**ECE 418 Lab 9**


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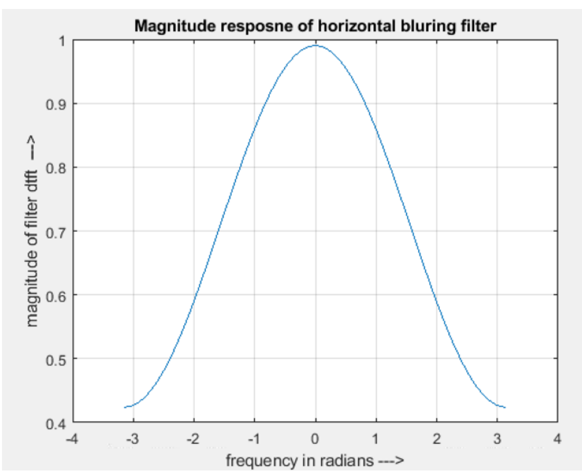
In this lab we examine Wiener filters for restoring noisy images, either blurred images with no noise or blurred images with randomly added noise. We also try to find the best filter design to recover images.

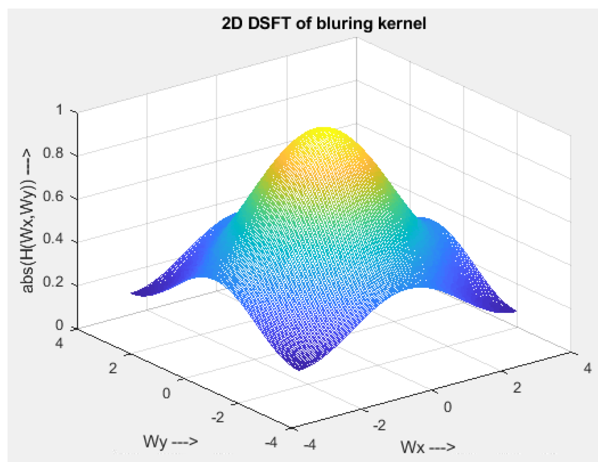
**Part A: Wiener Filter with Zero Additive Noise**

In this part we apply Wiener filter to the zero additive noise where the wiener filter is the same as the inverse filter in this setting.
The frequency coefficients of the blurring filter is : [0.1414  0.7071  0.1414]

The frequency coefficients of the 2D blurring kernel is:

$$h = \begin{matrix} 0.02 & 0.10 & 0.02 \\ 0.10 & 0.50 & 0.10 \\ 0.02 & 0.10 & 0.02 \end{matrix}$$

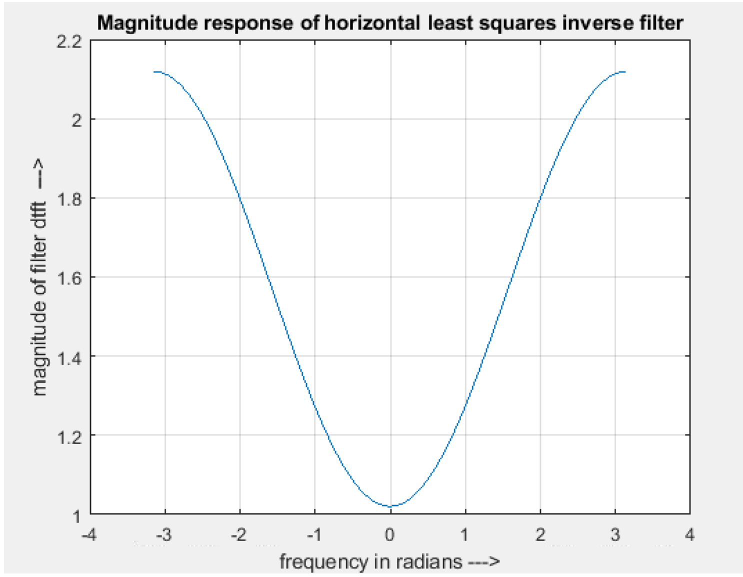



After Row Filtering:

MSE = 3.137509

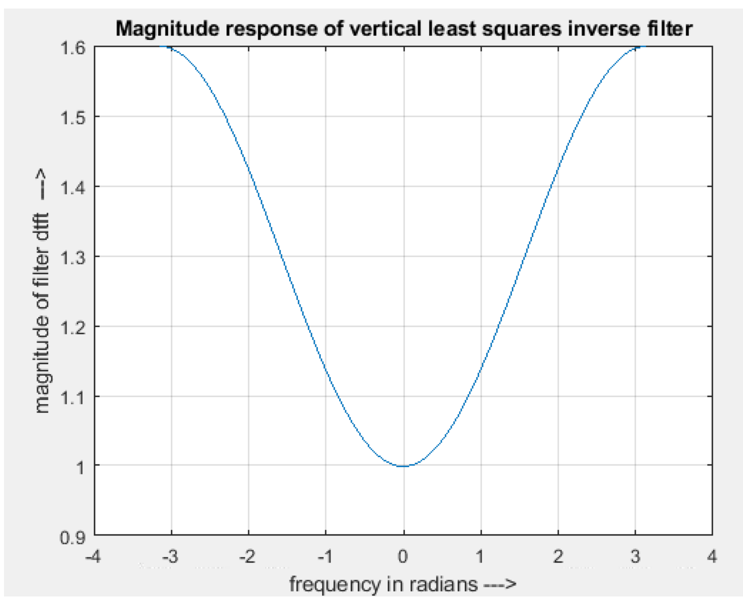
Filter Coefficients: [ -0.2748  1.5697  -0.2740 ]




After Column Filter:

MSE: 0.7491332

Filter Coefficients: [ -0.1497  1.2990  -0.1503 ]



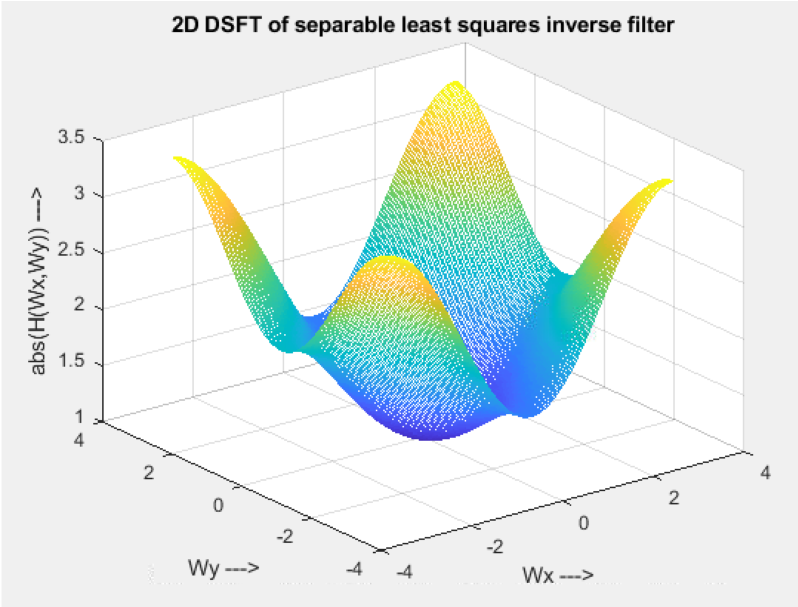

**Part B: Wiener Filter**

Inverse Filter:

MSE: 0.9777777

Filter Coefficients:

| | | |
|---|---|---|
| 0.0411 | -0.2350 | 0.0410 |
| -0.3570 | 2.0390 | -0.3560 |
| 0.0413 | -0.2359 | 0.0412 |




We now apply the Wiener filter from part A into the noisy blurred image and we get the following image:


With MSE = 56.47175. The image looks pretty good but it looks a little blurry. However it still has noise that the filter couldn't eliminate and therefore it doesn't seem to have the best quality.

