INDIAN INSTITUTE OF TECHNOLOGY
KHARAGPUR

IMAGE PROCESSING LABORATORY

A REPORT ON
EXPERIMENT 02

Histogram Equalisation and Matching

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Introduction

Histogram :

The intensity distribution of an image is given by the histogram of the image. It gives the data of the number of pixels in an image that have a particular level of intensity. It is only a statistical representation of an image and hence does not provide any information as to where the pixels of a certain intensity are placed in the image. The following is a figurative explanation of what a histogram is.

0	2	1	3	4
1	3	4	3	3
0	1	3	1	4
3	1	4	2	0
0	4	2	4	4

Image

Intensity	Number of Pixels
0	4
1	5
2	3
3	6
4	7

Histogram Table

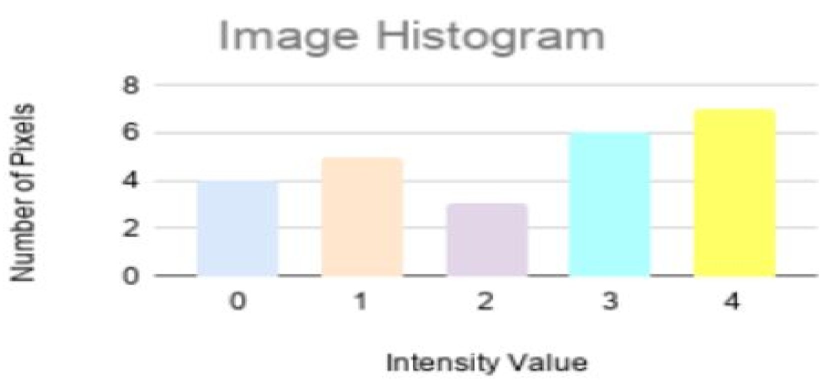


Image Histogram

Histogram Equalization :

Histogram Equalization spreads out intensities of pixels which are concentrated within a tight range of values and distributes the intensities uniformly over a larger intensity range. So, the purpose is to enhance the contrast in images. This improves the quality of images that have the background and foreground which are either both bright or both dark and also blur images.

Here we have used the cdf calculation method of histogram equalization. The following is a detailed process of the method.

1. Calculating the histogram :

    The probability of a random pixel having a particular intensity level i is given by

    $$h(i) = p_i$$
    $$= \text{(number of pixels of intensity level i / total number of pixels)}$$
    $$= \text{normalized histogram} = \text{probability density function PDF}$$

    The plot of probability density function, h(i), vs the intensity, i, gives the histogram of an image.

2. Calculating the cumulative distribution function CDF.

    This gives us the probability of a random pixel to have an intensity ranging from 0 to j. So, in terms of probability density function (h[i]), we have the cumulative distribution function, CDF ie., H(j), as follows.

    $$CDF = H(j) = \sum_{i=0}^{j} h(i) \qquad where\ j = 0, 1, \ldots\ldots, 254, 255$$

    Here, H(255) will be equal to 1 as the sum of all possible independent probabilities will be equal to 1.

3. Calculating the new intensity level distribution :

    The intensity levels are distributed all through the range 0 to 255 on the basis of CDF of the input intensity distribution. The new intensity value, T(j), is given by,

    $$T(j) = \text{floor}((K - 1) * CDF_j)$$

    Here, K = the maximum amount of intensity levels available for any given pixel.

4. Mapping of pixels with new intensities :

A pixel that had an input intensity of j, will be assigned the new intensity level of T(j). The new intensity distribution will have an equalized histogram.

Histogram Matching :

Histogram Matching provides us an operation over the image that transforms the histogram of the input image to a specified histogram of a target image. So, the histogram of the input image is manipulated to achieve the shape of the histogram of the target image. The initial steps are similar to those of Histogram Equalization. The following is a detailed step wise procedure.

1. Calculating histogram for both input and target images :

   The probability distribution functions of both the images are as given below. Here, h_{input} (i) = PDF of input image; $h_{specified}$(i) = PDF of target image.

