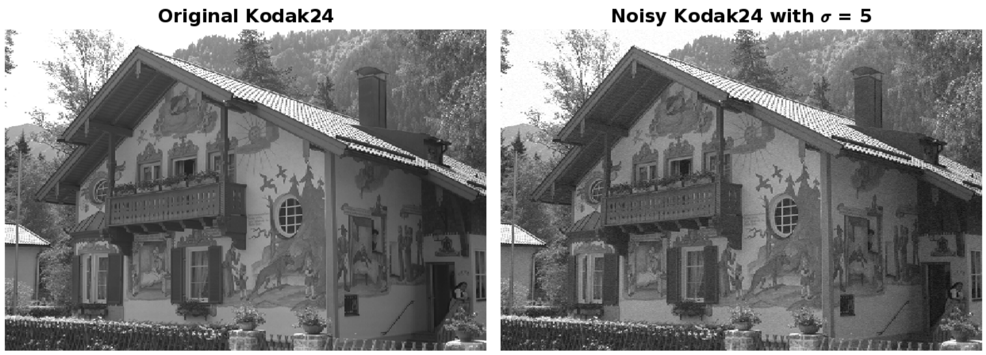
(c) $\sigma = 5, \sigma_s = 3, \sigma_r = 15$

Figure 2. Barbara Images after applying Mean Shift based Filter

From the above results, we observe that the effect of mean-shift-based filter is not much on the noisy image when implemented using parameters ($\sigma_s = 0.1, \sigma_r = 0.1$). There is slight smoothening at some small regions for ($\sigma_s = 2, \sigma_r = 2$), and there is too much filtering for ($\sigma_s = 3, \sigma_r = 15$). In fact, in the last case, although it removed noise, but it also lost some important image details (like eyes) due to excessive filtering.
This is because as the value of σ_s and σ_r increases, the number of local maximas of kernel density estimate decreases, so now more number of points get converged to a same point. For low values of these parameters, almost every point's feature vector is a local maxima for itself and hence the effect of filtering is not much because points get clustered to themselves.
In general, smaller values of σ_s make the filter more sensitive to local variations, while smaller σ_r values will make it more sensitive to pixel intensity differences.
In implementation of gradient accent, we used $\epsilon = 0.01$ as hyper-parameter for the condition of convergence. Also, while running the code, we observed that it takes more time to filter image when using high values of σ_s, σ_r because with lesser local maximas, many points have to perform the accent more number of times to reach their cluster's local maxima point.

SECTION 2

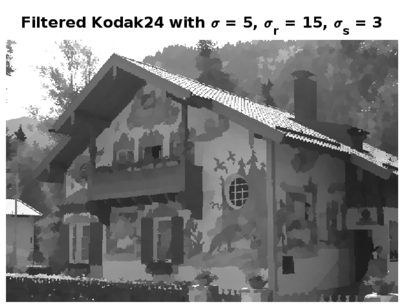
Kodak24 with Gaussian Noise ($\sigma = 5$)



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



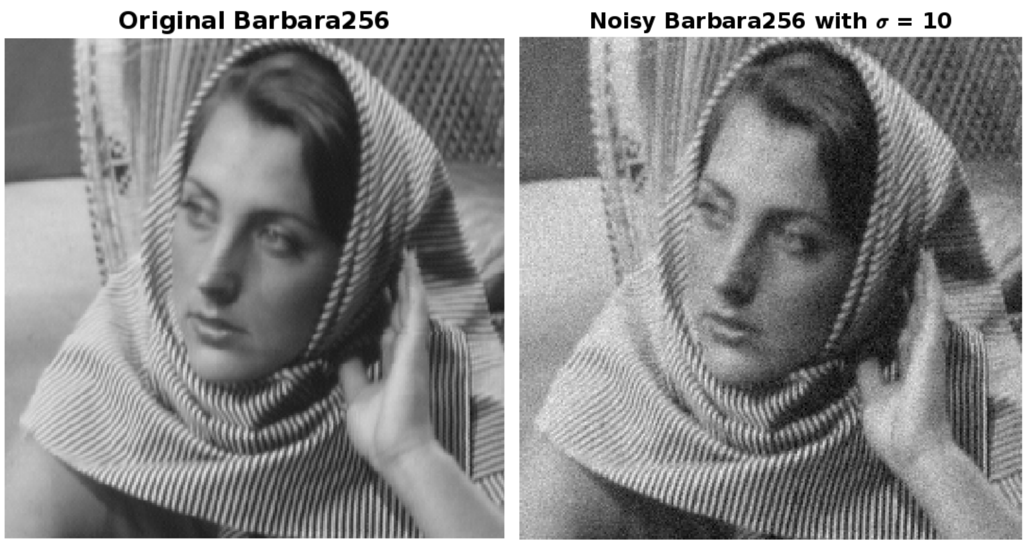
(c) $\sigma = 5, \sigma_s = 3, \sigma_r = 15$

