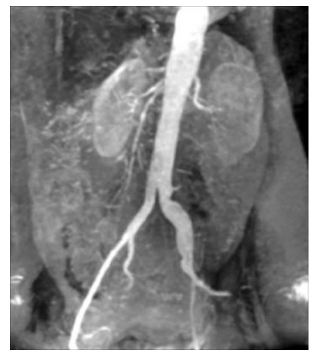
Digital Image Processing Homework 2

Problem 1:

In this assignment, you are asked to try Gamma transformation, histogram equalization, unsharp masking, and two additional methods of your choice to enhance the image shown on the right. For the two additional methods, you are encouraged to create your own based on the techniques you have learned from Chapter 3 (by, for example, mixing or modifying them). There is no standard solution. The score will be based on the quality of your enhanced image compared to the results of other students.

(a) Original Image.

(b) Box filtered image.



(c) Median filtered image.

For Problem 1, I have implemented several spatial transformations, including Gamma transformation, histogram equalization, unsharp masking, box filter, median filter, Laplacian and Sobel operators. In order to enhance the angiogram, I first noticed that the image is quite pixelated. Hence, I first applied box filter with 3x3 kernel to smoothen the image (Fig. b). Next, to remove the graininess of the image without losing much details, I tried a median filter with 3x3 kernel to denoise it (Fig. c). With above methods, now I have a rather less noisy image, I need to enhance the edges and features of the image, thus I performed the unsharp masking on it. The box filtered image is subtracted from the original image, and the unsharp mask is then added to the processed image with coefficient k=2.85 to highboost as much details as possible (Fig. d).

(d) Highboosted image.

(e) Hist equalized image.

(f) Final image.

After making sure to preserve the edges, I then proceed to perform histogram equalization to make sure the contrast is well-distributed (Fig. e). I think local histogram equalization would work well here to preserve details, however I only implemented global histogram equalization. Finally, for better illustration, I used gamma correction of gamma=1.95 to further darken the background and edges to achieve better contrast (Fig. f).

This transformation took a lot of time in fine-tuning the parameters to get better illustration to the details. To me, this enhancement looks quite OK as in the final enhanced image, there is a well distributed histogram and nice contrast, without really loosing much details. For example, the ducts in the left kidney is still preserved.

Problem 2:

Explain why the product of (b) and (e) in Fig. 3.57 serves as a mask image?

It works together as a mask image in the way that Laplacian is used to highlight the fine details and with smoothed Sobel gradient to emphasize on edges. The smoothed gradient has an effect on Laplacian such that the strong edges stay dominant and suppress the noise. It basically is just works as a mask for the Laplacian. Also, in [3], it stated that due to Laplacian is a second derivative operator, it gives greater response to the areas with rapid intensity discontinuities but prone to noises as compared to Sobel operators. So, by masking a smoothed Sobel gradient onto Laplacian, it gives us the benefits of both filters.

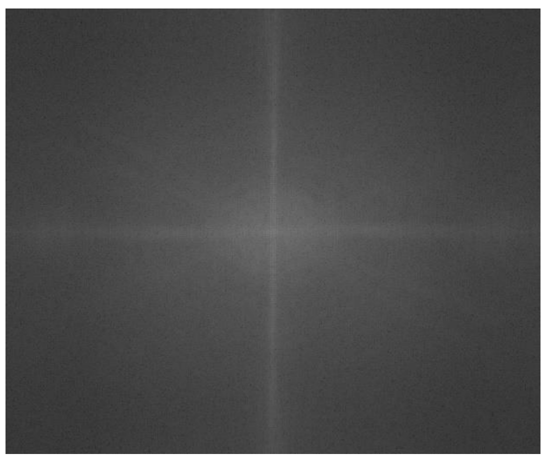
Problem 3:

Follow the steps outlined in Section 4.7 to repeat the experiment described in Example 4.15, pp. 271-273, on the vertical Sobel kernel shown in Fig. 4.38(a) and the test image "keyboard.tif". You may use any existing library to compute Fourier transform.

