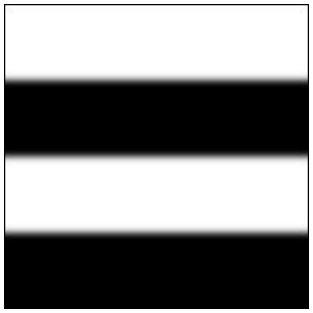
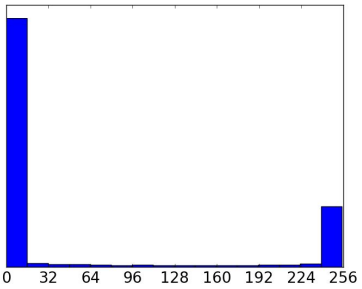
| Fundamentals of Computer Vision - Midterm Exam | B. Nasihatkon | دانشگاه صنعتی خواجه نصیرالدین طوسی<br>K. N. TOOSI UNIVERSITY OF TECHNOLOGY |
|---|---|---|
| **Name:** | **ID:** | **Ordibehesht 1397 - April 2018** |

# Question 1- Histogram (14 points)

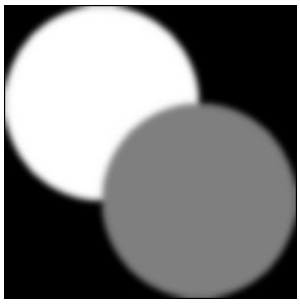
What is the corresponding histogram for each image? **Explain.**



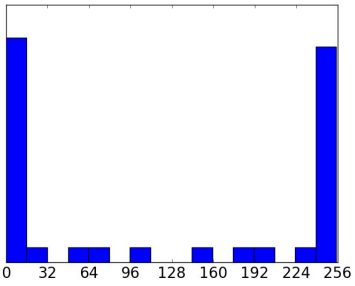
(B) Approximately equal number of black and white pixels. Few gray pixels.



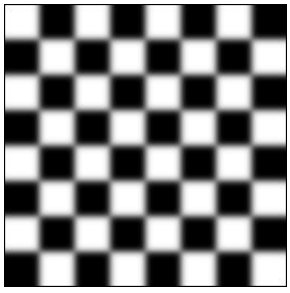

(A)



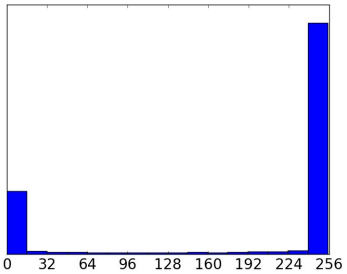
(D) It mostly consists of three colors: black, white and an average gray color. Besides these, other gray colored pixels are few. Thus, the histogram must have three major peaks.



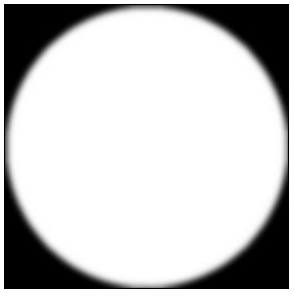

(B)



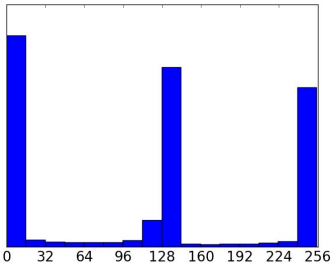
(B) approximately equal number of black and white pixels, and few gray pixels.




(C)



(C) Mostly consists of pure black and pure white pixels, but the white pixels are more than the black ones.




(D)

# Question 2: Image Filtering (18 points)

Write down the elements of the 3x3 linear filter that takes the input image (left) to the output image (right), for (A) a correlation operation, and (B) a convolution operation. **Write down your derivations.**

**Input image**

| | | | | |
|---|---|---|---|---|
| 1 | 2 | 1 | 3 | 1 |
| 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 |
| 1 | 2 | 0 | 0 | 4 |
| 0 | 0 | 0 | 0 | 0 |

**Filtered image**

| | | | | |
|---|---|---|---|---|
| X | X | X | X | X |
| X | 1 | -2 | 2 | X |
| X | -4 | 6 | -16 | X |
| X | 0 | -8 | 12 | X |
| X | X | X | X | X |

**Correlation Filter (11 potins)**

| | | |
|---|---|---|
| 0 | 1 | -1 |
| -4 | 2 | 3 |
| 3 | -3.5 | -4 |

**Convolution Filter (7 points)**

| | | |
|---|---|---|
| -4 | -3.5 | 3 |
| 3 | 2 | -4 |
| -1 | 1 | 0 |

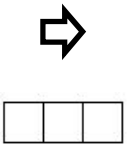
# Question 3: Median Filtering (16 points)

Apply a 1x3 Median Filter on the input image `I0` to obtain `I1`, then apply a 3x1 median filter on `I1` to get `I2`. Now, directly apply a 3x3 median filter on `I0` to obtain `I3`. Fill in the blank pixel values in `I1`, `I2` and `I3`.

