HW2: Histogram and Spatial Filtering

DIP Teaching Stuff, *Sun Yat-sen University*

Welcome to your second DIP homework! Histogram and Filtering are two of the **core** components of this course (the other core component is Fourier Transform in Chapter 4), hence you need to pay more attentions to this homework. All right, we know you can finish it well! Please submit a report (in **PDF** format) and all relevant codes as the homework solution. Warning: We encourage discussions among students, but homework solutions should be written and submitted **individually**, without copying existed answers. Plagiarism = Fail. Besides, there may be at least 30% penalty for late homework.

1 Exercises

Please answer the following questions in the report.

1.1 Linearity (15 Points)

Is histogram equalization a linear operator? Prove your answer.

1.2 Spatial Filtering (20 Points)

Consider a 4×4 gray image and a 3×3 filter:

$$Image: \begin{bmatrix} 1 & 2 & 2 & 1 \\ 2 & 3 & 3 & 2 \\ 2 & 3 & 3 & 2 \\ 1 & 2 & 2 & 1 \end{bmatrix} \qquad Filter: \frac{1}{9}\begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix}$$

1. Convolve the gray image with the given filter with zero-padding, and show your result (whose size should be 4×4). (7 Points)
2. Discuss the limiting effect of repeatedly applying the given filter to an image. (5 Points)
3. What is the difference between convolution and correlation? (5 Points)
4. Discuss some applications of the given filter based on your knowledge. (3 Points)

1.3 Spatial Filtering (10 Points)

There are a 5×5 input image and a 5×5 output image convolved with zero-padding, calculate the 3×3 convolution filter.

$$Input: \begin{bmatrix} 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 1 & 1 & 0 \\ 0 & 1 & 1 & 1 & 0 \\ 0 & 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix} \quad Output: \frac{1}{9}\begin{bmatrix} 1 & 2 & 3 & 2 & 1 \\ 2 & 4 & 6 & 4 & 2 \\ 3 & 6 & 9 & 6 & 3 \\ 2 & 4 & 6 & 4 & 2 \\ 1 & 2 & 3 & 2 & 1 \end{bmatrix}$$

2 Programming Tasks

Write programs to finish the following three tasks, and answer questions in your report. Don't forget to submit all relevant codes.

2.1 Pre-requirement

Input Please download the archive "hw2.zip", unzip it and choose the image corresponding to the last two digits of your student ID. This image is the initial input of your programming tasks in HW2. For example, if your student ID is "14110349", then you should take "49.png" as your input. You can convert the image format (to BMP, JPEG, ...) via Photoshop if necessary. Make sure that you have selected the correct image. Misusing images may result in zero scores.

Language Any language is allowed (python is recommended). Please submit the executable file and define the corresponding input in README.txt additionally.

Others There remain some issues that you should pay attention to:

1. You can use third-party packages for operating images. But you should manually implement your programming tasks. For example, though you can use "imread" of Matlab to load an image, you cannot invoke "conv2" or "filter2" or so forth of Matlab for spatial filtering.
2. Good UX (User Experience) is encouraged, but will only bring you negligible bonuses. Please don't spend too much time on it, since this is not an HCI course.
3. Keep your codes clean and well-documented. Bad coding styles will result in 20% penalty at most.

2.2 Histogram Equalization (30 Points)

Write a function that applies histogram equalization on a gray scale image. The function prototype is "**equalize hist(input img) → output img**", returning a gray scale image whose histogram is approximately flat. You can modify the prototype if necessary. For the report, please load your input image and use your program to:

1. Compute and display its histogram. Manually paste the histogram on your report. Note: You must compute the histogram by yourself, but 3rd-party APIs can be used for display. (5 Points)

2. Equalize the histogram, and paste the histogram-equalized image and the corresponding histogram on your report. (10 Points)

3. Equalize the histogram again, and paste the resulting histogram on your report. Does this second pass of histogram equalization produce exactly the same result as the first pass? Why? (10 Points)

4. Please discuss how you implement the histogram equalization operation in details, i.e., the "equalize hist" function, in **less** than 2 pages. Please focus on the algorithm part. Don't widely copy/paste your codes in the report, since your codes are also submitted. (5 Points)

2.3 Spatial Filtering (25 Points)

Write a function that performs spatial filtering on a gray scale image. The function prototype is "**filter2d(input img, filter) → output img**", where "filter" is the given filter. Modify the prototype if necessary. For the report, please load your input image and use your "filter2d" function to:

1. Smooth your input image with 3 × 3, 7 × 7 and 11 × 11 averaging filters respectively. Paste your three results on the report. (9 Points)

2. Sharpen your input image with a 3 × 3 Laplacian filter (using the variant specified in Fig. 3.37(b) of the textbook) and then paste the result. In addition, briefly discuss why Laplacian filter can be used for sharpening. (6 Points)

3. Perform high-boost filtering (i.e., $g(x,y) = f(x,y) + k * g_{mask}(x,y)$, see Eq. (3.6-9) of the textbook for other details) on your input image. The averaging part of the process should be done using the filter in Fig. 3.32(a) of the textbook. Choose a k (the weight in Eq. (3.6-9)) as you see fit. Write down the selected k and paste your result on the report. (5 Points)

4. Detailedly discuss how you implement the spatial filtering operation, i.e., the "filter2d" function, in **less** than 2 pages. (5 Points)

3 Reference

$$\frac{1}{9}\times\begin{array}{|c|c|c|}\hline 1 & 1 & 1 \\ \hline 1 & 1 & 1 \\ \hline 1 & 1 & 1 \\ \hline\end{array}\qquad \frac{1}{16}\times\begin{array}{|c|c|c|}\hline 1 & 2 & 1 \\ \hline 2 & 4 & 2 \\ \hline 1 & 2 & 1 \\ \hline\end{array}$$

a b

FIGURE 3.32 Two 3×3 smoothing (averaging) filter masks. The constant multiplier in front of each mask is equal to 1 divided by the sum of the values of its coefficients, as is required to compute an average.

0	1	0	1	1	1
1	−4	1	1	−8	1
0	1	0	1	1	1
0	−1	0	−1	−1	−1
−1	4	−1	−1	8	−1
0	−1	0	−1	−1	−1

a b
c d

FIGURE 3.37
(a) Filter mask used to implement Eq. (3.6-6).
(b) Mask used to implement an extension of this equation that includes the diagonal terms.
(c) and (d) Two other implementations of the Laplacian found frequently in practice.