Fundamentals of Computer Vision - Midterm Exam	B. Nasihatkon	دانشگاه صنعتی خواجه نصیرالدین طوسی K. N. TOOSI UNIVERSITY OF TECHNOLOGY
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Question 1- Histogram (22 points)

In the image below the intensity values are integers between 0 and 7. Obtain the

a. image histogram (5 points),
b. cumulative histogram (5 points),
c. histogram-equalized image. **Write down your derivations.** Round off and quantize the output to integers between 0-7. (Round up at 0.5, e.g. 3.5 -> 4) (12 points)

Input image

0	**1**	**6**	**7**
5	**2**	**3**	**1**
4	**1**	**3**	**7**
3	**3**	**3**	**2**

histogram

histogram-equalized

cumulative histogram

Question 2- Linear filtering (30 points)

The input image below (left) has been correlated with the 3x3 filter in the middle to give the filtered image on the right. As you can see, some of the entries in the filter and the destination image are unknown. Obtain the unknown values (a,b,..,f and A,B, …, J). Write down full derivations. **Assume zero pixel values outside the input image boundaries.**

Input image

2	**6**	**2**	**7**
12	**8**	**7**	**4**
1	**2**	**3**	**5**
8	**2**	**4**	**3**

Correlation filter

a	b	c
d	e	1
f	1	1

Filtered image

20	**-19**	A	**-25**
B	C	D	E
F	G	H	**-18**
I	**27**	J	**0**

Input image

2	6	2	7
12	8	7	4
1	2	3	5
8	2	4	3

Correlation filter

a	b	c
d	e	1
f	1	1

Filtered image

20	-19	A	-25
B	C	D	E
F	G	H	-18
I	27	J	0

Question 3- Median filtering (15 points)

Apply a 3x3 median filter to the source image below. Notice that there is an unknown pixel value in the source image specified by "**?**". Obtain the result of the median filtering for each of the six blank boxes in the destination image on the right. For each case argue why the median can be obtained regardless of the value of the unknown pixel.

source image

4	**9**	**4**	**9**	**10**
4	**3**	**?**	**9**	**10**
4	**9**	**9**	**3**	**10**
6	**6**	**6**	**6**	**9**

3x3 median-filtered image

X	X	X	X	X
X				X
X				X
X	X	X	X	X

Question 4- Hough Transform (20 points)

Consider the Hough line transform with the linear formulation where each line

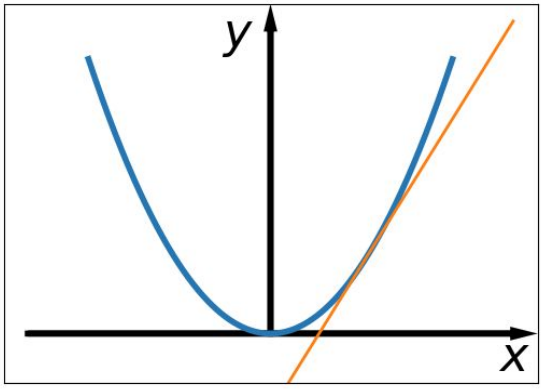
$$y = m\,x + b$$

is represented by a point (m, b) in the Hough space. Consider the parabola

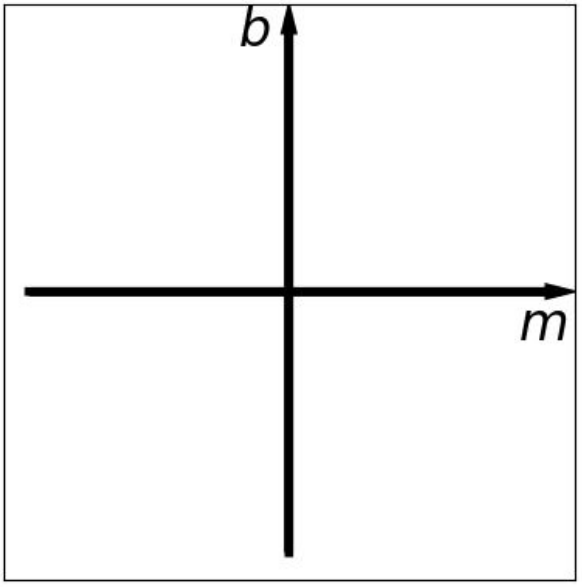
$$f(x) = 0.5\ x^2.$$

The set of tangent lines to the parabola forms a curve in the hough space. What is this curve? Find an equation describing the curve and draw it in the Hough coordinates below.

Image Space



Hough Space



Question 5- Harris Corner Detection (13 points)

The Harris matrix for a window W around a pixel can be computed as

$$H = \sum_{(x,y)\in W} \begin{bmatrix} I_x(x,y)^2 & I_x(x,y)I_y(x,y) \\ I_x(x,y)I_y(x,y) & I_y(x,y)^2 \end{bmatrix}$$

Show that if the gradient is constant inside the window W, the Harris matrix H is singular (has zero determinant).