Image Processing HW02 - Image Sharpening in the spatial and frequency domains - CSIE 4B 408410120 鍾博丞

Date Information

- Due: 2022.11.18
- Last Modified: 2022.11.18

Environment Requirement

- python 3.5 or newer - for f-strings `f"Something {variable}"` and type hinting.
- Another requirements are written in `requirements.txt`, just type `pip install -r requirements.txt` in the terminal.
  - matplotlib
  - numpy
  - opencv-python == 4.5.5.62 (for auto-complete working on pycharm)
    - https://stackoverflow.com/questions/73174194/opencv-autocomplete-not-working-on-pycharm

Execution

The main python code is `main.py`, type the following command and then you can run the program.

```
python main.py
```

There are some parameters in `main.py`.

Note that the program will always save all images in `Img`.

Warning: The program will always ask user whether user want to delete the existing folder `Img` and recreate it or not. The default behavior is **No**. You can only press **Enter** into the console, which also means No.

- `is_show`: Tell the program if you want to show the result on the screen or not.
  - `True`: Show the result on the screen.
  - `False`: Don't show. Save it only.
- `radius_ratio`: This value is set for Ideal Low Pass Filter and Ideal High Pass Filter, determine the ratio of min(height / 2, width / 2).
  - For example, the height M and width N of `skeleton_orig.bmp` are 800 and 500. Therefore, the maximum radius of this image is 500 / 2 = 250.
  - If this value is 0.8, then the radius of these filters is 250 * 0.8 = 200.
- `high_boost_A`: The constant *A* of the high-boost filter.
  - $f_{hb}(x, y) = (A - 1)f(x, y) + f_{hp}(x, y)$
  - $A \geq 1$

All the methods are implemented in `spatial_image_enhancement.py` and `frequency_image_enhancement.py` and import in main as `sie` and `fie`, respectively.

Technical Description

fftshift - For Shifting the Image Center (M/2, N/2) to (0, 0)

Because of the repeatability of every signal, the shift method $(-1)^{x+y}$ equals to swap both sides cut from center for each axes (dimensions).

If the size is even, then the forward shifting is same as the inverse shifting.

However, if the size is odd, then we have to determine the cut boundary.

Here, we determine **ceiling** in forward shifting.

$$c_m = \left\lceil \frac{M}{2} \right\rceil,\ c_n = \left\lceil \frac{N}{2} \right\rceil$$

ifftshift - For Shifting the Image Center Back to (M/2, N/2)

Here, we determine **floor** in forward shifting when the size is odd.

$$c_m = \left\lfloor \frac{M}{2} \right\rfloor,\ c_n = \left\lfloor \frac{N}{2} \right\rfloor$$

calspec - Calculate Magnitude Spectrum

- Calculate the magnitude of each complex number.
- Take logarithm of the magnitudes: $\log(x+1)$. We add every magnitudes by 1 to prevent $\log(0) = -\infty$
- Normalize to [0, 1] and then transfer back to [0, 255].

Laplacian Filter in Frequency Domain

Since $\mathcal{F}(f(x,y)) = \dfrac{1}{MN} \displaystyle\sum_{u=0}^{M-1} \sum_{v=0}^{N-1} f(x,y) e^{-j2\pi(ux/M+vy/N)} = F(u,v)$,

then $\mathcal{F}(\dfrac{\partial^2 f(x,y)}{\partial x^2} + \dfrac{\partial^2 f(x,y)}{\partial y^2}) = F(u,v)(-j2\pi u)^2 + F(u,v)(-j2\pi v)^2 = -4\pi^2(u^2+v^2)F(u,v)$

Therefore, the Laplacian can be implemented in the frequency domain by using the filter

$H_{laplacaion}(u,v) = -4\pi^2(u^2+v^2)$.

Unsharp Masking

Sharpening images can be implemented by subtracting a blurred version of an image from the image itself, i.e., unsharp masking

$f_{hp}(x,y) = f(x,y) - f_{lp}(x,y) \Leftrightarrow F_{hp}(u,v) = F(u,v) - F_{lp}(u,v)$

Then, we add the mask to the original.

$f_{unsharp}(x,y) = f(x,y) + f_{hp}(x,y) \Leftrightarrow F_{unsharp}(u,v) = F(u,v) + F_{hp}(u,v)$

We can observe that the two steps can merge to a equation.