   $h_{input}(i) = p_i$

   = (number of pixels of intensity level i / total number of pixels)

   = normalized histogram

   = probability density function PDF

   $h_{specified}(i) = p_i$

   = (number of pixels of intensity level i / total number of pixels)

   = normalized histogram

   = probability density function PDF

2. Calculate cumulative distribution function CDF for both the images :

   Same as in Histogram Equalization.

$$CDF = H(j) = \sum_{i=0}^{j} h(i) \qquad where\ j = 0, 1, \ldots\ldots, 254, 255$$

3. Calculate the new intensity value distribution for both the images :

$$T_{input}(j) = floor((K - 1) * CDF_j)$$

$$T_{specified}(j) = floor((K - 1) * CDF_j)$$

In the above equations,	T_{input} (j)	=	new intensity level of input image;
	$T_{specified}$(j)	=	new intensity level of target image;
	K	=	maximum possible intensity level

4. Assigning new intensity values to the input image:
   i) For a given input intensity value j, there will be a T_{input} (j) after as a result of Histogram Equalization.
   ii) Now, the intensity value $T_{specified}$ (k) is chosen such that $T_{specified}$ (k) is the closest to T_{input} (j). After choosing the $T_{specified}$ (k), the intensity value j is mapped to the intensity value k.
   iii) Thus, the pixels of the input image which initially were at intensity level j, will now have intensity level of k after Histogram Matching.

For example, if for input intensity level of 4, T_{input} (4) = $T_{specified}$ (1) = 3, then, every pixel in the input image with an initial intensity of 4 will now be assigned a new intensity value of 1.

$$T_{input}(4) = 3 \qquad T_{specified}(1) = 3$$

$$T_{input}(5) = 4 \qquad T_{specified}(2) = 4$$

Similarly, if for input intensity level of 5, T_{input} (5) = $T_{specified}$ (2) = 4, then, every pixel in the input image with an initial intensity of 5 will now be assigned a new intensity value of 2.

Histogram Equalization vs Histogram Matching :

Histogram Equalization aims at distributing the existing histogram evenly over the entire range of available intensity levels and thereby flattening the histogram. Histogram Matching gives out the output image that has a histogram of any given specified shape

(shape of the target image). So, it can be said that Histogram Equalization is a special case of Histogram Matching where the specified shape is the most uniform histogram possible for the given input image (the histogram equalized image of the input image will act as the target image).

Algorithm

The following functions have been used in the program to perform Histogram Equalization and Matching:

- **`readImg:`** This function reads the input image file using imread and returns the image in a Mat image container.

- **`imgToHist:`** Takes a Mat image and its size as input and maps the image pixels into the histogram array by counting the number of pixels present for each intensity value.

- **`CDF:`** This function calculates the transfer function, ie., the cumulative distribution function for the given histogram.

- **`intensityMapping:`** This function maps the histogram to cover the entire intensity range using the transfer function calculated.