Figure 4. kodak Images after applying Mean Shift based Filter

Similar results as explained before in barbara image are obtained for kodak image also in terms of varying σ_r and σ_s

Section 3

Barbara256 with Gaussian Noise ($\sigma = 10$)

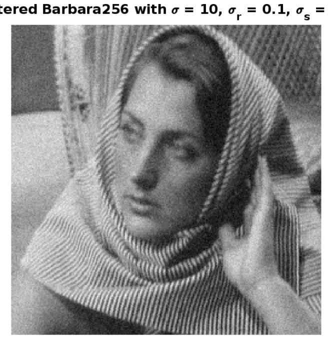


(a) Original Barbara Image (b) Noisy Barbara Image

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, and it performed too much filtering, but the filtering effect was not much in case of $\sigma_s = 0.1, \sigma_r = 0.1$.
Since the noise added is more for $\sigma = 10$, the filtering effect is more clearly visible.

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



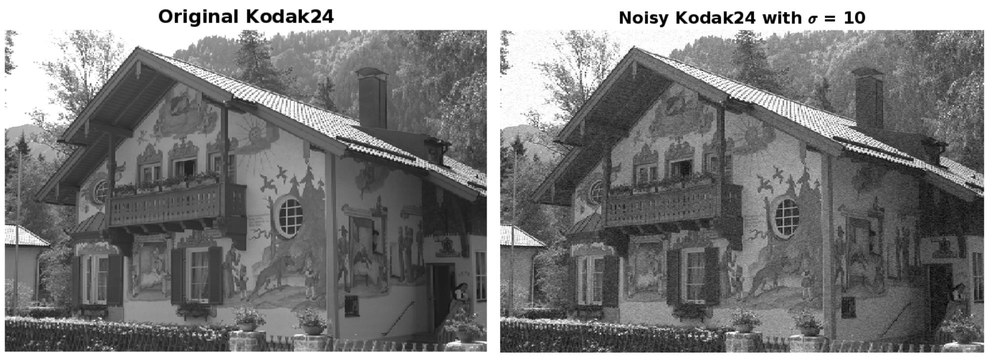
(b) $\sigma = 10, \sigma_s = 0.1, \sigma_r = 0.1$

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

Figure 6. Barbara Images after applying Mean Shift based Filter

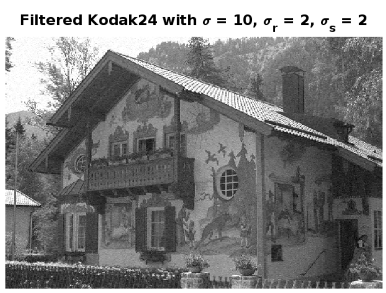
Section 4

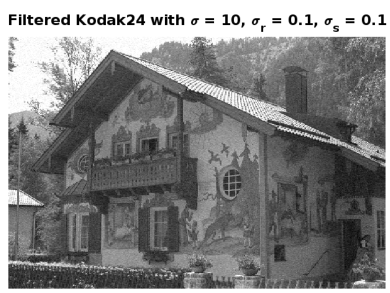
Kodak24 with Gaussian Noise ($\sigma = 10$)



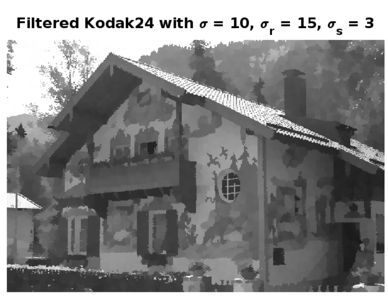
(a) Original Kodak Image (b) Noisy Kodak Image

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 Mean Shift based Filter