$f_{unsharp}(x,y) = 2 \times f(x,y) - f_{lp}(x,y) \Leftrightarrow F_{unsharp}(u,v) = 2 \times F(u,v) - F_{lp}(u,v)$

High-Boost Filtering

High-boost filtering generalizes this by multiplying $f(x,y)$ by a constant $A \geq 1$:

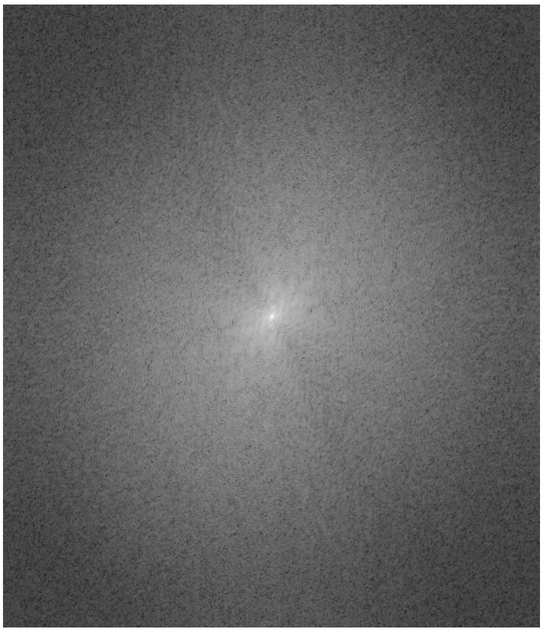
$$
\begin{aligned}
f_{hb}(x,y) &= Af(x,y) - f_{lp}(x,y) \\
&= (A-1)f(x,y) + f(x,y) - f_{lp}(x,y) \\
