Advanced Image Processing: Assignment 3 (Due Apr 27, 2021)

Note: Answer all questions by supporting your answers with suitable plots and observations in a report. You will need to upload code that you may have written to solve the problems. Please provide detailed comments for any such code. The assignment will be evaluated not just based on the final results but also how you obtained them. Late submissions will be penalized.

Problem 1: Image denoising (30 points)
Take the lighthouse image provided to you, convert to greyscale and add white Gaussian noise with variance $\sigma_Z^2 = 100$ to it. Be sure to add noise in the grey scale domain where the range of pixel values is between 0 and 255. Compute and compare (subjectively and using mean squared error) the results of the following denoising methods

1. Low pass Gaussian filter: Vary the filter length in the set $\{3, 7, 11\}$ and standard deviations in the set $\{0.1, 1, 2, 4, 8\}$ to identify the filter with the best mean squared error (MSE).
2. Adaptive MMSE: Compute an adaptive version of the MMSE filter where the estimates are computed for patches of size 32×32 with overlap of 16 in the high pass domain. All pixels belonging to multiple patches need to be assigned the average values arising from the output due to multiple patches. You need to estimate the variance of the high pass coefficients of the original image and the variance of noise in the high pass image given the noise variance $\sigma_Z^2 = 100$ in the pixel domain.
3. Adaptive Shrinkage: Shrinkage estimator on the high pass coefficients of the noisy image with the threshold optimized using *SureShrink* for patches of size 32×32. Here it is implicit that you need to the determine the threshold parameter t for every patch. (Ref: D. L. Donoho, and I. M. Johnstone, "Adapting to unknown smoothness via wavelet shrinkage," Journal of the American Statistical Association, vol. 90, no. 432, 1995)

Problem 2: Image sharpening (10 points)
Sharpen the output of the image denoised using the low pass Gaussian filter in Problem 1 using a combination of a high pass filter and constant gain as discussed in class. Be sure to incorporate saturation of pixel values below 0 or above 255. Use the following high pass filter:

$$M = \begin{bmatrix} -1 & -1 & -1 \\ -1 & 8 & -1 \\ -1 & -1 & -1 \end{bmatrix}$$

Plot the mean squared error between the sharpened image and the original image as a function of the gain. Comment on the curve.

Problem 3: Block Matching and 3D Filtering (20 points)

Read the paper "Image denoising by sparse 3D transform-domain collaborative filtering" available at `https://www.cs.tut.fi/~foi/GCF-BM3D/BM3D_TIP_2007.pdf`. Obtain the BM3D implementation available at `http://www.cs.tut.fi/~foi/GCF-BM3D/`. Based on your reading of the paper and the code, perform the following experiments:

1. Compare the MSE performance at the output of the first and second stages of the BM3D method. The BM3D algorithm has two stages in its implementation. You can use the cameraman noise image in Problem 1.
2. Study the performance variation of the entire algorithm with respect to the choice of the input noise variance σ_Z^2 in the algorithm. You can plot a curve between MSE and σ_Z^2 to understand this relationship. Explain why you get such a curve.
3. Replace the Wiener filter in the second stage with a hard thresholding estimate and compare the performance with the former in terms of MSE.