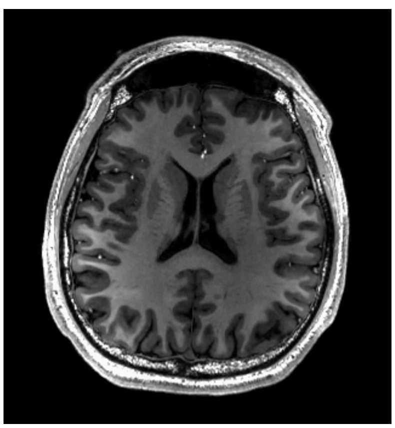
CSE428: Image Processing

Problem Set 1

Lecture 1: Intro to Image Processing

Question 1

Mention what type of image (**Reflection/Emission/Absorption**) each of the following are based on the image given in the left column.

Image	Image Type
	
	
	

Question 2

You are given a **grayscale** image with an **aspect ratio of 5:3** and **pixel resolution of 960000 pixels** in total. Calculate the dimensions of the image **(#columns, #rows)**. Also, calculate the **size** of the image (Each pixel = 8 bit).

Question 3

Differentiate between **1D**, **2D** and **3D** signals (data).

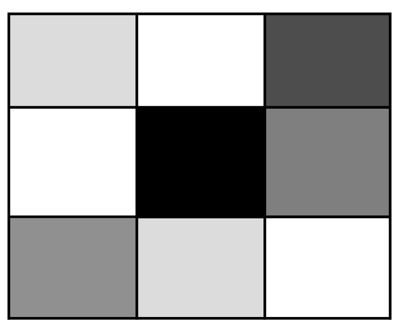
Question 4

Observe image **f(x,y)** below. What is the Pixel value for **f(1,3)**?

6	2	1	9
2	0	2	4
1	9	9	5
2	0	1	2

Question 5

The shape below represents a 3*3 4-bit image. Assign intensity values (tentatively) to each of its pixels. Write your answer in the form of a matrix.



Lecture 2: HVS, Image Sensing & Digitization

Question 1

Suppose, a camera captures an intensity **f(x,y) = 490** for a particular pixel. The source illumination **i(x,y)** was **700**. Calculate the reflectance **r(x, y).** Also mention the ranges of possible values for **r(x,y)** and **f(x,y)**.

Question 2

X-ray images are often "inverted" in appearance compared to traditional photographs. Explain why this **inversion** is done using the concepts of the **power of brightness discrimination** & **Weber Ratio**.

Question 3

Discuss **the stages** of a typical **pipeline of digital image acquisition using** a camera.

Question 4

What is **Dynamic Range**? Explain why High Dynamic Range is usually desirable for digital images. Also, which of the following images represent a higher dynamic range? Discuss.

(a) (b)

Question 5

Discuss how **Image Sensing** is done in a camera. What kind of signal (response) is generated when light falls on the surface of a sensor?

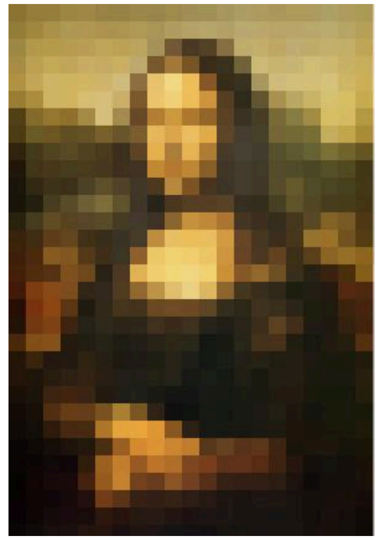
Question 6

Discuss the two steps of **Image Digitization** with examples. Why is Digitization necessary?

Question 7

For each of the images shown below, explain what went wrong. What could've been done to avoid the deterioration in image quality?

a



b

Question 8

Upsample the following image to make it **8*8**. Also, **downsample** it to make it **2*2**. Show both upsampled and downsampled versions in your script. Use an interpolation method of your choice for upsampling.