&= (A-1)f(x,y) + f_{hp}(x,y) \\
F_{hb}(u,v) &= (A-1)F(u,v) + F_{hp}(u,v) \\
H_{hb}(u,v)F(u,v) &= (A-1)F(u,v) + H_{hp}(u,v)F(u,v) \\
H_{hb}(u,v) &= (A-1) + H_{hp}(u,v)
\end{aligned}
$$

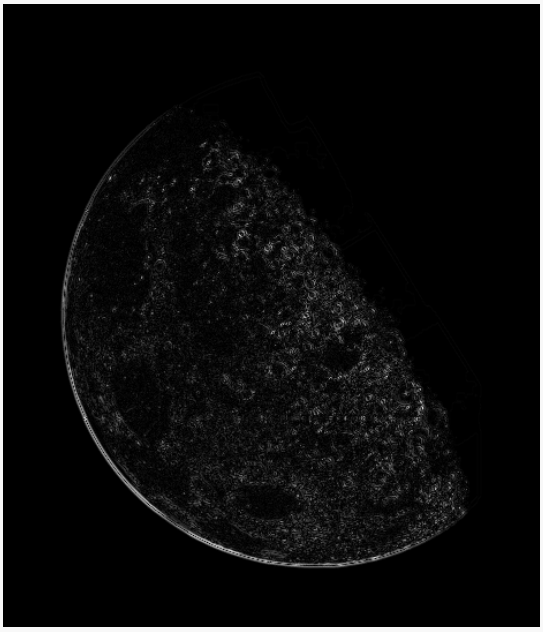
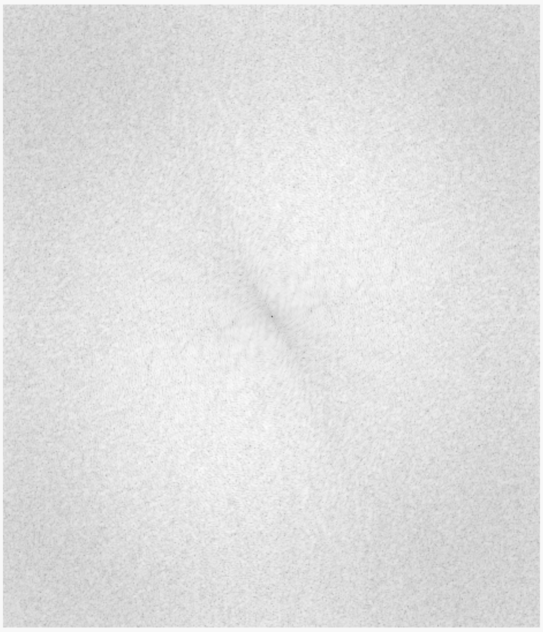
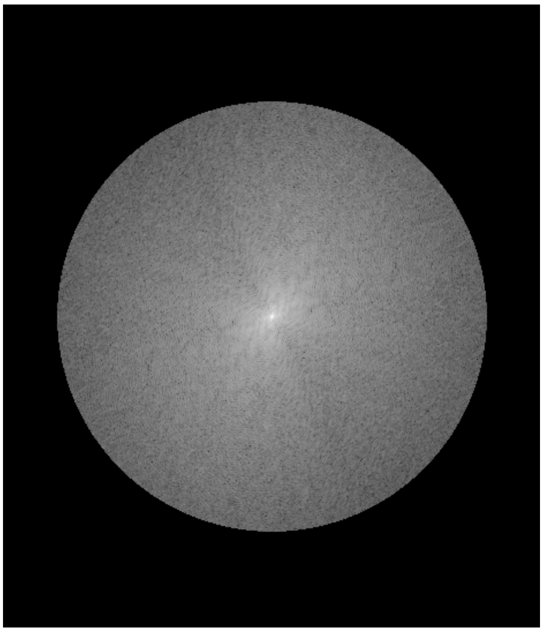
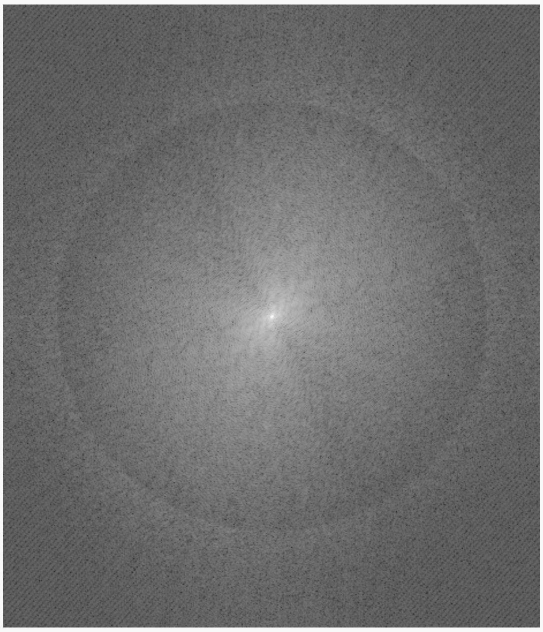
If $A = 2$, then it is same as unsharp masking.

