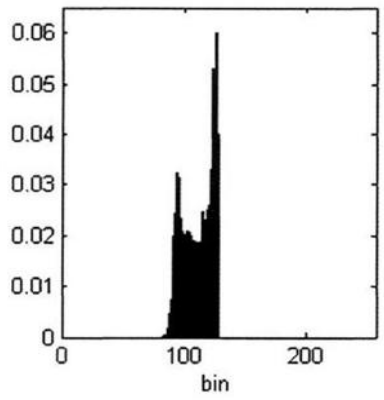
LAB # 04: Histogram Equalization

Lab Objective:

The objective of this lab is to enhance contrast of an image using contrast stretching and histogram equalization.

Lab Description:

Contrast stretching: is a simple image enhancement technique that attempts to improve the contrast in an image by `stretching' the range of intensity values it contains to span a desired range of values. Normally (min, max) should be (0, 255). An example is shown below:

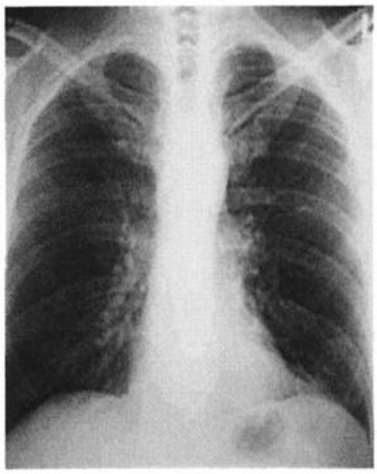


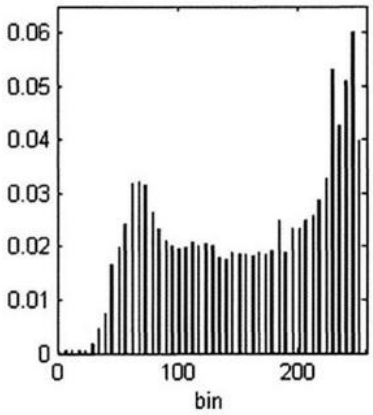
p = ((p-min)/ (max-min)) *255

Where:

p is pixel value at a certain pixel location

max, min is the max, min pixel value in the entire image





Instead of computing the dynamic range using just the minimum and maximum pixel values, a more robust and adaptive technique is to use the **5th and 95th percentiles** of the input values when deriving the dynamic range of the input image.

Histogram equalization:

Histogram of an image shows the frequency of different intensities values present in the image. This gives a clear idea of what intensities dominate the image. **Histogram equalization** is a technique that uses this information to enhance the contrast using the probability of a certain pixel to occur.

Steps:

Suppose we have a 3-bit image (L = 8) of size 64x64

Histogram equalization:

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Steps:

Suppose we have a 3-bit image (L = 8) of size 64x64

a) Calculate number of pixels per pixel value.

Pixel Value (r_k)	0	1	2	3	4	5	6	7
No of Pixels (n_k)	790	1023	850	656	329	245	122	81

b) Calculate probability density function PDF = n_k / size of the image

No of Pixels (n_k)	790	1023	850	656	329	245	122	81
PDF	0.19	0.25	0.21	0.16	0.08	0.06	0.03	0.02

c) Calculate cumulative density function CDF = sum of n_k from 0 - k

PDF	0.19	0.25	0.21	0.16	0.08	0.06	0.03	0.02
CDF	0.19	0.44	0.65	0.81	0.89	0.95	0.98	1

d) Calculate transformation function by multiplying CDF with (L – 1) and round of it.

CDF	0.19	0.44	0.65	0.81	0.89	0.95	0.98	1
TF	1.33	3.08	4.55	5.67	6.23	6.65	6.86	7
TF (s_k)	1	3	5	6	6	7	7	7

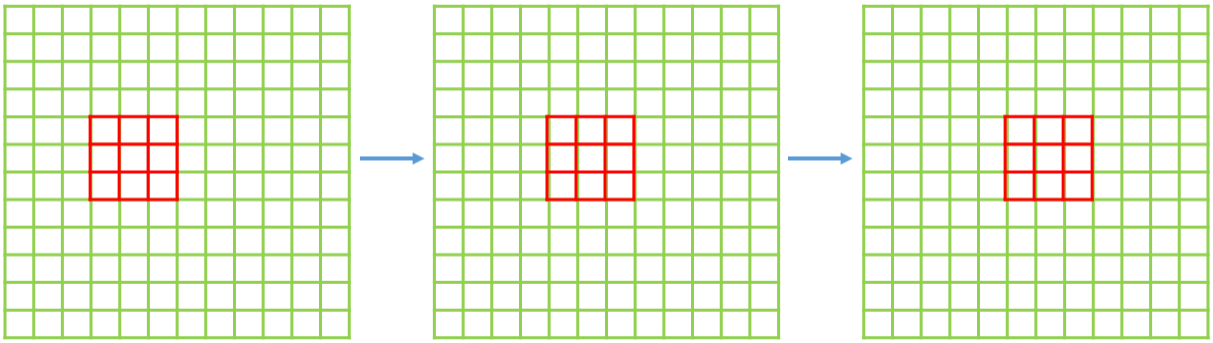
e) Replace original Pixel values with the s_k values

Pixel Value (r_k)	0	1	2	3	4	5	6	7
TF (s_k)	1	3	5	6	6	7	7	7

Spatial filtering is an important step of preprocessing images. Different types of filters like smoothing filters, sharpening filters and rank filters etc. can be applied to images to achieve the desired result.

Averaging or smoothing filters consist of integration, and they can be used for blurring or noise reduction. Blurring helps to remove small details from an image before further processing like object extraction can be performed on it.