6	2	1	9
2	0	2	4
1	9	9	5
2	0	1	2

Question 9

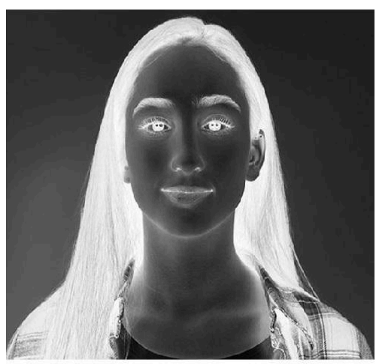
Match the components of a camera (left column) with their equivalent parts in the human eye (right column).

Camera Components	**Eye Parts**
Sensor	Iris & Pupil
Lens	Retina
Shutter	Ciliary Body
Focusing Region	Fovea
Autofocus System/Focus Ring	Optical Lens

Lecture 3: Point Processing (Part 1)

Question 1

Plot the approximate mapping functions for each of the intensity transformations shown below. Plot input intensity along the X-axis and output intensity along the Y-axis. Use **[0, 1] range** for simplicity.

Input Image, r	Transformed Image, s	Plot of Mapping func. From r to s
		
		
		

Question 2

Suppose, for an intensity transformation of an image, the following transformation mapping function is used:

$$s = (2 * r + 6)/255$$

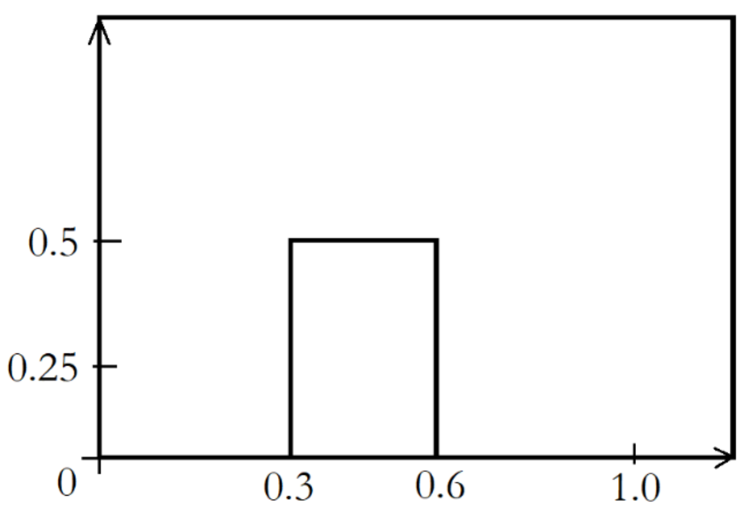
State and explain what will happen to the following:

i. Brightness **ii.** Contrast **iii.** Whether there will be any data loss

Question 3

A **histogram (PDF)** is depicted for an image, **I**, below. Answer the questions:

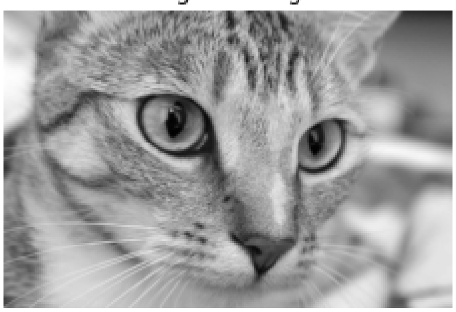
a) Draw the **CDF** of the image with proper labeling.
b) You have been tasked to **contrast-stretch** this image from **0.0 to 1.0** range and use the mapping function **S = C1(I-C2)**. Calculate the correct values of **C1** and **C2**.
c) You are asked to perform a logarithmic transformation: **S = log(1+3I)** . Draw the new histogram after this type of transformation.
d) Draw the histogram of the **negative** image of **I.**



Question 4

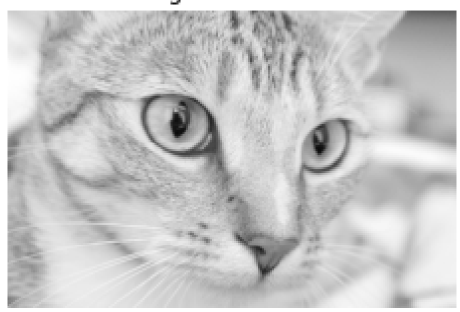
Three images are given in Figs. (a-c), three *approximate* histograms are given in Figs. (d-f), and three transformations for contrast enhancement are given in Figs. (g-i). For each image, specify which histogram corresponds to that image, and which transformation is best to enhance its contrast. (*Complete the table in your script with <u>short</u> explanations*.)

