CS663: Digital Image Processing - Homework 3

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1 Homework 3 - Question 3

1.1 Introduction

In this question, we consider two images: 'barbara256.png' and 'kodak24.png'. We add zero-mean Gaussian noise with standard deviation $\sigma = 5$ and $\sigma = 10$ to both images. We then apply a mean shift based filter with different parameter configurations and analyze the results.

1.2 Original Images

Figure 1: Original Images

1.3 Noisy Images

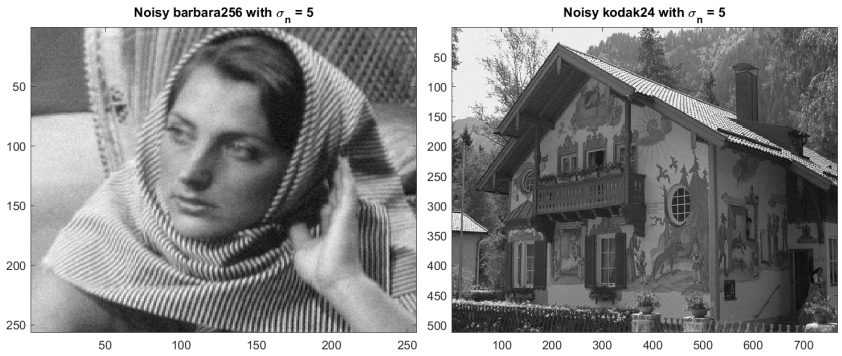

Figure 2: Images corrupted with zero-mean Gaussian noise ($\sigma = 5$).

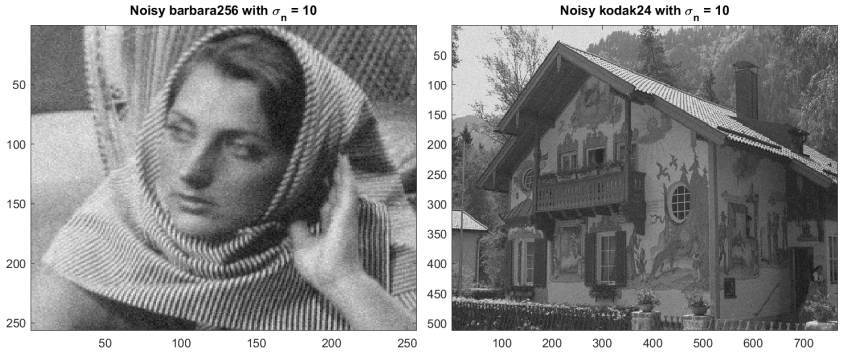

Figure 3: Images corrupted with zero-mean Gaussian noise ($\sigma = 10$).

1.4 Mean Shift Filter Results

1.4.1 Parameter Configuration: $\sigma_s = 2$, $\sigma_r = 2$

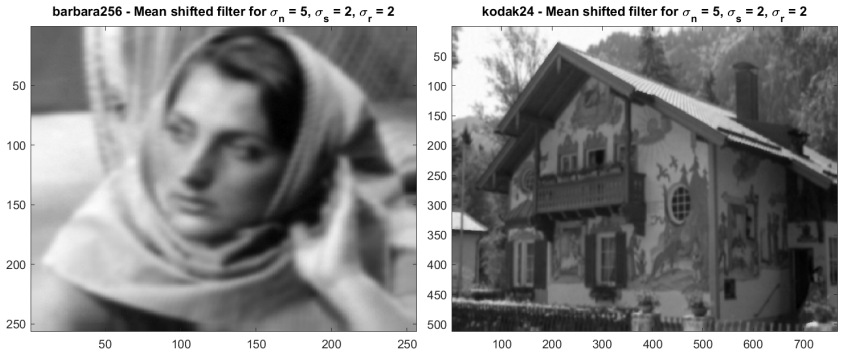

Figure 4: Mean shift filter results ($\sigma = 5$, $\sigma_s = 2$, $\sigma_r = 2$).

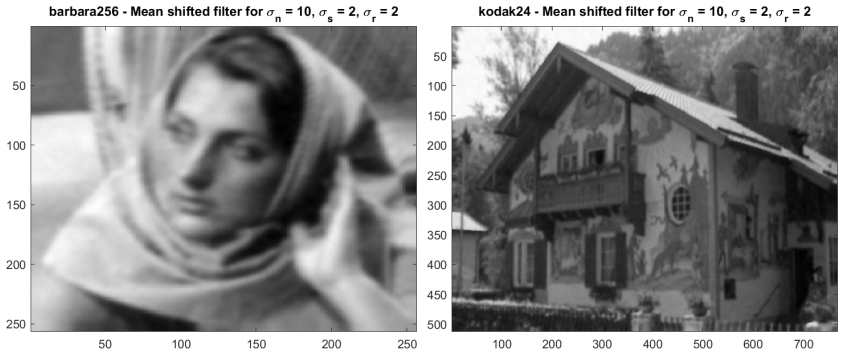

Figure 5: Mean shift filter results ($\sigma = 10$, $\sigma_s = 2$, $\sigma_r = 2$).