Original image "keyboard.tif".

(a) Show the Fourier spectrum of the test image "keyboard.tif".

The Fourier spectrum of the test image under log transformation is as shown as the image below:

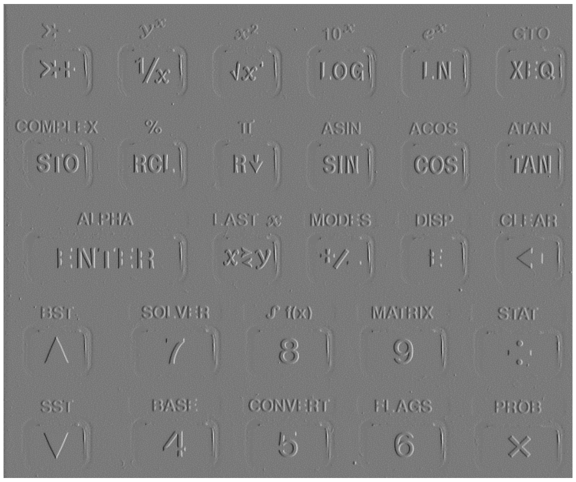


(b) Enforce odd symmetry on the kernel. Show the kernel.

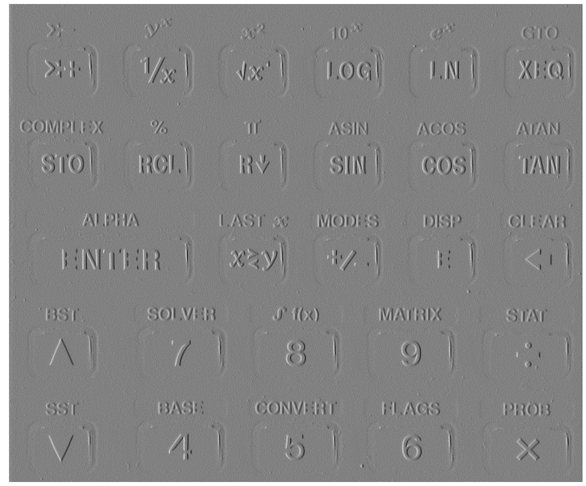
$$w_o(x, y) = -w_o(-x, -y)$$

The original Sobel kernel is not odd as its first element is not 0. According to Example 4.15, by adding leading rows and columns of zeros, we can convert the kernel into odd symmetry with the smallest size.

```
[[ 0.  0.  0.  0.]
 [ 0. -1.  0.  1.]
 [ 0. -2.  0.  2.]
 [ 0. -1.  0.  1.]]
```



(i) Frequency-domain filtering of test image.



(ii) Spatial-domain filtering of test image.

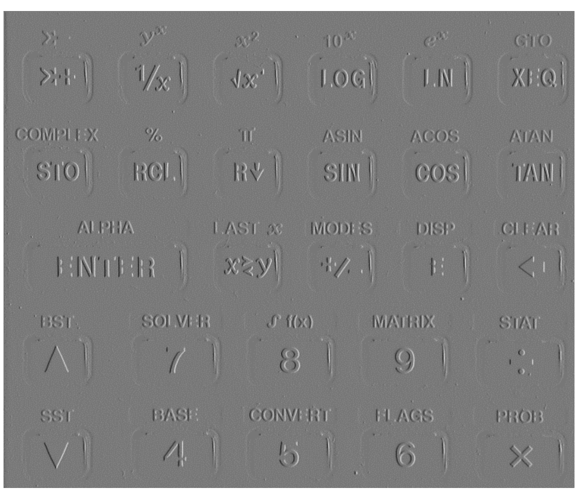
(c) Show the result of frequency-domain filtering of the test image using the vertical Sobel kernel.