**I0**

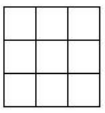
| | | | | |
|---|---|---|---|---|
| 1 | 2 | 1 | 3 | 4 |
| 4 | 3 | 48 | 44 | 0 |
| 2 | 37 | 40 | 5 | 1 |
| 1 | 2 | 0 | 1 | 4 |

1x3 filter



**I1**

| | | | | |
|---|---|---|---|---|
| X | 1 | 2 | 3 | X |
| X | 4 | 44 | 44 | X |
| X | 37 | 37 | 5 | X |
| X | 1 | 1 | 1 | X |



3x3 filter

3x1 filter

**I3**

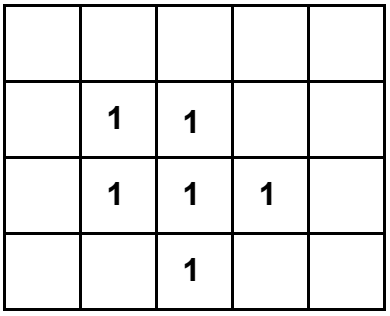
| | | | | |
|---|---|---|---|---|
| X | X | X | X | X |
| X | 3 | 5 | 4 | X |
| X | 3 | 5 | 4 | X |
| X | X | X | X | X |

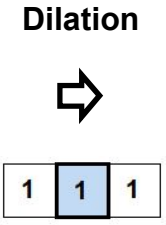
**I2**

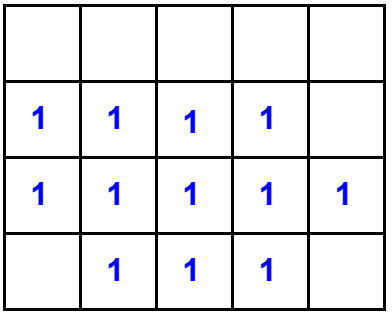
| | | | | |
|---|---|---|---|---|
| X | X | X | X | X |
| X | 4 | 37 | 5 | X |
| X | 4 | 37 | 5 | X |
| X | X | X | X | X |

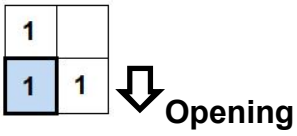
# Question 4: Morphology (16 Points)

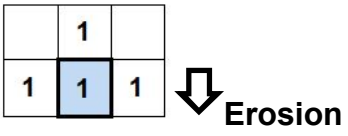
Apply the morphological operations as shown in the images below. Notice that some operations are applied to the output of other operations. In each case the centre of the structuring element has been highlighted. In both the input image and structuring elements only the ON pixels (value=1) are shown. The blank pixels are zero-valued. Also, the value of pixels outside the image boundary is 0.