1.4.2 Parameter Configuration: $\sigma_s = 15$, $\sigma_r = 3$

The attainment of convergence takes a longer time for this configuration due to a higher spatial bandwidth leading to very slow convergence and hence the results were not attained in the observed time ($\sim$ 15 minutes). Reasons for this are explained in the observations section in detail.

1.4.3 Parameter Configuration: $\sigma_s = 3$, $\sigma_r = 15$

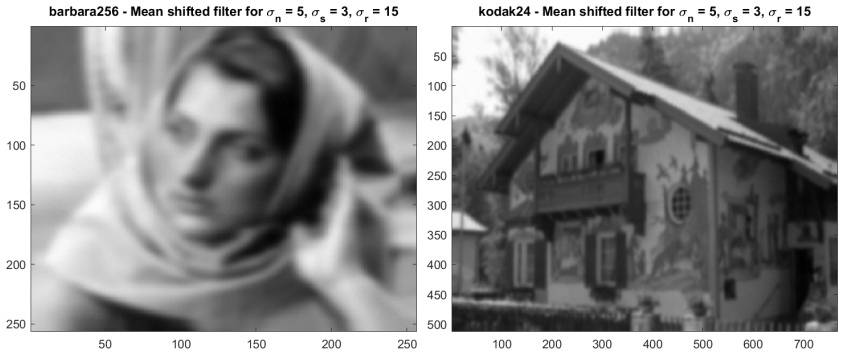

Figure 6: Mean shift filter results ($\sigma = 5$, $\sigma_s = 3$, $\sigma_r = 15$).

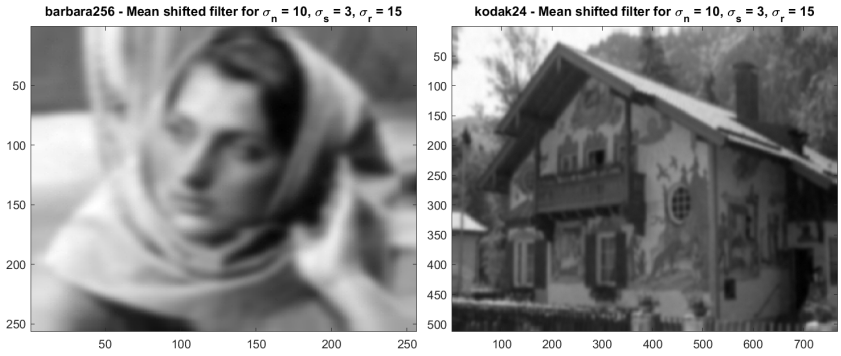

Figure 7: Mean shift filter results ($\sigma = 10$, $\sigma_s = 3$, $\sigma_r = 15$).

1.5 Observations

- For σ_s:
  - As it increases, a larger and larger neighborhood of values around $p = (x, y)$ will contribute to the averaging (more noise reduction but possible contribution from dissimilar regions)
  - For higher values of σ_s (the spatial bandwidth), convergence tends to be slow or may not be reached because the algorithm searches over a much larger neighborhood in the spatial domain. This means:
    - A larger σ_s causes the algorithm to consider a broader area around each pixel when computing the weighted mean shift, resulting in smaller shifts per iteration since the influence of far-away points dilutes the update.

        * As the spatial weights (Gaussian kernel) are spread over a larger area, the gradient of the weight function becomes flatter, making it harder for the algorithm to push the feature vector towards a stable mode quickly.

- For σ_r:
    - For moderate values, only intensities close to $I(p)$ will affect the averaging
    - Features or edges with intensity difference less than σ_r will be blurred, others will be preserved
    - A behavior similar to σ_s isn't seen with σ_r (the range bandwidth) because σ_r controls the sensitivity to intensity differences (or range differences), not spatial differences. This results in convergence being reached more easily with higher values of σ_r as seen in the third configuration.

Thus, for higher value of σ_s, the edges are not very well preserved and for very high values convergence is not attained in a feasible duration. For higher value of σ_r, more averaging occurs compared to smaller values.
As σ_n increases, that is, the noise added increases and higher mean shift filtering is required to smoothen the image (like in the case of $\sigma_s = 3, \sigma_r = 15$).