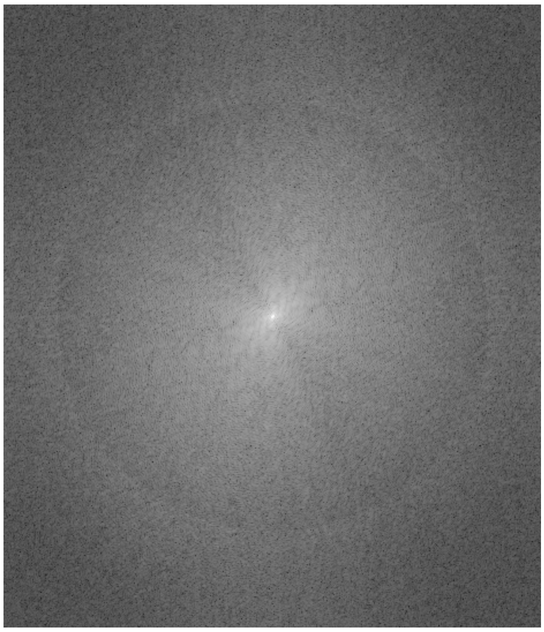
We define $A = 3$ here.

Experimental results

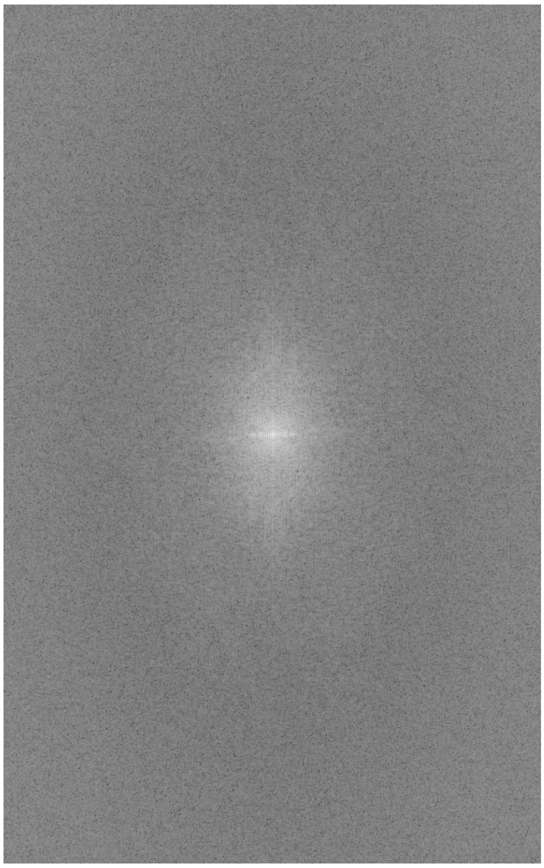
Blurry Moon

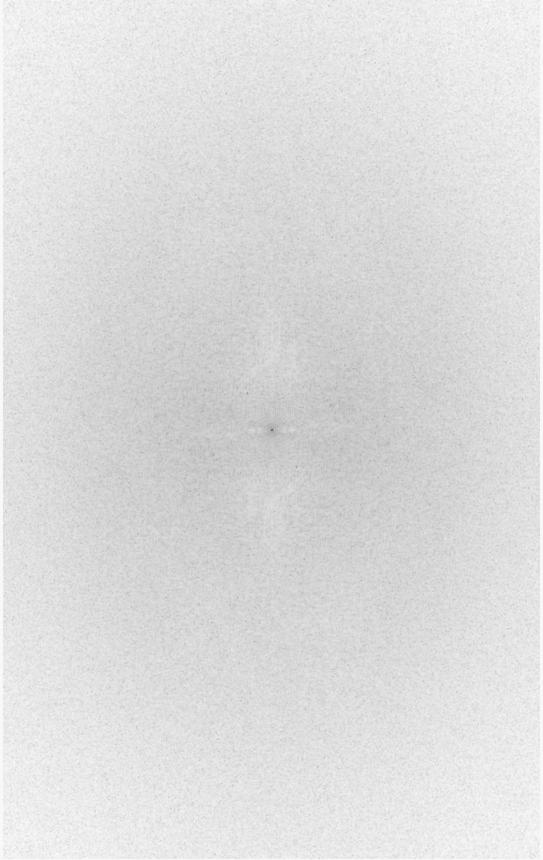
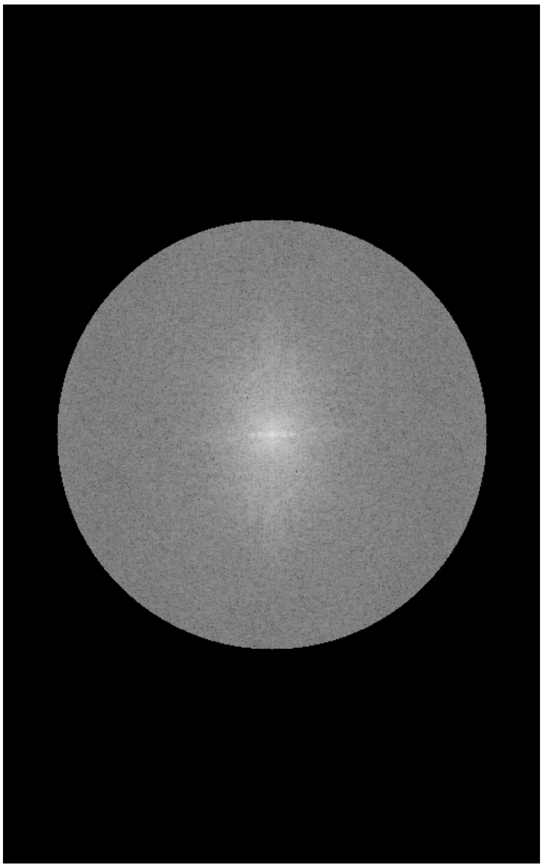
Method	Image	Spectrum
Origin		

