APPM4058A - Digital Image Processing
Class Test I

March 19, 2018

Student Number:

Instructions

- Specified course materials, i.e., lecture slides, students' own notes, and exercises they have done, are allowed to be used during the test. When these materials are not in print, students are allowed to view them using laptops or pads.
- Electronic devices other then those specified above, and Internet are not allowed during the test.
- You may use a calculator.
- Test duration: 14:00 p.m. – 16:00 p.m.
- Write your student number in the header of each page.

Total Mark: [ ]/**60**

Part I **[20]**

1. Suppose a 4-bit greyscale image, I, has a histogram associated with a table of the possible grey values and their respective number of occurrences, n_i:

Grey level i	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
n_i	15	0	0	0	0	0	0	0	0	70	110	45	80	40	0	0

   (a) What would you expect the overall appearance of the image I to be? [2]

   (b) Apply a contrast stretching on the image I.

      i. Write down the transform function you used. Clearly describe each variable in the function, and the chosen values for the parameters if there is any. [1]

      ii. Put your final result in Table 1, where for each grey level, i, in the full dynamic range, write down the corresponding new value, s_i, in the transformed image, and the number of occurrences, n_i. [6]

i	0	1	2	3	4	5	6	7
s_i								
n_i								
i	8	9	10	11	12	13	14	15
s_i								
n_i								

Table 1: Write your results for the contrast stretching in this table.

(c) Apply a histogram equalization on the image I using the following transform function:

$$s_k = 15 * \sum_{j=0}^{k} p(n_j),\ k = 0, 1, \ldots, 15,$$

where $p(n_k) = \frac{n_k}{n}$, and n is the total number of pixels. (Round a fraction after the decimal point to 1 if it is greater than or equal to 0.5, and 0 otherwise.) [6]

(d) Comparing the results from contrast stretching and histogram equalization of image I, which method gives the better result for this particular image in terms of human perception? Why? [2]

2. A piecewise transform function with grey level range of $[0,255]$ is shown in Figure 1. Given that $(r_1,s_1) = (95,31)$ and $(r_2,s_2) = (159,223)$, find the corresponding transform function which consists of the equations for each piece of line. [3]

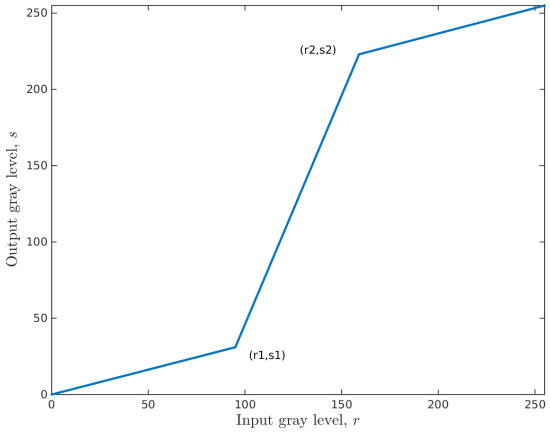


Figure 1: A piecewise linear transform function

Part II [19]

1. A 6-bit greyscale image, A, and two 3×3 filters, B_1 and B_2, are given in Table 2.

51	53	50	52	48	22	20	16	17	12
52	**50**	**51**	**54**	**50**	**21**	**16**	**21**	**16**	20
58	**57**	**54**	**60**	**57**	**24**	**14**	**23**	**19**	18
57	**55**	**57**	**62**	**55**	**22**	**12**	**24**	**17**	16
55	**54**	**58**	**64**	**60**	**20**	**10**	**25**	**18**	19
56	61	54	59	58	22	28	20	17	15

A

$\frac{1}{9}$

1	1	1
1	1	1
1	1	1

B_1

-1	0	1
-2	0	2
-1	0	1

B_2

Table 2: An image A, and two filters B_1 and B_2

(a) What is the effect of applying filter B_1 to the central part (displayed in bold) of image A? Why? [2]