The result of frequency-domain filtering of test image is shown in (i).

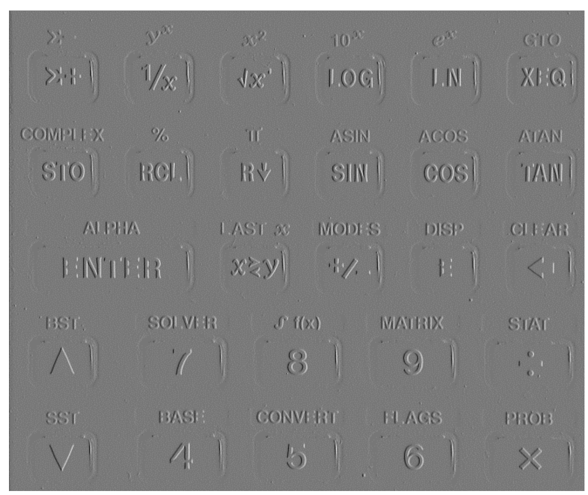
(d) Compare you result in (c) with the result of space-domain filtering.

The result of spatial-domain filtering of test image is shown in (ii). Filtering in both domains generates the same result.

(e) Show the result of frequency-domain filtering without enforcing odd symmetry on the kernel.



(iii) Odd symmetry on the kernel.



(iv) Without enforcing odd symmetry kernel.

Results of frequency-domain filtering with and without enforcing odd symmetry on the kernel are shown in (iii) and (iv) respectively. Although there is not much difference seeing with naked eyes, I have checked using functions that they indeed have different values.

Problem 4:

Similar to Problem 1 except that image enhancement is to be performed in the frequency domain, you are asked to try at least five methods to enhance the image shown on the right. Among the five methods, two can be your own creation. Your score will be based solely on the quality of the enhanced image. If you choose an inappropriate method that leads to a poor result, you score will be low.

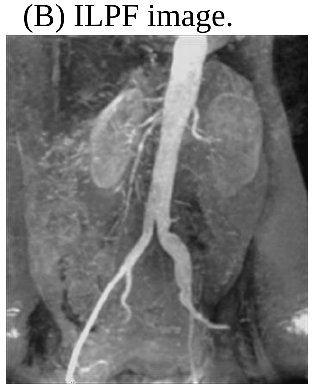
Since the test image is the same as in Problem 1, I used a similar thought process throughout enhancing the image in frequency domain. I have implemented transformations in frequency domain, including ideal lowpass and highpass filter, Butterworth lowpass filter, Laplacian, unsharp masking, Gaussian bandreject filter and homomorphic filter. In this instance, I used ideal lowpass filter to first smoothen the image with D_0=300 (Fig. A). Then, I used the Laplacian to focus on preserving the edges of the image (Fig. B). Furthermore, I applied the unsharp masking to further enhance the edges with k1=50, k2=5 (Fig. C). However, I wish to attain some sort of balance in between, hence I performed a Gaussian bandpass filter to preserve the band frequency in the middle, while lower some impact of the higher frequency and DC components with Co=160 and W=120 (Fig D). Finally, in order to enhance the contrast in the image to highlight the edges, I used the homomorphic filtering and control the frequency components with gamma_h=2.5, gamma_low=0.2 and D_0=70.

(A) Original Image.

(B) ILPF image.

(C) Laplacian image.

(D) Unsharp masking image.



(e) GBRF image.

(f) Final homomorphic image.

Overall, I think the filtering done in frequency domain is still OK, however I find it hard to manipulate the contrast of the image in f-domain, as there is not much transformation that has direct impact on it.

Reference(s):

[1] Digital Image Processing International Edition, 3nd Edition by R. C. Gonzalez.
[2] Lectures by Prof. Chen.
[3] Gupta, S., & Porwal, R. (2016). Combining Laplacian and Sobel gradient for greater sharpening. *IJIVP*, *6*, 1239-1243.