Advanced Image Processing: Assignment 3 (Due Mar 23, 2025)

Note: Answer all questions by supporting your answers with suitable plots and observations in a report. You will also need to upload your code. Please provide detailed comments for your 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. Only 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. Low pass filter with high pass processing: Shrinkage estimator on the high pass coefficients of the noisy image with the threshold optimized using *SureShrink*. Here it is implicit that you need to determine the threshold parameter t.(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).

3. Implement a multiscale version of SureShrink where the low pass filter is kept the same across scales and different scales are obtained by downsampling. Evaluate the performance with respect to the number of scales ranging between 1 and 4.

Problem 2: 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 for the noisy lighthouse image in Problem 1.

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.