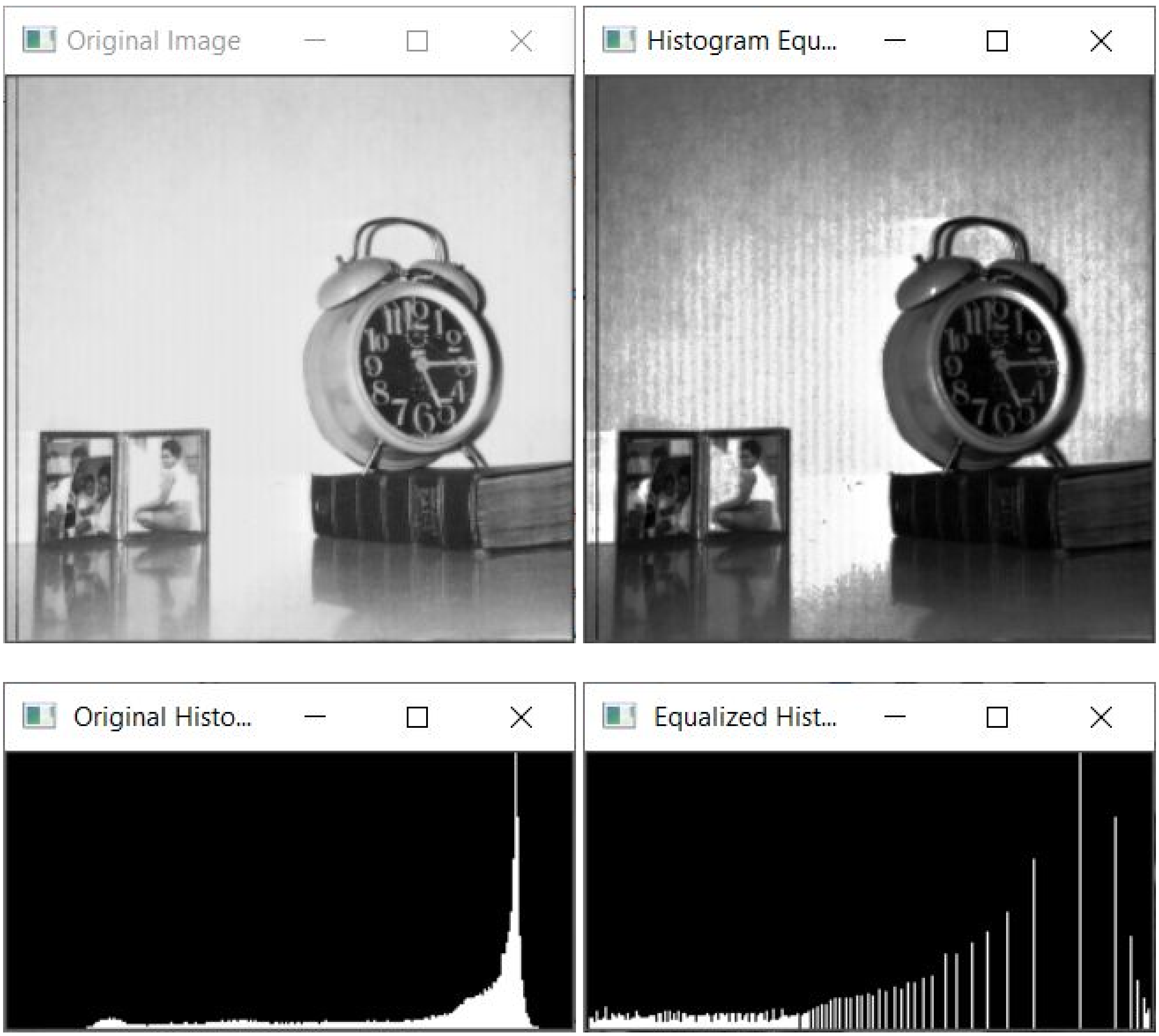
- **`histogramMatching:`** Takes the transfer function of both the input and target image as input, creates a new matched histogram by comparing both the transfer functions.

- **`showHist:`** Takes an image as input, calculates and displays its histogram.

