Question 1

CS663 (Digital Image Processing) Assignment 5

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Question 1

SECTION 1

(a) `myPCADenoising1`

(a) Image with Gaussian Noise ($\sigma = 20$)

(b) RMSE: 0.072107

Figure 1. PCA Denoising1 applied on noisy `barbara256.png`

(a) Image with Gaussian Noise ($\sigma = 20$)

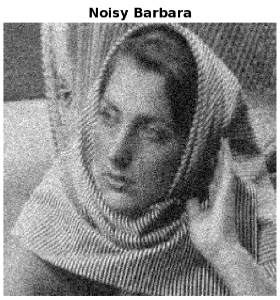
(b) RMSE: 0.077589

Figure 2. PCA Denoising1 applied on noisy `stream.png`

Note that in all the parts, we took top-left 256×256 portion of `stream.png`

Section 2

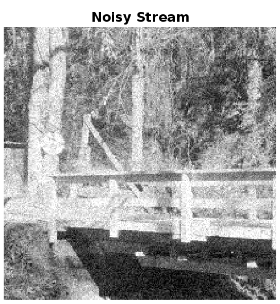
(b) `myPCADenoising2`



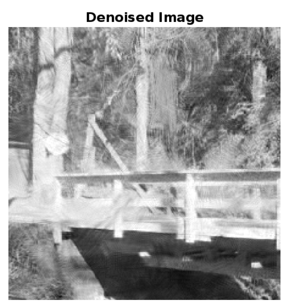
(a) Image with Gaussian Noise ($\sigma = 20$)

(b) RMSE: 0.057169

Figure 3. PCA Denoising2 applied on noisy `barbara256.png`



(a) Image with Gaussian Noise ($\sigma = 20$)



(b) RMSE: 0.073553

Figure 4. PCA Denoising2 applied on noisy `stream.png`

The RMSE of the denoised images is calculated as

$$\text{RMSE} = \frac{||image_{denoised} - image_{original}||_2}{||image_{original}||_2}$$

where $image_{original}$ is the original image (without noise). The RMSE values obtained for each method are displayed on the caption of each denoised image in the report.
Also note that code for `myPCADenoising2` takes around 40-50 seconds to run, as it performs more calculations

Section 3

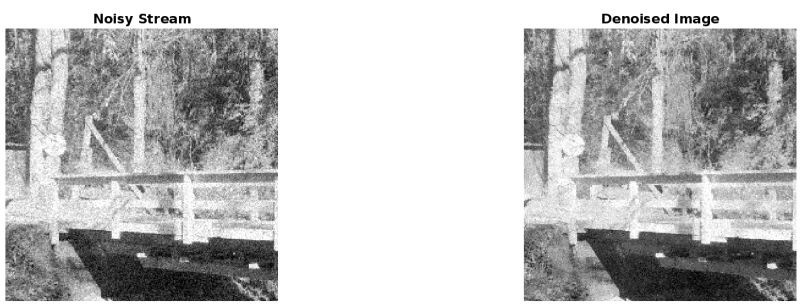
(c) Bilateral Filter based Denoising

We used the `mybilateralfilter.m` from homework2 with $\sigma_s = 3, \sigma_r = 15$

(a) Image with Gaussian Noise ($\sigma = 20$)

(b) RMSE: 0.117554

Figure 5. Bilateral filter applied on noisy `barbara256.png`



(a) Image with Gaussian Noise ($\sigma = 20$)

(b) RMSE: 0.104199

Figure 6. Bilateral filter applied on noisy `stream.png`

Subsection 3.1

Observation and Differences

- From the results obtained, we observe that PCADenoising2 performed better than PCADenoising1, and PCADenoising1 performed better than bilateral filter, as the RMSE values are in that order. The best performance is observed in PCADenoising2

- But also note that there is a little-bit of loss of sharpness of the image in PCADenoising2. This is because it doesn't explicitly account for edge preservation, but aims to denoise patches. On the other hand, bilateral filter is a non-linear method that considers spatial and intensity information and is particularly effective at preserving edges and fine details along with denoising.

- The PCA-based approach also relies on the statistical properties of patches (like Gaussian noise added) and depends on patch similarily within local neighborhoods, but bilateral filter considers pixel-wise similarity in terms of intensity and spatial location

- Also, another difference is that PCA-based approach has higher computational complexity (specially PCADenoising2) than bilateral filter, thereby leading to more time taken by the code to run. This is because it has to compute eigen-decomposition for each patch.

- Overall, we see that if the noise is Gaussian-like and preserving fine details is not needed much, then PCA-denoising is good, because PCADenoising2 result's are better. But if fine details are needed to be preserved then a non-linear filter like bilateral filter can be a suitable choice

Section 4

(d) Clamping-based approach

Problem 1

Consider that a student clamps the values in the noisy image'im1' to the [0,255] range, and then denoises it using the aforementioned PCA-based filtering technique which assumes Gaussian noise. Is this approach correct? Why (not)?

Answer This approach is **not** correct. This is because clamping may introduce non-Gaussian artifacts and a deviation from the assumed Gaussian model of noise. But the PCA-based denoising relies on the statistics of the noise, because it uses the σ of the Gaussian noise model in the Weiner filter update. So, after clamping to [0,255] range, the noise may not be Gaussian and hence PCA-based filtering may lead to incorrect results