Original image



(a)

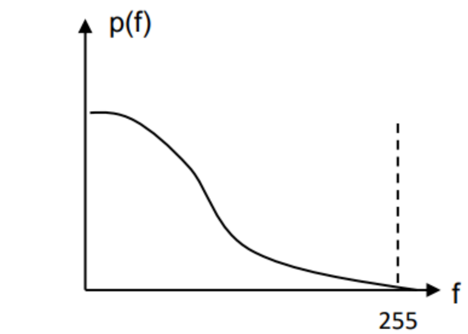
Brighter version



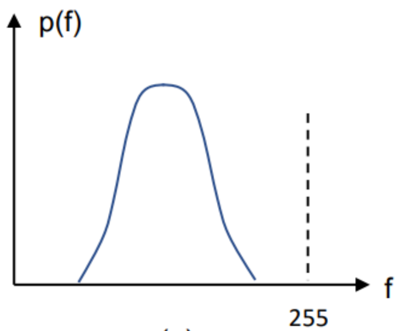
(b)

Darker version

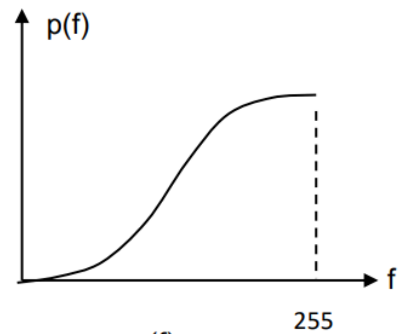
(c)



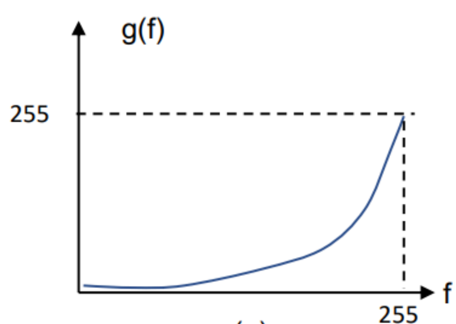
(d)



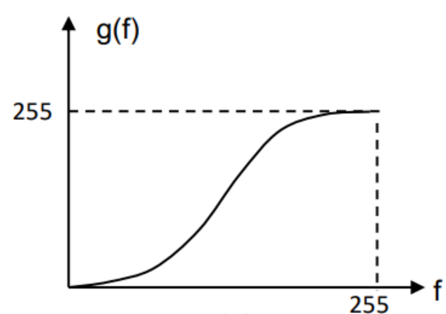
(e)



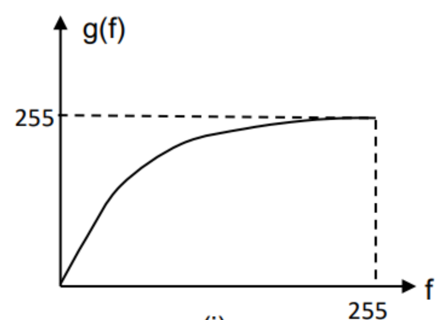
(f)



(g)



(h)

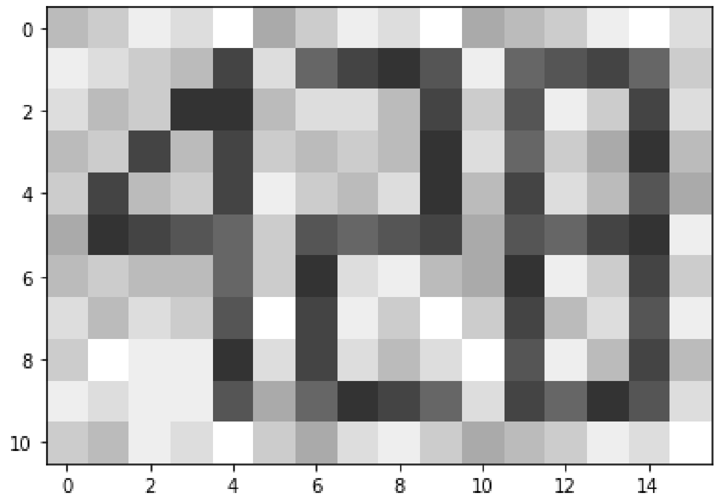


(i)