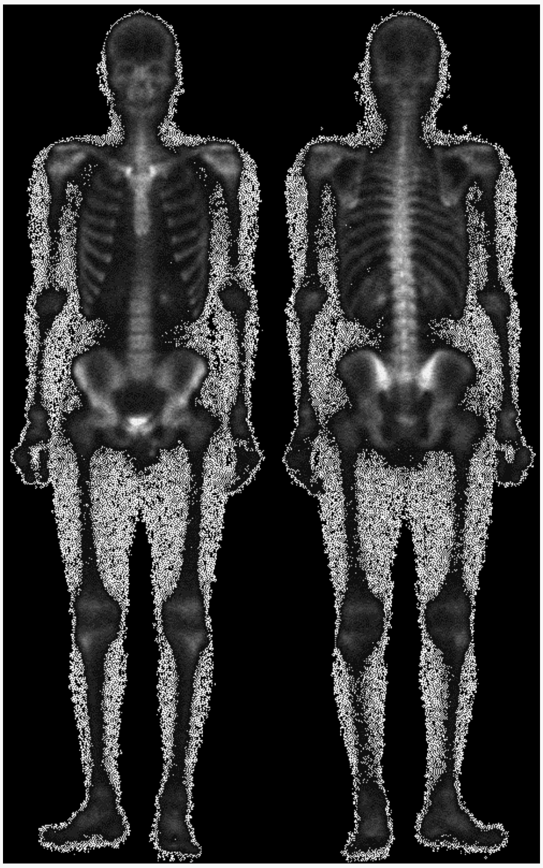
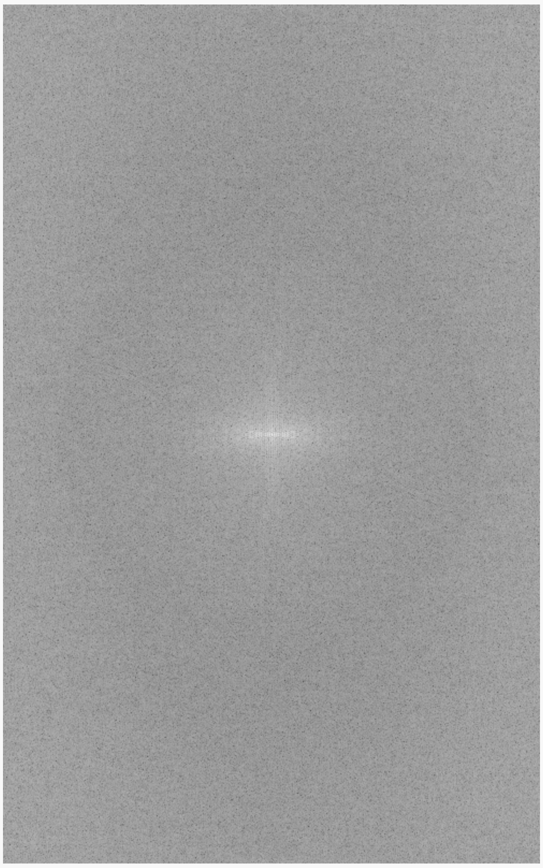
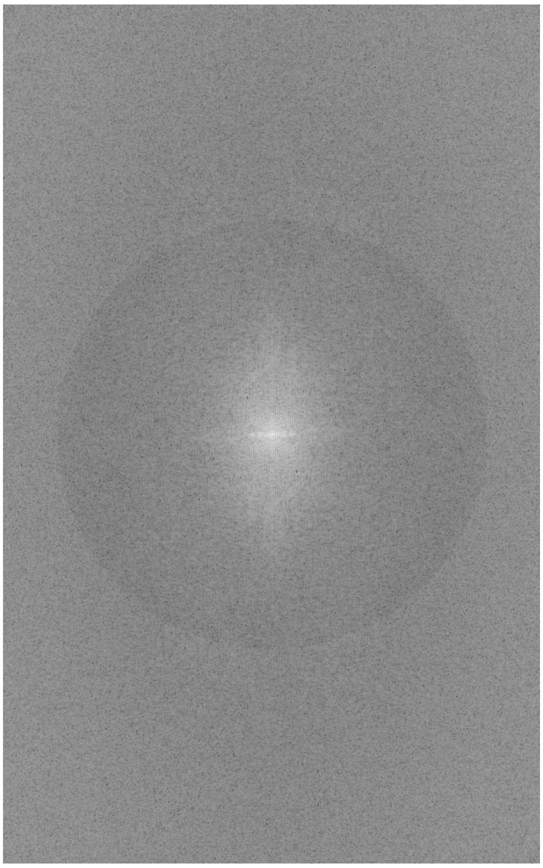
Method	Image	Spectrum
Laplacian Filtering		
ILPF r = 0.8		
Unsharp Filtering		

Method	Image	Spectrum
High-Boost A = 3		

Skeleton Original

Method	Image	Spectrum
Origin		

Method	Image	Spectrum
Laplacian Filtering		
ILPF r = 0.8		

Method	Image	Spectrum
Unsharp Filtering		
High-Boost A = 3		

Discussions

- Laplacian sometimes get too many edges. Same as unsharp filtering
- High-boosting tends to get better results.

- Fail to implement DFT and inv DFT. We use `np.fft.fft2` and `np.fft.ifft2` here.

Reference

- Course slides Ch03, Ch04.
- https://geek-docs.com/opencv/opencv-examples/gamma-correction.html
- https://levelup.gitconnected.com/introduction-to-histogram-equalization-for-digital-image-enhancement-420696db9e43
- https://medium.com/analytics-vidhya/2d-convolution-using-python-numpy-43442ff5f381
- https://gist.github.com/bistaumanga/5682774