For the optimal filter for the noisy image we use wiener2() function on the noisy image and for 3 different window size giving us the following MSE values:

MSE 3x3: 17.71117
MSE 5x5: 17.71117
MSE 7x7: 17.71117

Which results in the following images:

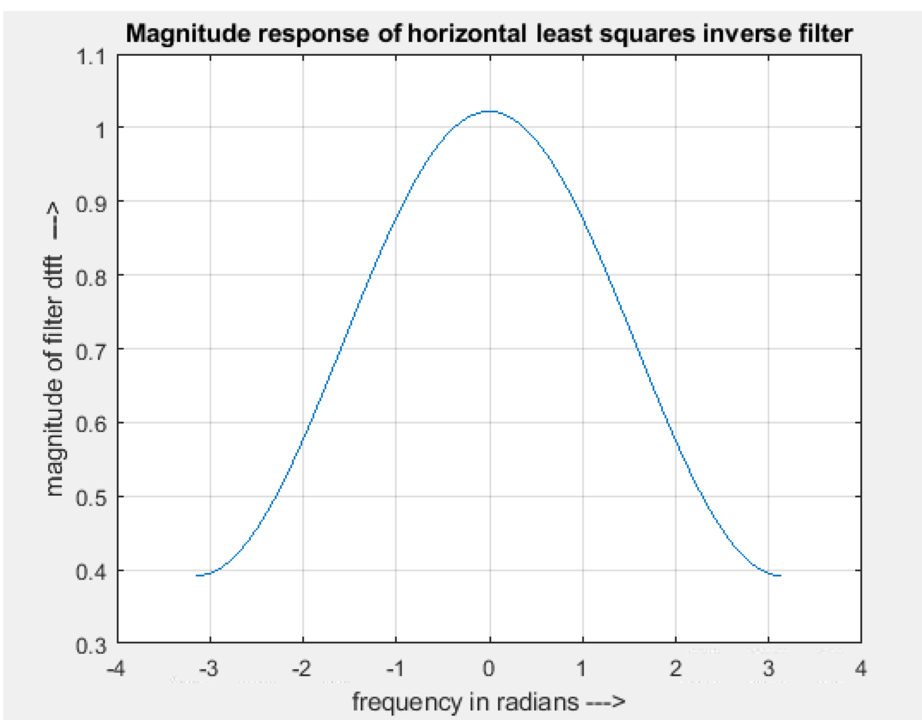


*Generating Noise with Standard Deviation = 5, sigman = 5:*

After Row Filtering:

MSE = 28.64251

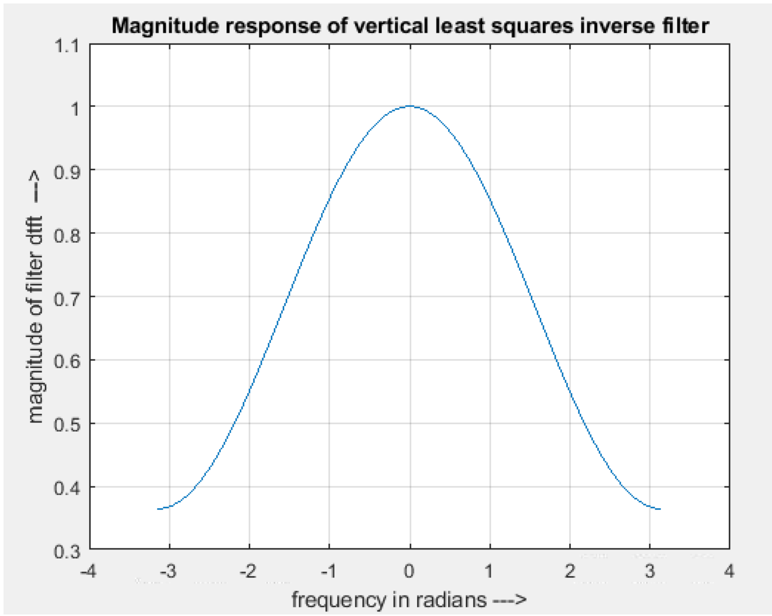
Filter Coefficients: [ 0.1572  0.7070  0.1577 ]



After Column Filtering:

MSE = 24.41462

Filter Coefficients: [ 0.1589  0.6823  0.1590 ]