Applying a smoothing filter (or any filter for that matter) involves convolving the filter of a specific size with the entire image. The mask moves pixel by pixel while convolving with the values of the pixel intensities that it covers as shown here:



104	100	108
99	106	98
95	90	85

Original Image Pixels

$*$

$1/9$	$1/9$	$1/9$
$1/9$	$1/9$	$1/9$
$1/9$	$1/9$	$1/9$

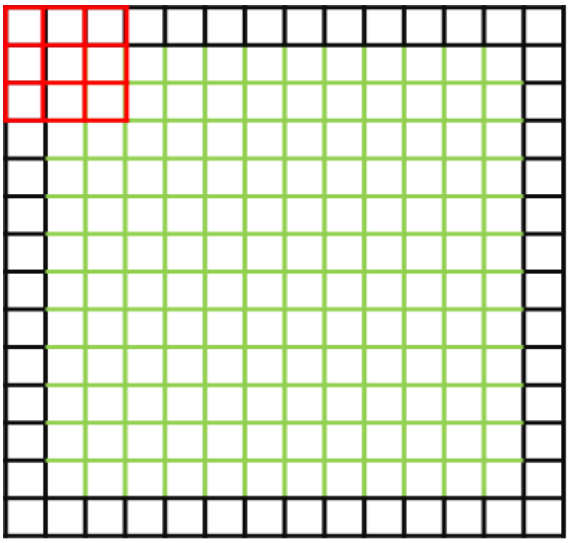
Filter

$$e = 1/9*106 + 1/9*104 + 1/9*100 + 1/9*108 + 1/9*99 + 1/9*98 + 1/9*95 + 1/9*90 + 1/9*85$$
$$= 98.3333$$

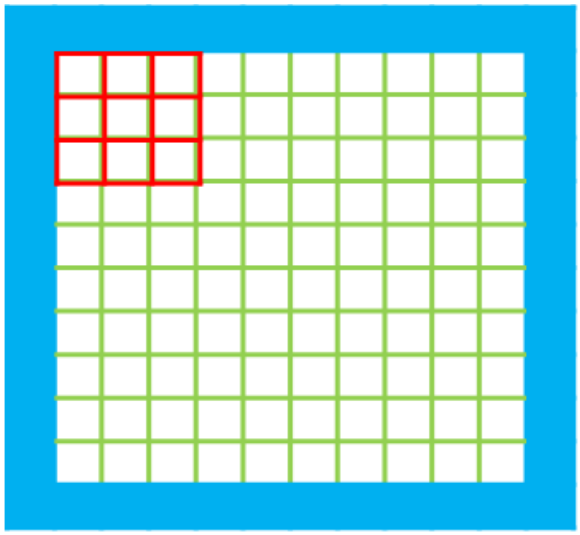
While applying a filter to an image, the boundary of the image imposes a unique challenge: for the first pixel of the first row, there are no pixels behind or above it that can be multiplied with the mask value. To counter this problem, two techniques can be used:

- **Padding**

  Adding a few rows of 0's all around the image helps the mask to function properly. The exact number of the 0 rows that are to be added depends on the size of the mask.



- **Ignoring some rows and columns:**
  The first few rows and columns can be ignored and the mask can be applied to the rest of the image. The number of the rows and columns that are to be ignored depends on the size of the filter.



Some Useful Commands:

Importing matplotlib: import matplotlib.pyplot as plt

1. To calculate the mean of 2D array using NumPy: my_mean = **numpy. mean (my_array)**
2. To calculate min (or max) of an array: **my_min = numpy.amin(my_array)**
3. To calculate the power of an array using NumPy: array_power = **numpy.power (my_array, power)**
4. To obtain percentile value. **percentile_array = numpy.percentile(my_array, percentile)**
5. To change data type of array. **my_array = my_array. astype(numpy. uint16)**

6. To plot a simple plot using matplottlib: **plt.plot(my_data)**
7. For label along x axis: **plt.xlabel ('Some cooked up data')**
8. For label along y axis: **plt.ylabel ('Some value')**
9. To show the graph: **plt.show()**

Lab Tasks:

1. Apply contrast stretching on the image provided by setting 5th and 95th percentiles of the input values to 0 and 255 respectively. The remaining values will be stretched as:

$$New\ Value\ for\ Pixel = 255 * (Current\ value\ for\ Pixel - 5th\ Percentile) / (95th\ Percentile - 5th\ Percentile)$$

2. Perform the following steps to do Hist. equalization to enhance the grayscale image.

- Calculate the histogram of the image and display it using the appropriate command. (Don't use the built in function of OpenCV or Numpy or Matplotlib etc.)
- Calculate probability density function (PDF) from the histogram and display it using the appropriate command PDF = H/(R*C). Where H is the Histogram and R and C is the number of Rows and Columns of the image respectively.
- Calculate cumulative PDF and display it using the appropriate command.
- Multiply the Cumulative PDF with 255 to find the transformation function then display it too using the appropriate command.
- From the transformation function, replace the gray levels of the image to create contrast enhanced (histogram equalized) image.
- Display the enhanced image.

3. Write a generic function that takes a mask of a specific size from and applies it to an image. Create the following masks and apply it to an image and display the results. The fiter will nxn size. You can use fig05.tif for this task.

Home Task:

1. Take a high-quality grayscale image (e.g., a landscape or a document scan) and simulate degradation by introducing blurring (you can apply an average mask).
2. Apply histogram equalization to enhance the contrast of the degraded image.
3. Compare the enhanced image with the original degraded image to assess improvement in visibility and details.