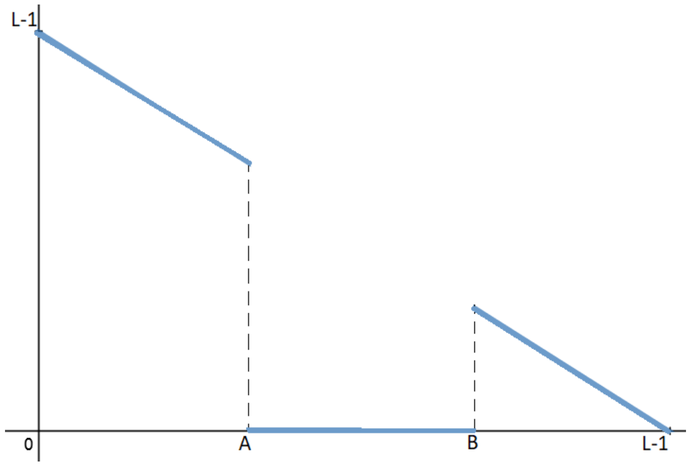
ANKARA UNIVERSITY
Computer Engineering
466 – Digital Image Processing
Final Examination

31.5.2020

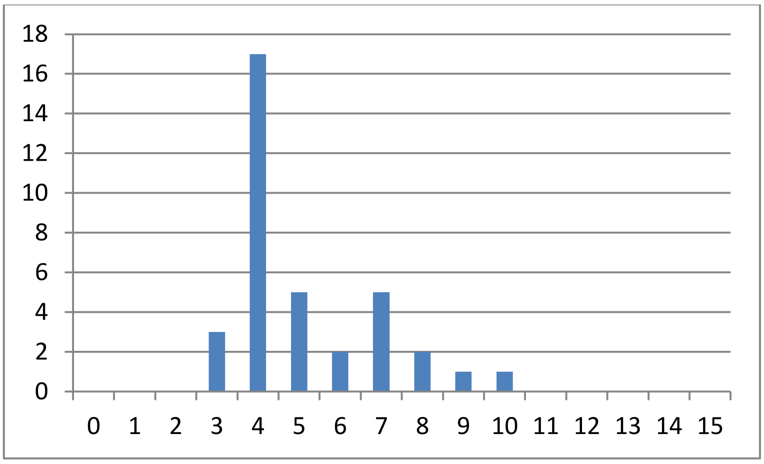
1. [10 points] Assume that we have a monochrome digital image in which intensities range between 0 and L-1. A and B (A<B) are 2 intensities in this range. We want to negate the intensities except those in between A and B. Intensities between A and B should become black (0). Plot the shape of the function to achieve this effect.



2. [35 points] The table below represents a 6x6 monochrome digital image with <u>4 bits per pixel</u>.

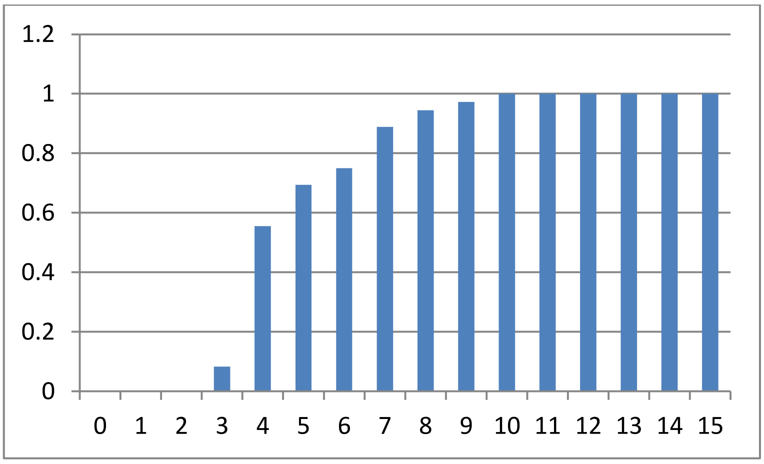
3	3	4	4	4	4
4	4	3	6	7	5
4	4	4	7	9	7
4	4	4	8	10	7
4	5	4	7	8	6
4	5	4	5	5	4

   a. [10 points] Show the histogram for this image.