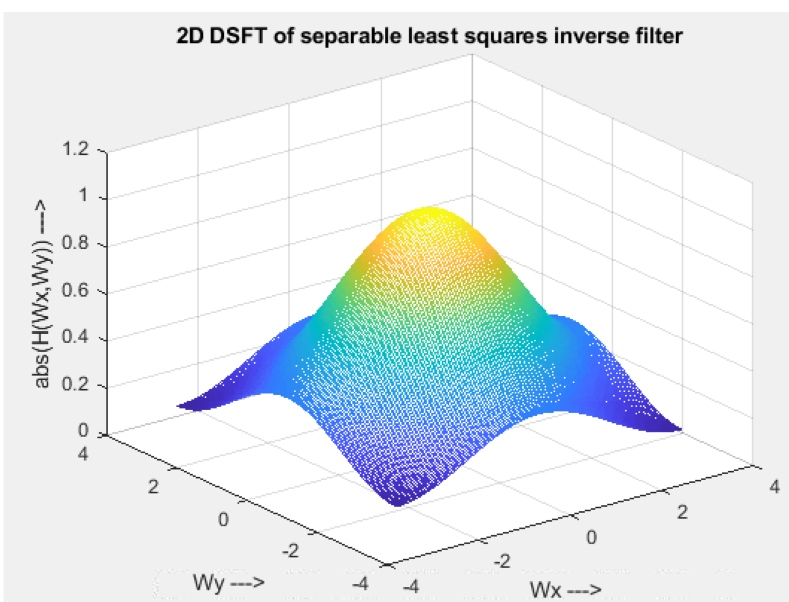



Inverse Filter:

MSE: 32.77662

Filter Coefficients:

| | | |
|---|---|---|
| 0.0250 | 0.1123 | 0.0251 |
| 0.1073 | 0.4824 | 0.1076 |
| 0.0250 | 0.1124 | 0.0251 |



We now apply the Wiener filter from part A into the noisy blurred image and we get the following image with MSE = 70.84469:


For the optimal filter for the noisy image we use wiener2() function on the noisy image and for 3 different window size giving us the following MSE values:
MSE 3x3: 4.566938e+01
MSE 5x5: 4.701762e+01
MSE 7x7: 4.905405e+01

Which results in the following images:

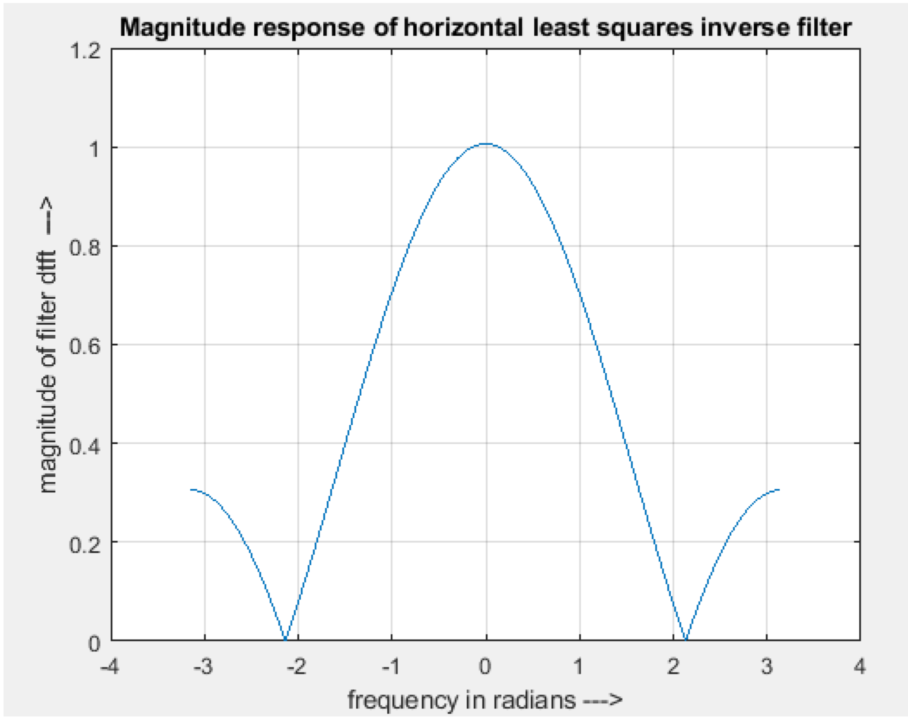


*Generating noise with Standard Deviation 30, sigman = 30:*

After Row Filtering:

MSE = 335.0856

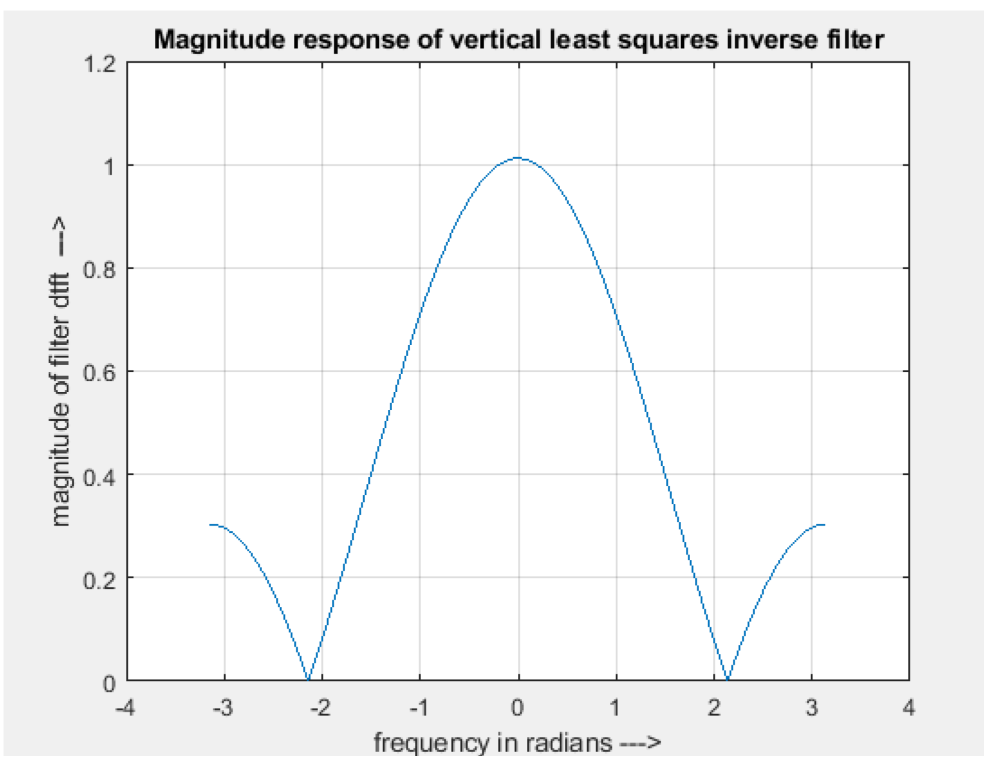
Filter Coefficients: [0.3282  0.3500  0.3274 ]




After Column Filtering:

MSE = 135.9569

Filter Coefficients: [ 0.3301  0.3541  0.3276 ]

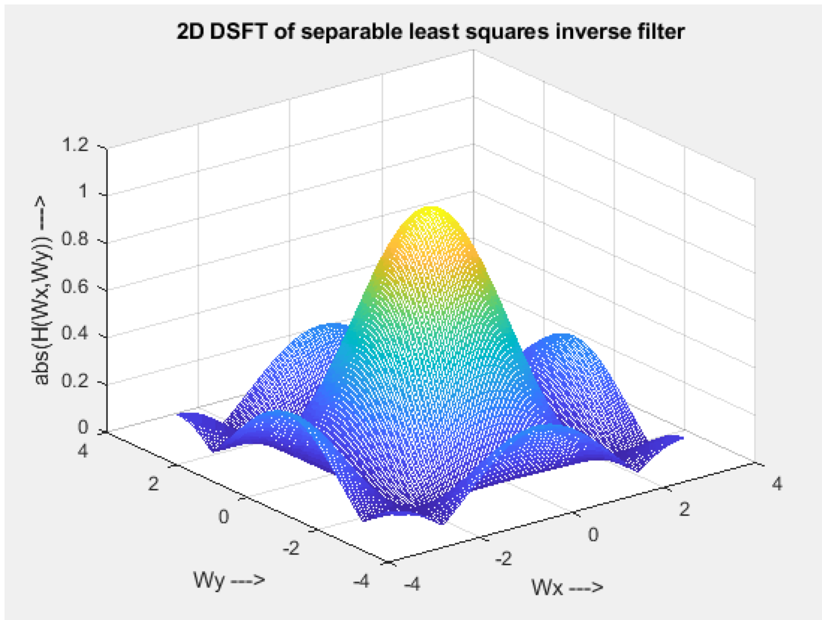


Inverse Filter:

MSE: 154.4721

Filter Coefficients:

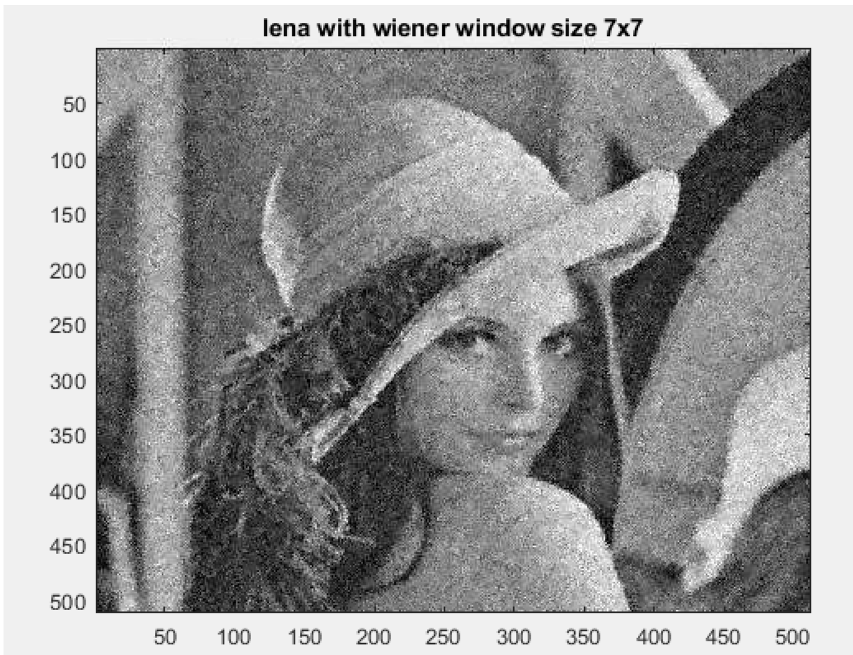
| | | |
|---|---|---|
| 0.1083 | 0.1155 | 0.1081 |
| 0.1162 | 0.1239 | 0.1159 |
| 0.1075 | 0.1147 | 0.1073 |




We now apply the Wiener filter from part A into the noisy blurred image and we get the following image with MSE = 579.2534:

For the optimal filter for the noisy image we use wiener2() function on the noisy image and for 3 different window size giving us the following MSE values:
MSE 3x3: 6.810683e+02
MSE 5x5: 6.025595e+02
MSE 7x7: 6.057018e+02

Which results in the following images:





The blurring filter provides the blurring effect on the image without adding noise to the image while wiener filter is used to unblur the image and to recover the image. The inverse blurring filter will be the inverse filter which performs better when recovering image with low noise than high noise, but not it is not optimal for recovering the blurred image with additive non-zero noise. Inverse wiener filter will perform better in images with lower noises.

The image recovery is pretty effective after applying the optimal filter to blurry images with additive noise. When additive noise is non-zero, we will need to find the optimal filter which can remove the high-frequency component which is due to the noise while preserving the high frequency component due to the original signal. After comparing the resulting recovered image for sigman = 0,5,30, we could find that as the standard deviation of gaussian noise is larger, the recovering is worse. The smoothing effect of filter increase as the noise level (standard deviation of gaussian noise) increase.

The inverse wiener filter in part A is same with inverse filter. It amplify the high-frequency noise components to preserve the high-frequency components of the original signal since there is no high- frequency noise. Therefore the wiener filter results in the inverse filter. The inverse wiener filter in part B need to preserve low frequency component of blurred image which are mostly given by the original signal. So we find a low pass filter in this end. Comparing 2 different noise realizations (sigman = 5 and 30), the frequency response of the one with sigman = 30 has shape of sinc function while the one with sigman = 5 is not, with magnitude of frequency response decaying on both side y axis.

Overall, in this lab we examine the wiener filters for both blurred image with zero noise and blurred image with non-zero noise. We also find the optimal filters for both situations and compare the resulting reconstructed image with different noise level.