

Introduction to Image Processing HW3

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Method

In this homework, we are trying to implement edge sharpening methods using both Laplacian filters in the spatial and frequency domains.

Spatial Domain:

- First, I apply `np.pad` to the original grayscale image in order to retain its size after applying convolution. After comparing the results with different kernels, the kernel that produces the best sharpening results is:
$$\begin{bmatrix} 0 & 1 & 0 \\ 1 & -4 & 1 \\ 0 & 1 & 0 \end{bmatrix}$$
 Thus, I select this kernel for my sharpening process. Based on the Laplacian sharpening function $g(x, y) = f(x, y) + c[\nabla^2 f(x, y)]$ where $g(x, y)$ is sharpened image, $f(x, y)$ is the original image, c is a constant of -1, and $[\nabla^2 f(x, y)]$ represents the Laplacian image, we can obtain the Laplacian image by convolving the original image with the kernel. Once we have it, we can follow the formula mentioned to get the final results.

Frequency Domain:

- First, normalize the image and transfer it to frequency domain by using `np.fft.fft2` and using `np.fft.fftshift` to shift the low frequency to the center. Second, create Laplacian filter function $H(u, v) = -4\pi^2[(u - P/2)^2 + (v - Q/2)^2]$ and thus we can get Laplacian image by the formula $\nabla^2 f(x, y) = \mathcal{F}^{-1}[H(u, v)F(u, v)]$ and return the low frequency back from center to corner with `np.fft.ifftshift` and apply inverse Fourier transform `np.fft.ifft2`. Third, convert the

Laplacian image value into range of $[-1, 1]$. Last, we can get the result image by the formula $g(x, y) = f(x, y) + c[\nabla^2 f(x, y)]$ where c is -1.

