Advanced Image Processing: Assignment 2 (Due Feb 23, 2017)

Note: Please provide detailed comments for code that may be written to solve the following problems. 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

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. MMSE filter on the high pass coefficients of the noisy image. 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. 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 the 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).
4. Denoising in two scales based on *SureShrink* discussed in class. Design an appropriate low pass filter for the second scale and choose a suitable threshold for the shrinkage estimator in the second scale. You can use the parameters estimated in the previous subpart for the first scale.

Problem 2: Image sharpening

1. 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.

2. Now, instead of a constant gain, use a gain curve as a function of high pass coefficient strength measured as absolute value of the high pass coefficient. The curve is described as follows:

$$\begin{aligned}\lambda(y_1) &= m|y_1| \text{ if } |y_1| \leq t \\ &= mt \text{ if } |y_1| > t\end{aligned}$$

Now compute the mean squared error as a function of m and t for 10 suitable values of each m and t totalling 100 pairs. Find (m, t) that minimizes the mean squared error. Compare with the solution obtained in the case with constant gain both through mean squared error and visually.

Prepare a report containing all the observations and performance analysis as instructed above for both problems.