Digital Image Processing (CSE/ECE 478)
Monsoon-2018
Assignment-2 (200 points)
Posted on: 23/08/18
Due on: 03/09/18

Grade Table (for teacher use only)

Question	Points	Score
1	30	
2	30	
3	20	
4	20	
5	20	
6	20	
7	10	
8	10	
9	50	
10	40	
Total:	250	

Note: Solve Q's 3, 5-8 on paper and scan them/take photos upload along with the report.

1. (30 points) Typically, the values within a linear spatial filter sum to either 0 or 1 (see Figure 1). This question is to investigate what happens when this is not the case.

    1. Construct modified instances of filters given in Figure 1 whose values do not sum to 1 or 0. Show results of filtering with these modified filters on images `sky.jpeg` and `sky2.jpg` (provided separately). You may have to choose values such that the sum of coefficients varies significantly from 0 or 1. Perform all your experiments/write code for grayscale version of images only. (20 points)
    2. Compare the results obtained using your modified filter and the results obtained using filters in Figure 1. What are your observations ? (5 points)
    3. For the filters in Figure 1, why do some filter coefficients sum to 1 while others sum to 0 ? (5 points)

$$\frac{1}{16}\begin{array}{|c|c|c|}\hline 1&2&1\\\hline 2&4&2\\\hline 1&2&1\\\hline\end{array}\qquad \frac{1}{256}\begin{array}{|c|c|c|c|c|}\hline 1&4&6&4&1\\\hline 4&16&24&16&4\\\hline 6&24&36&24&6\\\hline 4&16&24&16&4\\\hline 1&4&6&4&1\\\hline\end{array}\qquad \frac{1}{8}\begin{array}{|c|c|c|}\hline -1&0&1\\\hline -2&0&2\\\hline -1&0&1\\\hline\end{array}$$

Figure 1: Typical spatial image filters

2. (30 points) First, read the definition of a linear operator here : `http://vergil.chemistry.gatech.edu/notes/quantrev/node14.html`. Consider the operator A that acts on an image of size $m \times n$ and returns the first row of the image. In other words, given an image I with m rows and n columns, $A(I) = I_1$ where I_1 is the first row of I.
   1. Is A a linear operator ? Why ? (5 points)
   2. One way to represent a $m \times n$ image is by "flattening" - concatenate rows of the image into one long vector of length $m{*}n$. To achieve the same effect (i.e. obtaining the first row of the image) with a flattened image, what would A need to be ? More specifically, provide the matrix representation of A which can operate on a flattened image. (20 points)
   3. Read the definition of a nullspace here : `http://qr.ae/TUNRfb`. Images in the nullspace of operator A have a particular property. What is it ? (5 points)

3. (20 points) Prove that the median filter is a non-linear filter. Hint: Proof by counter-example.

4. (20 points) Consider Roberts, Prewitt, and Sobel filters (gradient operators shown in left figure), Laplacian filters (shown in the right image). Apply these filters on `barbara.jpg` and make observations upon comparing their outputs. Do the same for a suitable image of your choice.

Prewitt: $M_x = \begin{array}{|c|c|c|}\hline -1&0&1\\\hline -1&0&1\\\hline -1&0&1\\\hline\end{array}$; $M_y = \begin{array}{|c|c|c|}\hline 1&1&1\\\hline 0&0&0\\\hline -1&-1&-1\\\hline\end{array}$

Sobel: $M_x = \begin{array}{|c|c|c|}\hline -1&0&1\\\hline -2&0&2\\\hline -1&0&1\\\hline\end{array}$; $M_y = \begin{array}{|c|c|c|}\hline 1&2&1\\\hline 0&0&0\\\hline -1&-2&-1\\\hline\end{array}$

Roberts: $M_x = \begin{array}{|c|c|}\hline 0&1\\\hline -1&0\\\hline\end{array}$; $M_y = \begin{array}{|c|c|}\hline 1&0\\\hline 0&-1\\\hline\end{array}$

$\begin{array}{|c|c|c|}\hline 0&-1&0\\\hline -1&4&-1\\\hline 0&-1&0\\\hline\end{array}$

The laplacian operator

$\begin{array}{|c|c|c|}\hline -1&-1&-1\\\hline -1&8&-1\\\hline -1&-1&-1\\\hline\end{array}$

The laplacian operator (include diagonals)

5. (20 points) Question 3.14 from Chapter 3, Gonzalez and Woods, 3rd Edition

6. (20 points) Question 3.22 from Chapter 3, Gonzalez and Woods, 3rd Edition

7. (10 points) Question 3.27 from Chapter 3, Gonzalez and Woods, 3rd Edition

8. (10 points) Question 3.28 from Chapter 3, Gonzalez and Woods, 3rd Edition

9. (50 points) The implementation of linear spatial filters requires moving a mask centered at each pixel of the image, computing sum of products of mask coefficients and corresponding pixels.

1. Implement an algorithm for low-pass filtering a grayscale image by moving a $k \times k$ averaging filter of the form `ones(k)/(k^2)`. (5 points)
2. As the filter is moved from one spatial location to the next one, the filter window shares many common pixels in adjacent neighborhoods. Exploit this observation and implement a more efficient version of averaging filter. To appreciate the benefits of doing so, generate a plot of k vs run-time for various sized images. The plot diagram should contain a line plot for each image size you pick. Use different marker types to distinguish the default implementation and improved implementation. Just to give you a rough idea, look at `https://imgur.com/a/0HtYlTE`. (15 points)
3. Utilize the observation similar to above to implement an efficient version of a $k \times k$ median filter. Generate a plot figure similar to previous question. (30 points)

10. (40 points) Answer the following

    1. Implement the bilateral filter and apply it to the given gray-scale image `face.jpg` or some image of your choice to distinctly show the effect of the applied filter. (15 points)
    2. What is the effect of bilateral filtering in the regions of intensity discontinuity? How is this effect different from high-boost filtering? Compare results of bilateral filter with high-boost filtering on an image of your choice. (15 points)
    3. Show a table of result images demonstrating the effect of domain and range components of the bilateral filter. What are your observations ? (10 points)