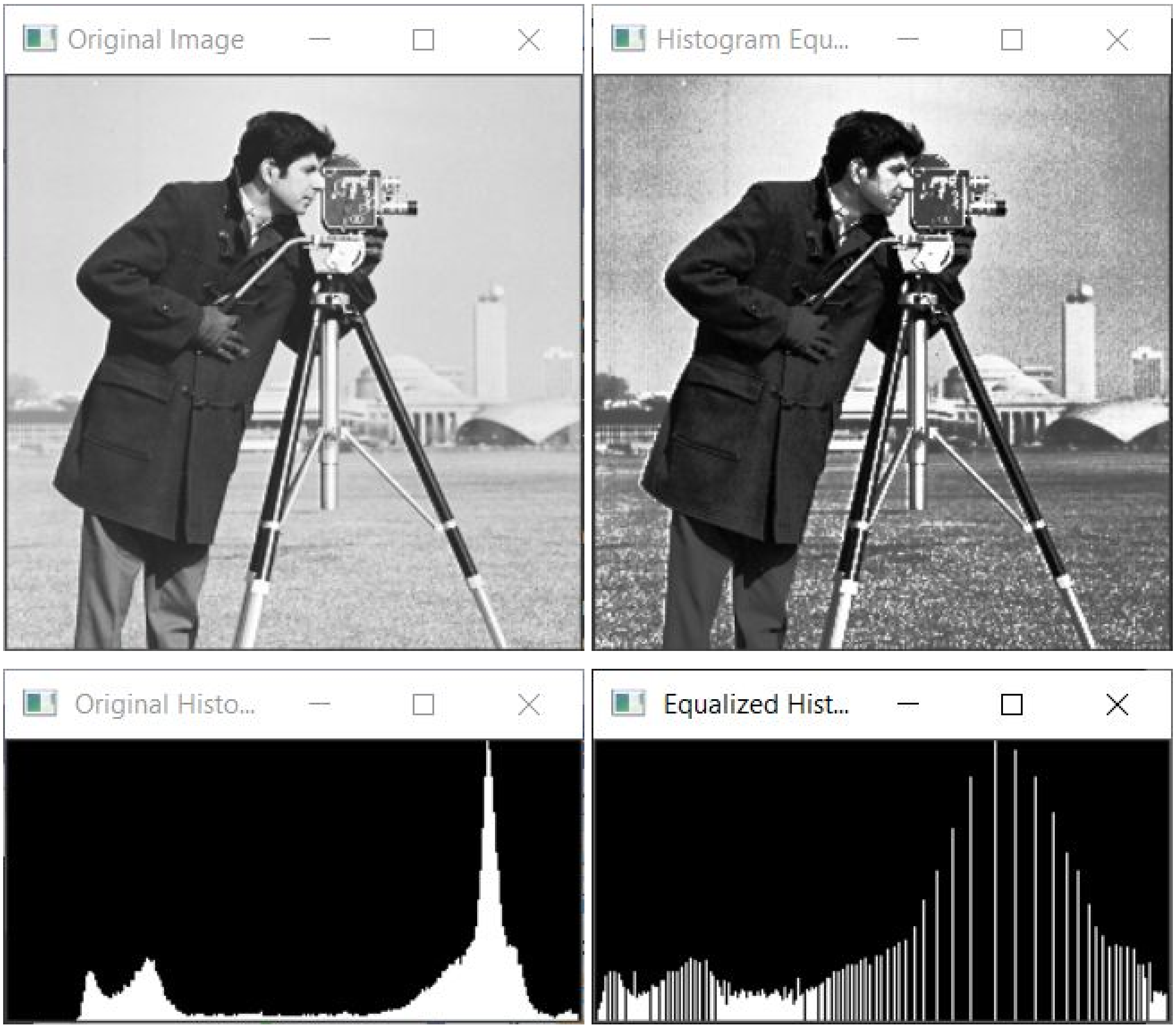
Results

Histogram Equalization

1.



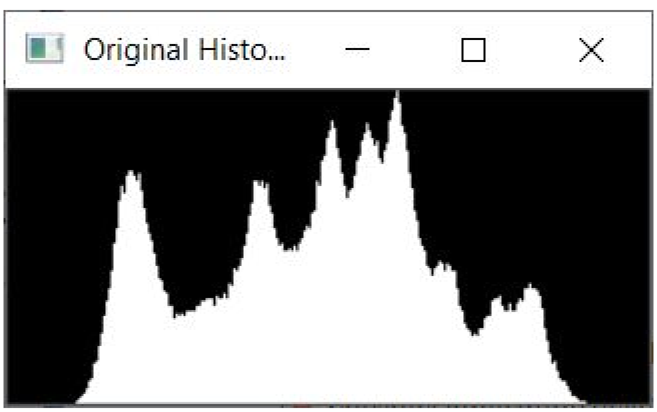
2.

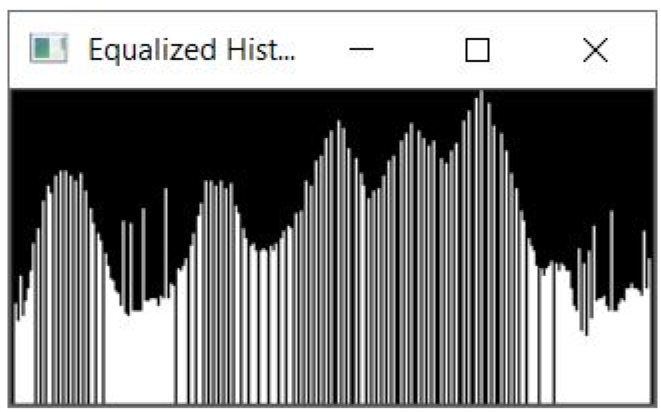

Original Image
Histogram Equ...
Original Histo...
Equalized Hist...