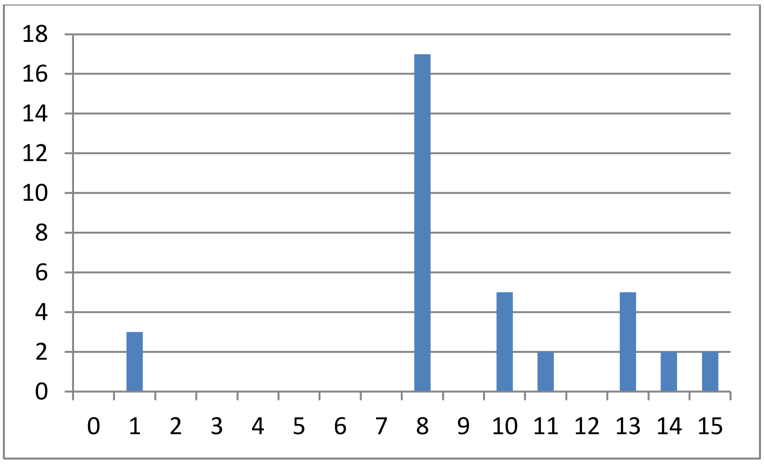
   b. [15 points] Apply histogram equalization to the image. Show your steps, resulting histogram, and the new image.

Cumulative histogram with values normalized to [0,1]



Old intensity	3	4	5	6	7	8	9	10
New intensity round(15*cumulativeValue)	1	8	10	11	13	14	15	15

The calculation above is only one possible calculation and one of the simplest ones. Other (and better) versions are also possible. Below are the resulting histogram and image.



1	1	8	8	8	8
8	8	1	11	13	10
8	8	8	13	15	13
8	8	8	14	15	13
8	10	8	13	14	11
8	10	8	10	10	8

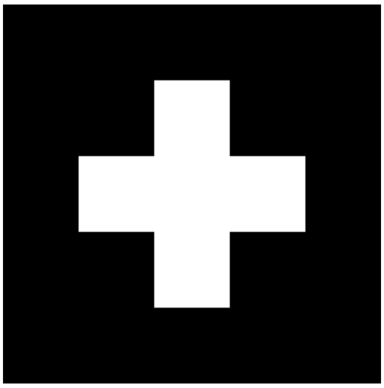
c. [10 points] Apply the weighted averaging filter given below to your result from part (b). If you did not answer (b) apply it to the original image above. Specify how you handled the missing pixels at the edges. You can choose any of the options described in the course.

1/16	2/16	1/16
2/16	4/16	2/16
1/16	2/16	1/16

One of the possible ways to handle the edges is to truncate the image. In other words, we only apply the 3x3 filter to non-edge pixels and the resulting image is 2 rows and 2 columns less than the input image. For the first placement of the filter on the image (when the filter is placed to the top left centering value 8 on second row and second column), the calculation is $\frac{1}{16}+\frac{2}{16}+\frac{8}{16}+\frac{8\times2}{16}+\frac{8\times4}{16}+\frac{2}{16}+\frac{8}{16}+\frac{8\times2}{16}+\frac{8}{16}\cong 5.81\cong 6$. The rest is the same calculation on other pixels.

6	7	10	11
8	8	12	14
8	10	12	14
9	10	12	12

3. [18 points] The image A below is a 15 x 15 binary image. White pixels should be considered as 1 and black pixels as 0. Sketch the result of the morphological operation $(A \ominus M1) \oplus M2$.

Image A: 

M1		
	1	
1	1	1
	1	

M2		
	1	
	1	
	1	

The image is numerically shown below.

0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	1	1	1	0	0	0	0	0	0
0	0	0	0	0	0	1	1	1	0	0	0	0	0	0
0	0	0	0	0	0	1	1	1	0	0	0	0	0	0
0	0	0	1	1	1	1	1	1	1	1	1	0	0	0
0	0	0	1	1	1	1	1	1	1	1	1	0	0	0
0	0	0	1	1	1	1	1	1	1	1	1	0	0	0
0	0	0	0	0	0	1	1	1	0	0	0	0	0	0
0	0	0	0	0	0	1	1	1	0	0	0	0	0	0
0	0	0	0	0	0	1	1	1	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

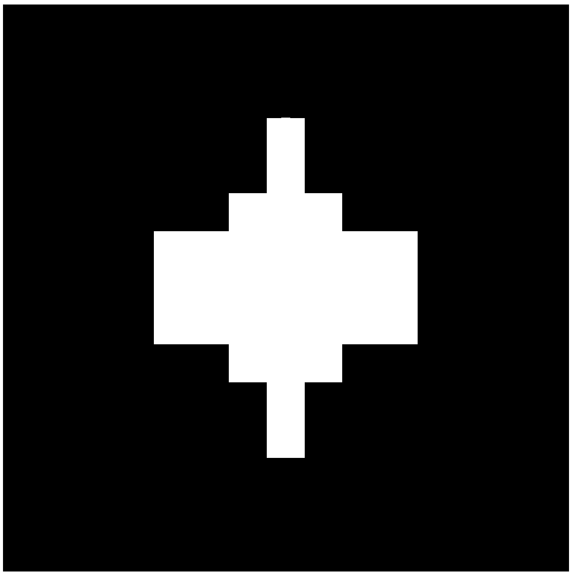
After eroding with M1 ($A \ominus M1$)