Image	Histogram	Transformation	Explanation
(a)			
(b)			
(c)			

Question 5

Consider the following 11×16 image with 16-level quantization ($L_{min} = 0, L_{max} = 15$)



The histogram of the image is given in the following table (r denotes intensity level, n_r denotes total number of pixels with intensity r):

r	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
n_r	0	0	0	13	20	13	11	0	0	0	10	26	28	25	21	9

(a) Plot the histogram and mark the **region of interest** in the histogram (i.e. the relevant intensity levels) assuming that you want to clearly identify the **"428"** from the image background using some image processing algorithms.

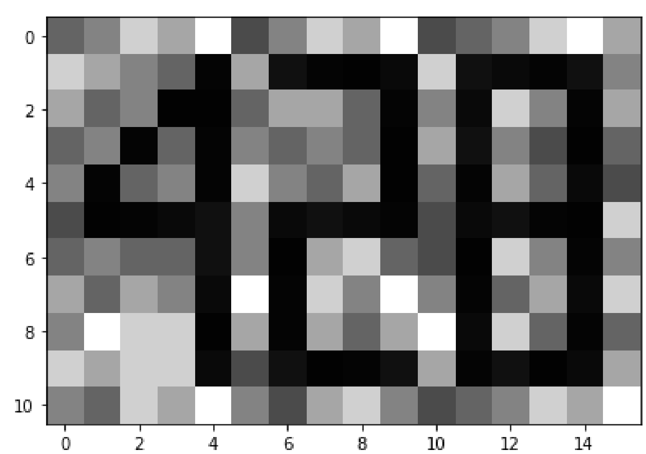
(b) Apply contrast stretching in the **region of interest** of the histogram and calculate the coefficients c_1 and c_2 of the mapping function $T(r)$ which has the following form:

$T(r) = c_1 \times (r - c_2)$

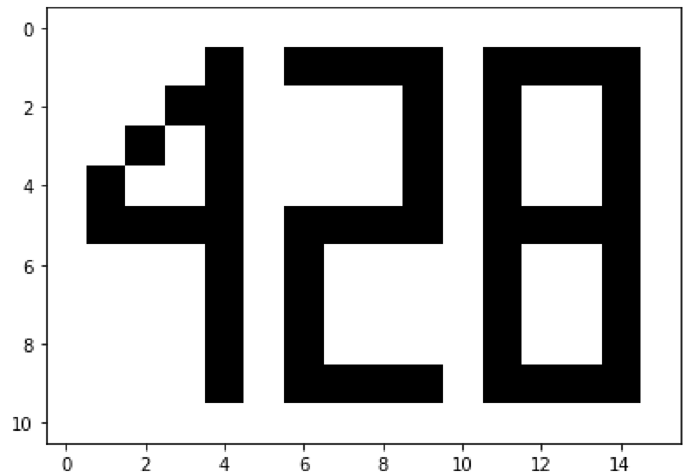
Plot the $T(r)$ vs r curve.

(c) Assume that a power law transformation $s = A\,r^{\gamma}$ (s: output intensity, r: input intensity) has been applied to the image and the transformation yields the following image:

By inspection, explain which value of gamma ($\gamma > 1$, $\gamma = 1$, or $\gamma < 1$) will yield the image below:



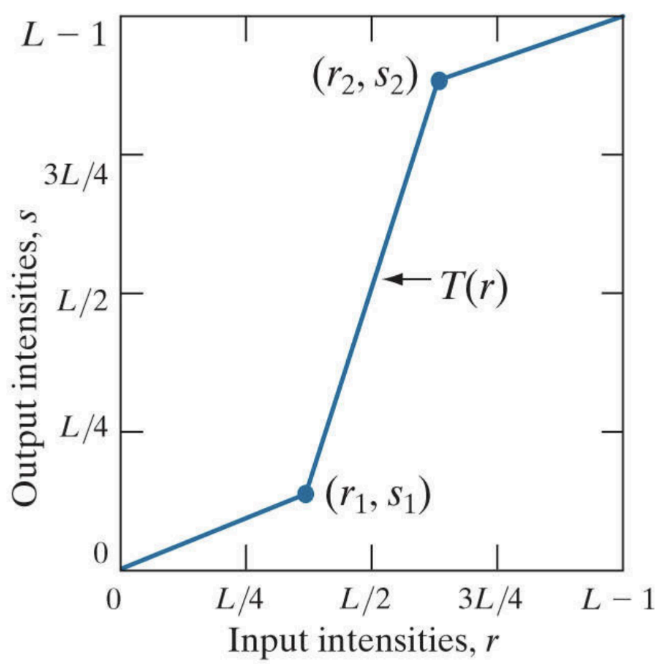
(d) Imagine using some other intensity transformation on our input image we derive the following binary image:



Plot the output-input intensity map that yields this output image.

(e) Refer to the same image given before question a and consider **(r_1, r_2)** as (9, 13) and **(s_1, s_2)** as (2, 14) respectively. Suppose you are going to apply piecewise linear transformation for contrast stretching as shown in the figure below.

a. Determine the values of the gradients (slopes) of your plot - for each linear region **($0 \rightarrow r_1$, $r_1 \rightarrow r_2$, $r_2 \rightarrow 1$).**
b. Use these slopes to derive the equations for each region to represent your mapping function. *{Hint: y = mx + c}*
c. Use the equations to complete the mapping from input pixels to output pixels (make a table with all 16 input pixels and the corresponding output pixels).



Lecture 4: Histogram Equalization

Question 1

Consider the following 4×4 image where each pixel are 2-bit (or 4-level) quantized:

1	2	0	0
1	0	1	3
0	1	0	1
2	0	1	1

(a) Calculate the histogram and PDF of the image by filling out the following table:

r_k	$h(r_k)$	$f_r(r_k)$

(b) Calculate the cumulative histogram and the CDF of the image, i.e. add the following two columns to the table of part a and fill out the values:

$H(r_k)$	$F(r_k)$

(c) Find a mapping $s_k = T(r_k)$ that will equalize the histogram of the image.

(d) Draw the equalized 4x4 image.

(e) Draw the Histogram of the Equalized image.

Question 2

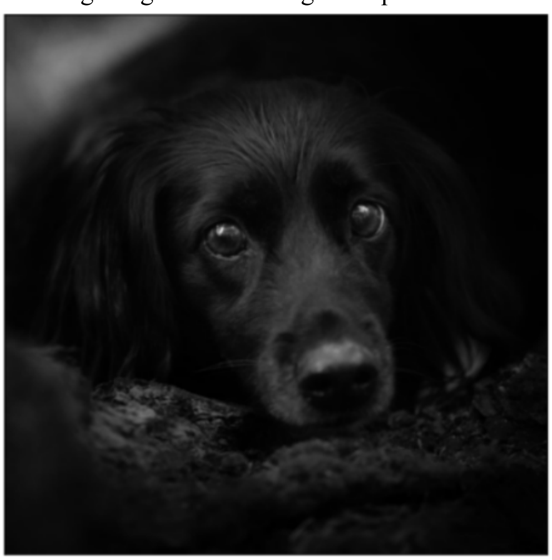
Consider a 14*14*1 image with quantization level = 3 bit.

r	$h(r_k)$	$f(r_k)$ [PDF]	$H(r_k)$	$F(r_k)$ [CDF]	HE Pixels
0	6				
1	0				
2	41				
3	66				
4	42				
5	23				
6	x				
7	7				

a. Calculate x.
b. Determine the values of **$f(r_k)$**, **$H(r_k)$**, **$F(r_k)$**, and **Histogram Equalized Pixels**.
c. Draw the CDF of the original image and the Histogram equalized image on your script. What kind of change do you notice? Discuss from the POV of Entropy.

Question 3

Consider the following image and its histogram equalized version given below.



a. Which Histogram Equalization technique was used here? **Global Histogram Equalization** or **AHE** or **CLAHE**? Discuss.
b. Also, What would happen if the other techniques were used?
c. How does Contrast Limited Adaptive Histogram Equalization (CLAHE) improve over Adaptive Histogram Equalization (AHE)?