(b) What is the effect of applying filter B_2 to the central part of image A? Why? [2]

(c) Suppose the filtered result of A by B_1 is A_{B_1}. What is the effect of the arithmetic operation $A - A_{B_1}$? [2]

2. If the transform function of a lowpass filter in frequency domain is $H_{LP}(u,v)$, what is the transform

function, H_{HP}, of the corresponding highpass filter? Given that $H_{LP} = \frac{1}{1+(D(u,v)/D_0)^{2n}}$, find the expression for H_{HP}. [3]

3. Given a filter $H(u,v)$ in frequency domain,

   (a) how do you apply it to an image? [3]

   (b) Assuming the character of filter H is as shown in Figure 2, what is the effect of applying it to an image? [2]

   (c) If the radius of the grey disk in Figure 2 is reduced, how does the effect change compared to that of using a larger disk? [2]

4. Considering two filters, one is in frequency domain, the other is in spatial domain, which one would you apply to an image degraded by periodic noise? What is your reason? [3]

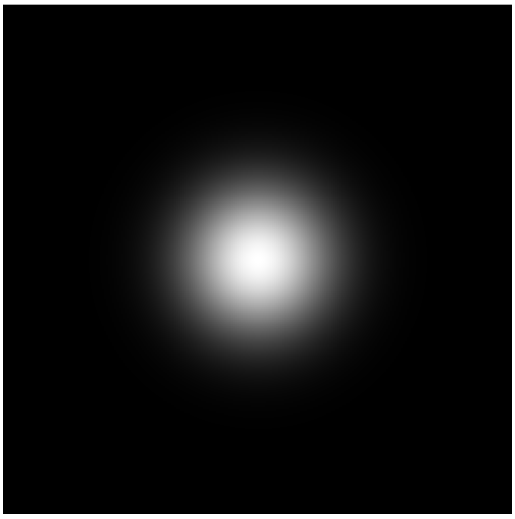


Figure 2: A filter in frequency domain

Part III [25]

1. Prove that $(A \circ B) \circ B = A \circ B$. [5]

2. Apply an morphology opening to the following 6×6 black and white image, A, using a 3×3 cross shaped structuring element, B. Write your answer in the provided tables in Table 3. Note that, in A and B, the foreground pixels are indicated using bullet points. However, in your result, you may use either a bullet point, or simply number '1' to indicate a foreground pixel. [6]

3. Given the result of the erosion of an image shown in Figure 3, which of the following structuring elements is most likely used to obtain the result? [2]

   A. A square structuring element with its origin at the top left corner.

   B. A square structuring element with its origin at the top right corner.

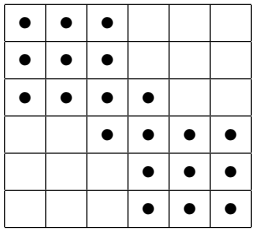
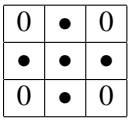
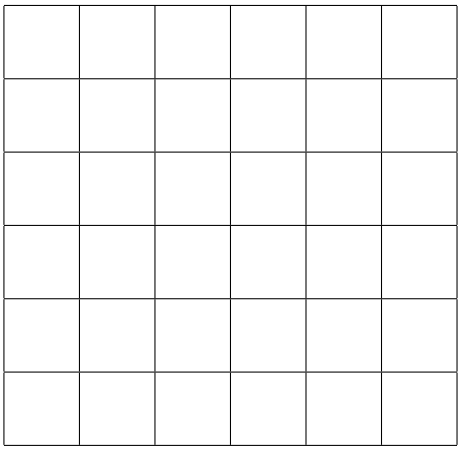