0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
0	0	0	0	0	0	1	1	1	0	0	0	0	0	0
0	0	0	0	1	1	1	1	1	1	1	0	0	0	0
0	0	0	0	0	0	1	1	1	0	0	0	0	0	0
0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

After dilating with M2 ($(A \ominus M1) \oplus M2$)

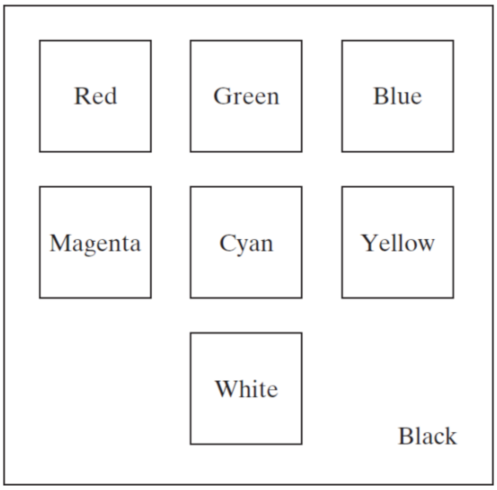
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
0	0	0	0	0	0	1	1	1	0	0	0	0	0	0
0	0	0	0	1	1	1	1	1	1	1	0	0	0	0
0	0	0	0	1	1	1	1	1	1	1	0	0	0	0
0	0	0	0	1	1	1	1	1	1	1	0	0	0	0
0	0	0	0	0	0	1	1	1	0	0	0	0	0	0
0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Without pixel values



4. [10 points] Consider the image given in the previous question as a MxN filter for a frequency domain filtering operation. In other words, we have the Fourier transform of a MxN image and we apply the plus shape filter you see above. What will be the effect of this operation on the image?

In the Fourier transform the center represents high frequencies and as we go away from the center, we are looking at lower frequencies. Because of this, the + shape above will be a type of high pass filter where the low frequencies are removed and the high frequencies are kept. The effect will be similar to the sharpening operation. But in addition, horizontal and vertical cutoff is not the same as diagonal cutoff. So, the shape allows more frequencies in the horizontal and vertical direction compared to diagonal directions. As a result, horizontal and vertical details are more likely to be kept compared to diagonal details.



5. [27 points] Consider the image on the right composed of solid color squares. For discussing your answer, choose a gray scale consisting of eight shades of gray, 0 through 7, where 0 is black and 7 is white. Suppose that the image is converted to HSI color space. In answering the following questions, use specific numbers for the pixels' values.
   a. [9 points] Sketch the hue image.

0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	2	2	2	0	5	5	5	0
0	0	0	0	0	2	2	2	0	5	5	5	0
0	0	0	0	0	2	2	2	0	5	5	5	0
0	0	0	0	0	0	0	0	0	0	0	0	0
0	4	4	4	0	6	6	6	0	1	1	1	0
0	4	4	4	0	6	6	6	0	1	1	1	0
0	4	4	4	0	6	6	6	0	1	1	1	0
0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0

   b. [9 points] Sketch the saturation image.

0	0	0	0	0	0	0	0	0	0	0	0	0
0	7	7	7	0	7	7	7	0	7	7	7	0
0	7	7	7	0	7	7	7	0	7	7	7	0
0	7	7	7	0	7	7	7	0	7	7	7	0
0	0	0	0	0	0	0	0	0	0	0	0	0
0	7	7	7	0	7	7	7	0	7	7	7	0
0	7	7	7	0	7	7	7	0	7	7	7	0
0	7	7	7	0	7	7	7	0	7	7	7	0
0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0

c. [9 points] Sketch the intensity image.

0	0	0	0	0	0	0	0	0	0	0	0	0
0	2	2	2	0	2	2	2	0	2	2	2	0
0	2	2	2	0	2	2	2	0	2	2	2	0
0	2	2	2	0	2	2	2	0	2	2	2	0
0	0	0	0	0	0	0	0	0	0	0	0	0
0	5	5	5	0	5	5	5	0	5	5	5	0
0	5	5	5	0	5	5	5	0	5	5	5	0
0	5	5	5	0	5	5	5	0	5	5	5	0
0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	7	7	7	0	0	0	0	0
0	0	0	0	0	7	7	7	0	0	0	0	0
0	0	0	0	0	7	7	7	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0