Result

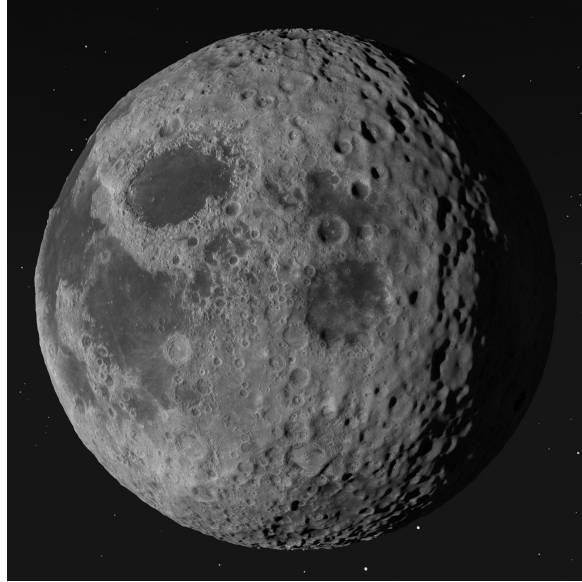


Figure 1: original image

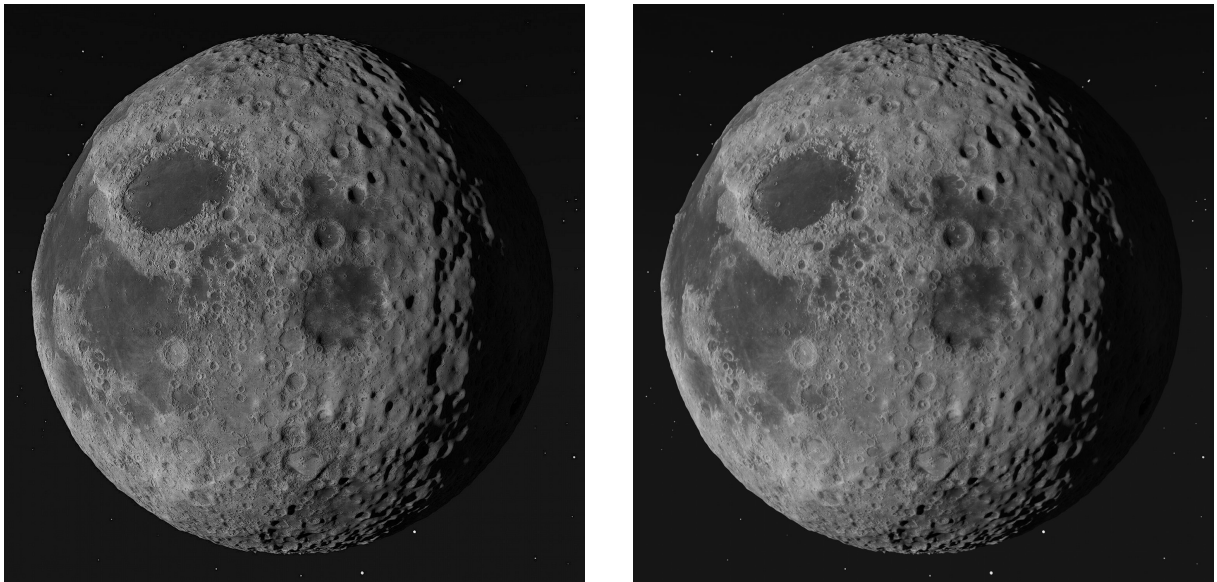


Figure 2: Left: spatial domain, Right: frequency domain

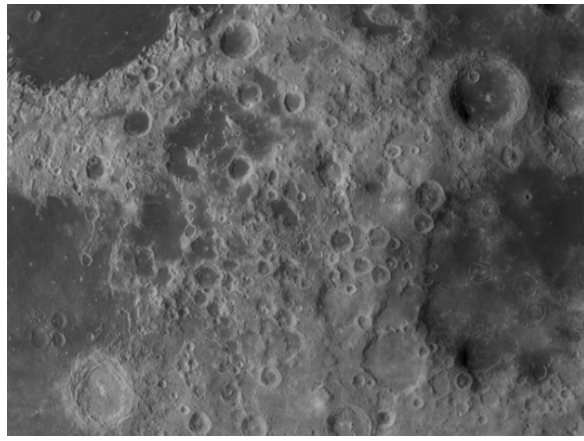


Figure 3: original_enlarge x5

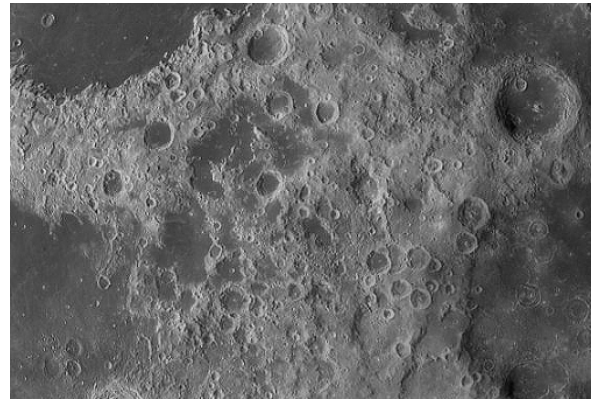
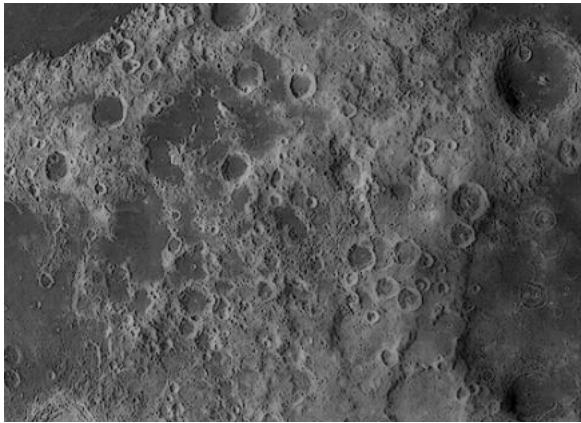


Figure 4: Left: spatial_enlarge x5, Right: frequency_enlarge x5

Feedback

After completing this homework, I've gained proficiency in applying Fourier transform to images, which has significantly enhanced my understanding of image sharpening techniques. Initially, the concept of the frequency domain seemed unfamiliar to me, but as I progressed through the homework, I gradually became more comfortable with it.