3.


Original Image

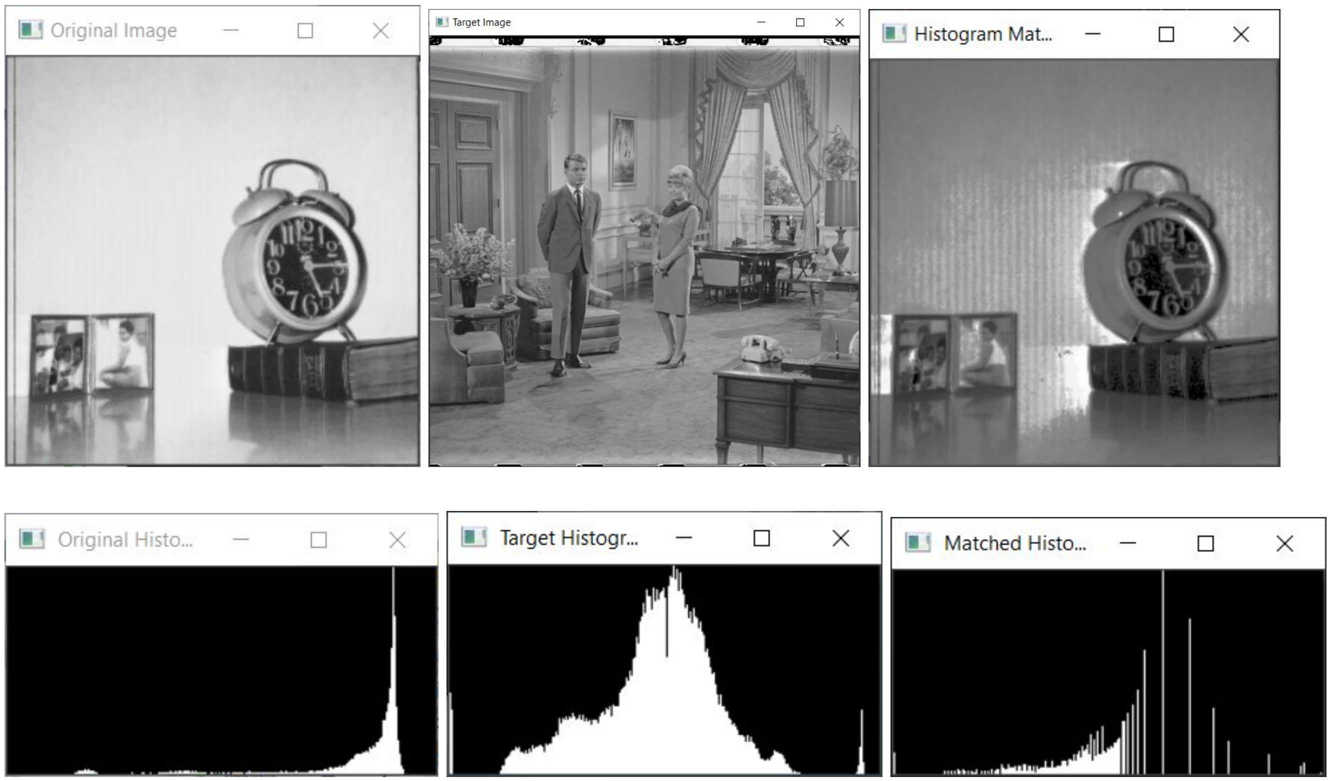

Histogram Equilized Image


Original Histo...


Equalized Hist...