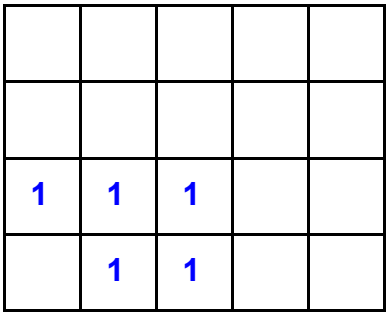


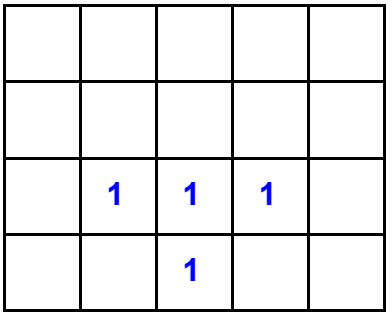


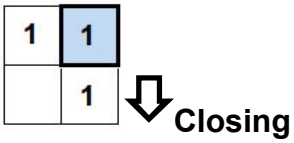



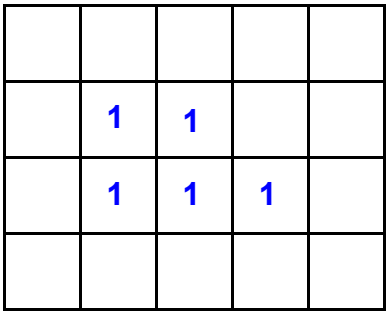


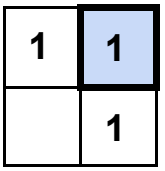









# Question 5 - Edge Detection/ non-maximum suppression (20 points)

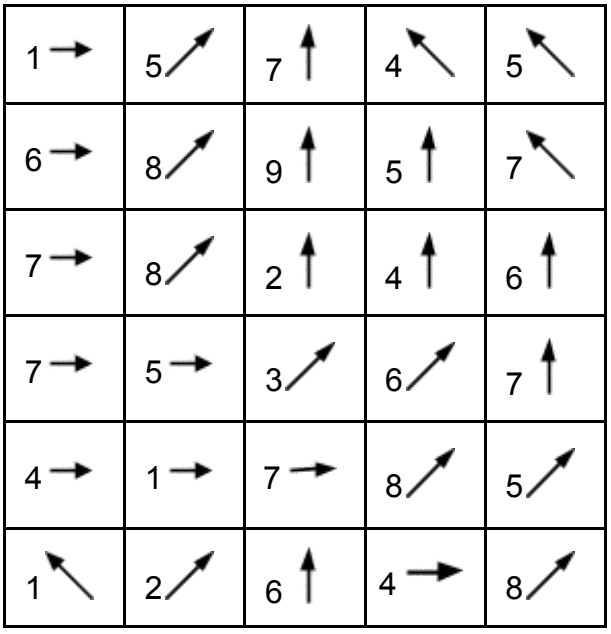
The figure below shows the gradient field computed for a 5x6 image. At each pixel, the magnitude and direction of the gradient are shown. Your task is to determine the edge pixels by thresholding and non-maximum suppression. All gradient directions are multiples of 45 degrees. The magnitude of the gradient is equal to zero outside the image boundaries. Find the edge pixels when

A) applying non-maximum suppression on the gradient field (without thresholding). This is equivalent to setting **threshold = 0**.

B) Just thresholding the magnitude of the gradient with threshold = **4.5**.

C) Apply non-maximum suppression after thresholding.

**gradient field**




A) non-maximum suppression on gradient field (no threshold)

| | | | | |
|---|---|---|---|---|
| | | | | 1 |
| | 1 | 1 | 1 | 1 |
| | | | | |
| 1 | | | | 1 |
| 1 | | | 1 | 1 |
| 1 | | | | 1 |

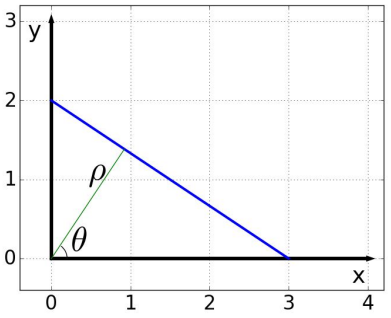
B) Thresholding Magnitude of Gradient (threshold = 4.5)

| | | | | |
|---|---|---|---|---|
| | 1 | 1 | | 1 |
| 1 | 1 | 1 | 1 | 1 |
| 1 | 1 | | | 1 |
| 1 | 1 | | 1 | 1 |
| | | 1 | 1 | 1 |
| | | 1 | | 1 |

C) Non-maximum Suppression after thresholding

| | | | | |
|---|---|---|---|---|
| | | | | 1 |
| | 1 | 1 | 1 | 1 |
| | | | | |
| 1 | | | | 1 |
| | | | 1 | 1 |
| | | | | 1 |

# Question 6 - Hough Transform (16 points)

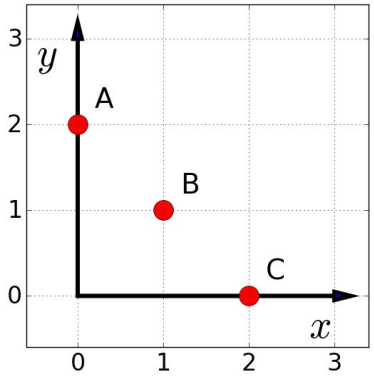



Assume that the lines are parameterized with an angle $\theta$ of the line normal and a distance $\rho$ from the origin:

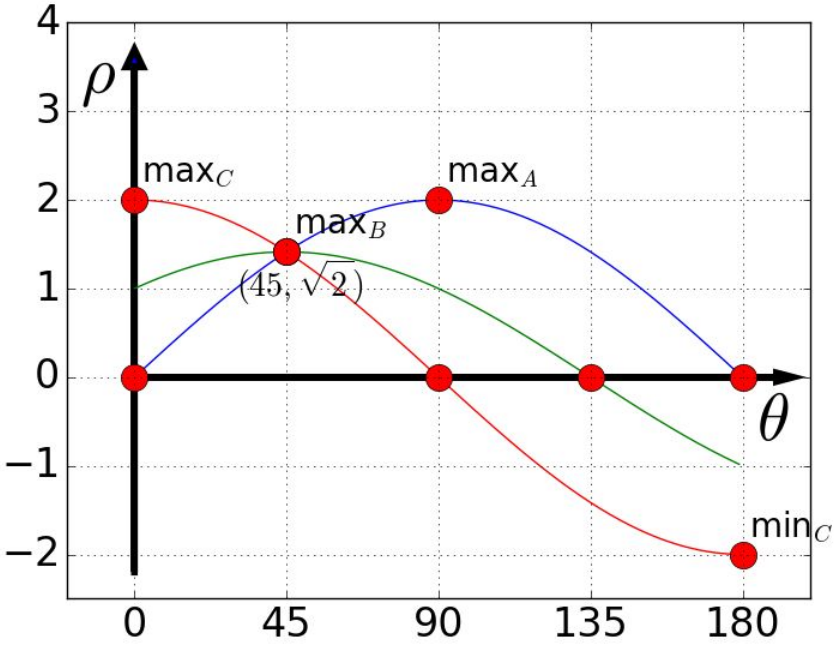
$$x\,cos(\theta) + y\,sin(\theta) = \rho$$

A) For each of the points in the image space below (left), draw the corresponding sinusoid in the hough space (on range of 0-180 degrees). Mark the ( $\theta$ , $\rho$ ) coordinates of the minimum and maximum of the sinusoid when applicable, plus the $\theta$ value of zero crossings. Also, mark the intersection point(s) of the three plots. What does the intersection(s) correspond to? (16 points)

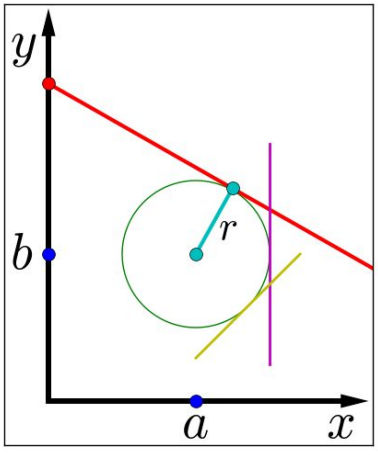
**Image Space**

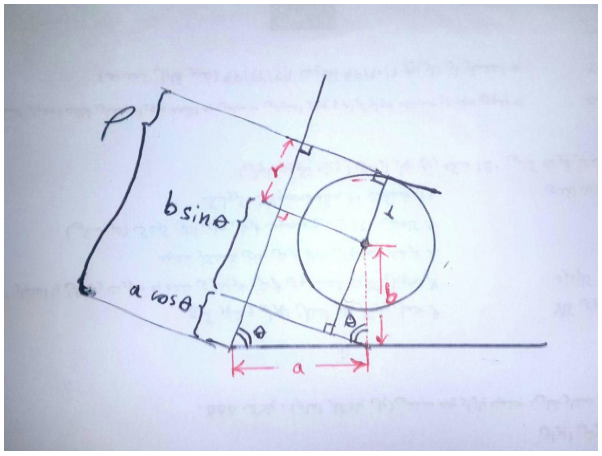



**Hough Space**




B) Consider a circle centred at (a,b) with radius r. What is the locus of all lines tangent to this circle in the hough space? Derive an equation describing the locus. **(+10 points)**




$$\rho = r + a\,cos(\theta) + b\,sin(\theta)$$

Notice that for r=0 it reduces to an ordinary hough sinusoid for the point (a,b).