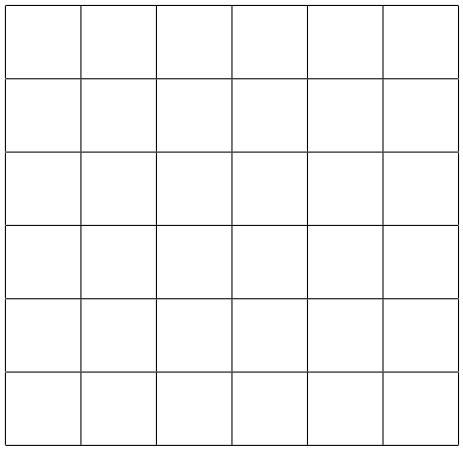
Image A



B



$A_E = A \ominus B$



$A_E \oplus B = A \circ B$

Table 3: The result of $A \circ B$

C. A square structuring element with its origin at the bottom left corner.

D. A square structuring element with its origin at the bottom right corner.

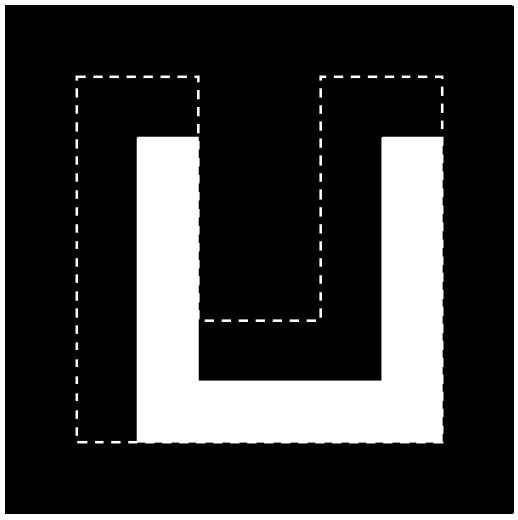


Figure 3: The result of an erosion. The original image is the 'U' shape shown in dashed line, and the result after erosion is shown in white solid 'U' shape.

Answer:

4. An image, A, is shown in Figure 4. A structuring element, B, is also shown in image A. However, B is not a part of A.

   (a) What does the resulting image, A_E, look like after an erosion of A using B? That is, the effect of the erosion on the image. [3]

   (b) Give an approach that would eliminate the noise in the image. Describe the effect of each step in your approach. [3]

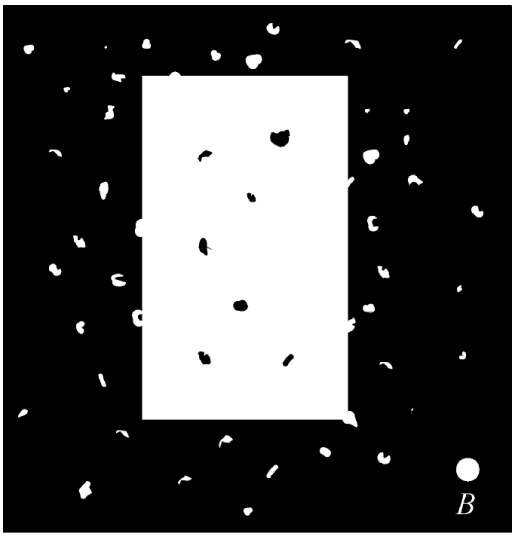


Figure 4: Image A

5. Compute the skeleton of the image in Table 4 using a square 3×3 structuring element shown in Table 5 with its origin at the center. You may use the provided tables to write your answers in. In such cases, clearly write down the expressions you computed underneath the tables. Either a bullet point or the

number ‘1’ can be used to indicate a foreground pixel. Note that the number of tables provided does not correspond to the number of steps for the computation. [6]

			•	•	•	•	•			
			•	•	•	•	•			
			•	•	•	•	•			
•	•	•	•	•	•	•	•	•	•	•
•	•	•	•	•	•	•	•	•	•	•
•	•	•	•	•	•	•	•	•	•	•
•	•	•	•	•	•	•	•	•	•	•
•	•	•	•	•	•	•	•	•	•	•
			•	•	•	•	•			
			•	•	•	•	•			
			•	•	•	•	•			

Table 4: Image C

1	1	1
1	1	1
1	1	1

Table 5: B