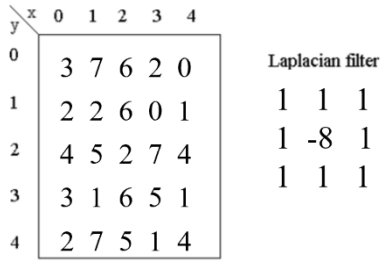
Student ID:

Question 1 (15 marks)

The following figure shows (a) a 3-bit image of size 5-by-5 image in the square, with x and y coordinates specified, (b) a Laplacian filter.



(a) (b)

Compute the following:

(a) The output of a 3 × 3 average smoothing filter at (3,3).
(b) The output of a 3 × 3 median filter at (2,3).
(c) The output of the 3 × 3 Laplacian filter shown above at (1,3).
(d) Obtain the histogram of the image.
(e) Apply histogram equalization on the above image and calculate the histogram equalized image, and the new histograms.

Solution:

(a) 1/9*(2+7+4+6+5+1+5+1+4)= 1/9*35

(b) 5 [1,1,2,5,5,5,6,7,7]

(c) -8*1+4+5+2+3+6+2+7+5=-8+34=26

(d)

Frequency	2	4	5	2	3	3	3	3
Intensity	0	1	2	3	4	5	6	7

(e)

Histogram equalization

r_k	n_r	$p_r(r_k)=n_r/MN$	$T_r=(L-1)P_r(r_k)$
0	2	2/25	7*3/25 =0.84 ->1
1	4	4/25	7*(2+4)/ 25 =1.68 ->2
2	5	5/25	7*(2+4+5)/ 25 =3.08 ->3
3	2	2/25	7*13/25 =3.64 ->4
4	3	3/25	7*16/25 =4.48 ->4
5	3	3/25	7*19/25 =5.52 ->5
6	3	3/25	7*22/25 =6.16 ->6
7	3	3/25	7*25/25 =7 ->7

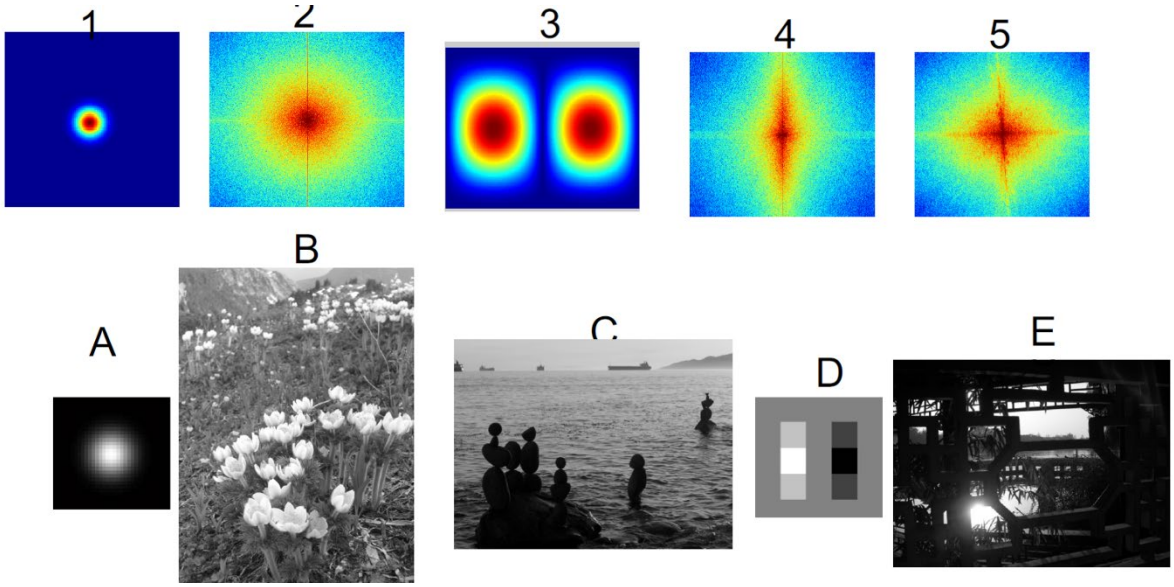
The new image:

4	7	6	3	1
3	4	6	2	2
4	7	3	5	4
4	1	6	3	2
5	7	5	2	3

New histogram:

Frequency	0	2	4	5	5	3	3	3
Intensity	0	1	2	3	4	5	6	7

Question 2 (15 marks)
Please match following images A-E with the corresponding Fourier spectrum 1-5? Explain the reasons.



Solution:

image A –> spectrum 1): a shape edge will result in high energy perpendicular to the edge.
image D –> spectrum 3): a shape edge will result in high energy perpendicular to the edge.
image B –> spectrum 2): Compared with other images, the changes in spatial domain of this image more slowly, therefore, it has more low frequency information in the frequency domain.

image E –> spectrum 5): By comparing images C and E, E has a fastly varying changes both in horizontal and vertical, therefore, image E has high frequency information in frequency domain in horizontal and vertical.
image C –> spectrum 4): E has a fastly varying changes both in vertical, therefore, image C has high frequency information in frequency domain in vertical direction.

Question 3 (10 marks)
Suppose that you form a lowpass spatial filter that average the four immediate neighbors of a point (x,y), but excludes the point itself.

(a) Find the equivalent filter H(u,v) in the frequency domain.
(b) Show that your result is a lowpass filter.

Solution:

(a) The spatial average is

$$g(x,y) = \frac{1}{4}\left[f(x,y+1) + f(x+1,y) + f(x-1,y) + f(x,y-1)\right]$$

$$\begin{aligned} G(u,v) &= \frac{1}{4}\left[e^{j2\pi v/N} + e^{j2\pi u/M} + e^{-j2\pi u/M} + e^{-j2\pi v/N}\right] F(u,v) \\ &= H(u,v)F(u,v), \end{aligned}$$

Therefore

$$H(u,v) = \frac{1}{2}\left[\cos(2\pi u/M) + \cos(2\pi v/N)\right]$$

(b) To see that this is a lowpass filter, it helps to express the preceding equation in the form of our familiar centered functions:

$$H(u,v) = \frac{1}{2}\left[\cos(2\pi[u - M/2)/M) + \cos(2\pi[v - N/2]/N)\right].$$

Consider one variable for convenience. As u ranges from 0 to M, the value of $\cos(2\pi[u - M/2)/M)$ starts at -1, peaks at 1 when $u = M/2$ (the center of the filter) and then decreases to -1 again when $u = M$. Thus, we see that the amplitude of the filter decreases as a function of distance from the origin of the centered filter, which is the characteristic of a lowpass filter. A similar argument is easily carried out when considering both variables simultaneously.

Question 4 (10 marks)

For given image "skeleton_orig.tif" in the canvas folder of 202202EE4211/Files/Lecture 2_Image enhancement in spatial domain/code, please utilize spatial enhancement methods, including both point processing and neighbourhood processing, to enhance the images. Please copy your codes here for the task, and put the original image and the enhanced one here. You can also upload the codes for checking.

Noted: There are many different ways to enhance this image. I just attached one example for your reference.