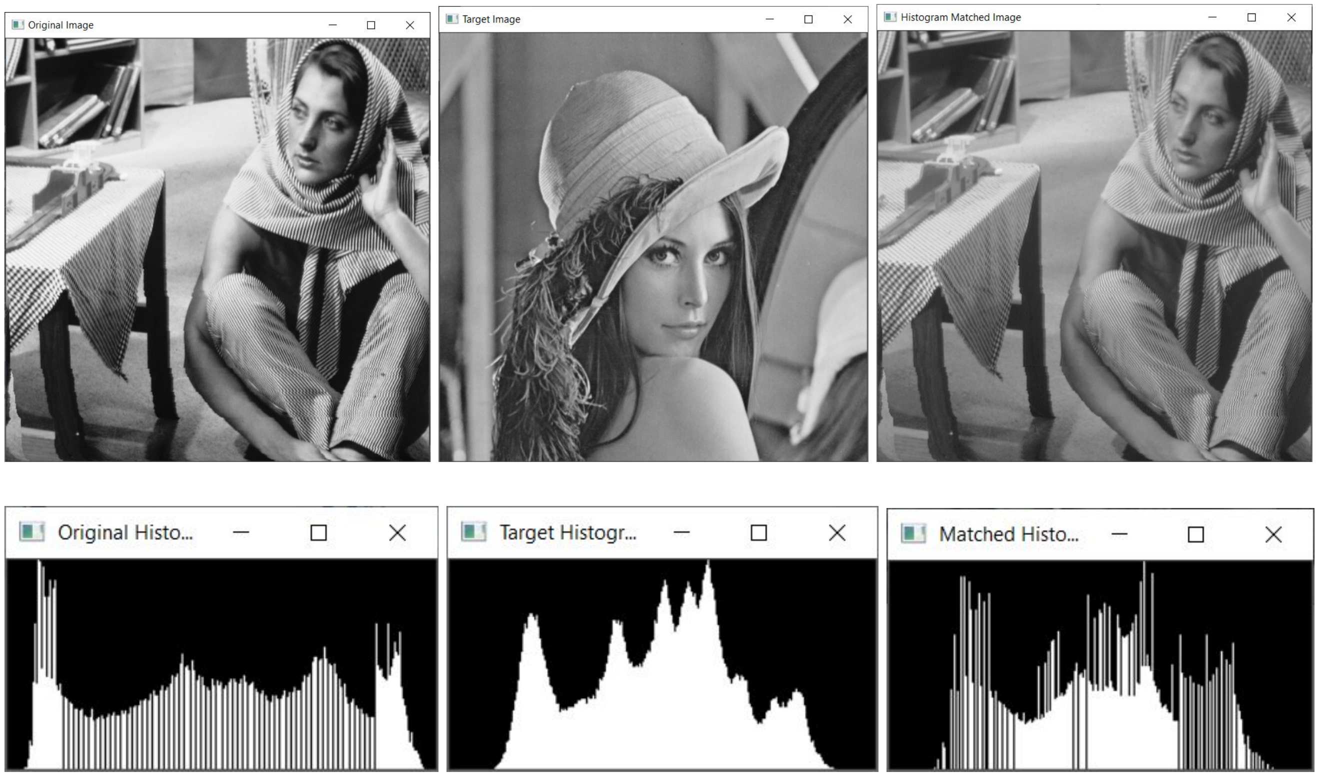
Histogram Matching

1.



2.

3.



Analysis

1. Decision of performing histogram equalization or matching on an image needs to be done wisely as in some cases (generally low contrast image), the functions improve the image appearance but degrade in other cases.
2. Similarly choice of target image is also important while performing histogram matching.
3. For histogram equalization of colored images, we cannot perform equalization on three individual channels as we need to keep color information intact. In this case, we need to convert the color space of the image from RGB into one of the color spaces which separate intensity values from color components. Some of these are HSV/HLS, YUV, YCbCr. Then histogram equalization is performed and the image is converted back to RGB.
4. The code was executed for JPEG, BMP, TIFF file types. Imread supports many other image file types like PNG, PFM etc. GIF file types are not supported.

References

I. Ali Pourramezan Fard (2020, October 16). *Histogram Matching*. Retrieved from https://towardsdatascience.com/histogram-matching-ee3a67b4cbc1

II. Automatic Addison (2019, December 15). *Difference Between Histogram Equalization and Histogram Matching*. Retrieved from https://automaticaddison.com/difference-between-histogram-equalization-and-histogram-matching/

III. Images source: http://sipi.usc.edu/database/database.php?volume=misc&image=17#top