Image Processing Lab

Histogram Equalization and Matching

GROUP-10

Submitted by:

Aditya Narayan (13EC35010)

Adarsh Kumar Kosta (13EC35008)

Objective

Write C++/Image-J modular functions to:

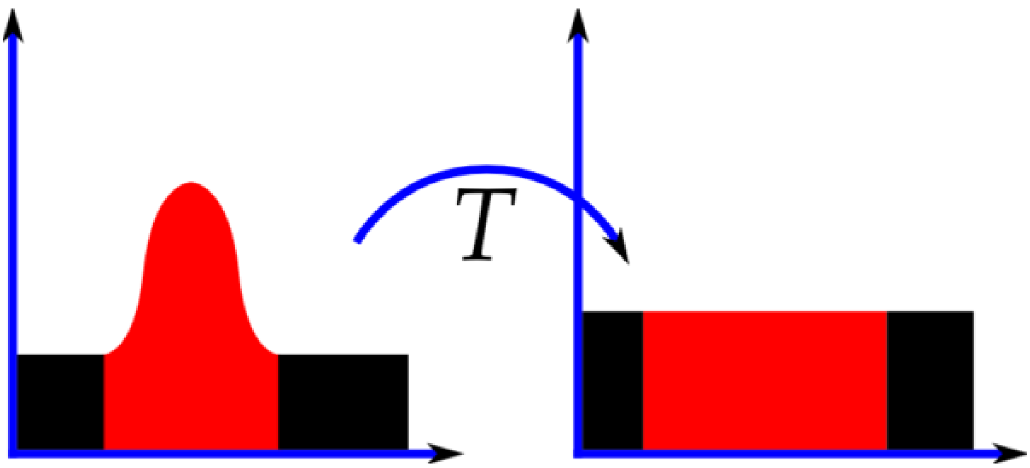
1. Perform histogram equalization on the 512 × 512 grayscale lena_gray_dark.jpg image. Perform the same on other low-contrast, dark, normal (gray/colored) images.
2. Perform histogram matching of the same images with respect to a standard image (e.g.lena.jpg, cameraman.jpg, walkbridge.jpg image, etc).

Display the histograms of the original image and the enhanced images and document the observations.

Introduction

Histogram Equalization

Histogram equalization is a method in image processing of contrast adjustment using the image's histogram.

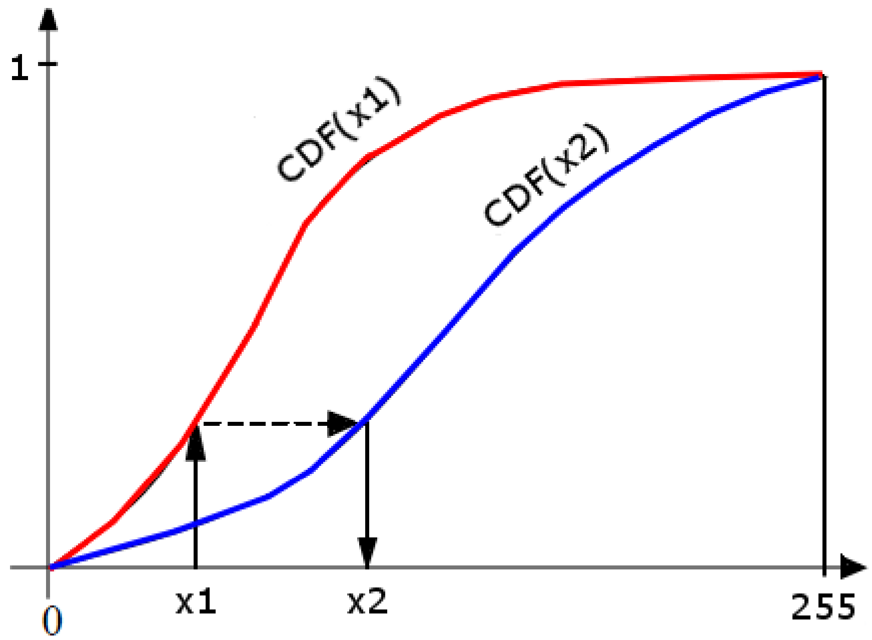


This method usually increases the global contrast of many images, especially when the usable data of the image is represented by close contrast values. Through this adjustment, the intensities can be better distributed on the histogram. This allows for areas of lower local contrast to gain a higher contrast. Histogram equalization accomplishes this by effectively spreading out the most frequent intensity values.

The method is useful in images with backgrounds and foregrounds that are both bright or both dark. In particular, the method can lead to better views of bone structure in x-ray images, and to better detail in photographs that are over or under-exposed. A key advantage of the method is that it is a fairly straightforward technique and an invertible operator. So in theory, if the histogram equalization function is known, then the original histogram can be recovered. The calculation is not computationally intensive. A disadvantage of the method is that it is indiscriminate. It may increase the contrast of background noise, while decreasing the usable signal.

Histogram Matching

In image processing, histogram matching or histogram specification is the transformation of an image so that its histogram matches a specified histogram. The well-known histogram equalization method is a special case in which the specified histogram is uniformly distributed.



It is possible to use histogram matching to balance detector responses as a relative detector calibration technique. It can be used to normalize two images, when the images were acquired at the same local illumination (such as shadows) over the same location, but by different sensors, atmospheric conditions or global illumination.

Given two images, the reference and the adjusted images, we compute their histograms. Following, we calculate the cumulative distribution functions of the two images' histograms ***F1()***, for the reference image and ***F2(),*** for the target image. Then for each gray level ***G1*** ε ***[0,255]*** , we find the gray level ***G2****,* for which ***F1(G1) = F2(G2)***, and this is the result of histogram matching function: ***M(G1) = G2***. Finally, we apply the function ***M()*** on each pixel of the reference image.

Implementation

First you'll have to compute the histogram of the reference image.

Next find the cdf of the image:

Next we have to make the second image follow the exact same cdf of the first image. This is usually known as histogram specification. Here is the algorithm:

Say you have a 3-bit image, that is 8 different intensity values 0>7. Now as for the second image

Find it's cdf as well.

Now as seen in the following image. The r_k is the pixel value of the second image.

s_k is the cdf of the second image.

z_k is the cdf of the firsk image (desired histogram).

z_k* and n_n are computed as the following:

$(z_k - s_k) >= 0$ for smallest value of n…and $n = g_k$

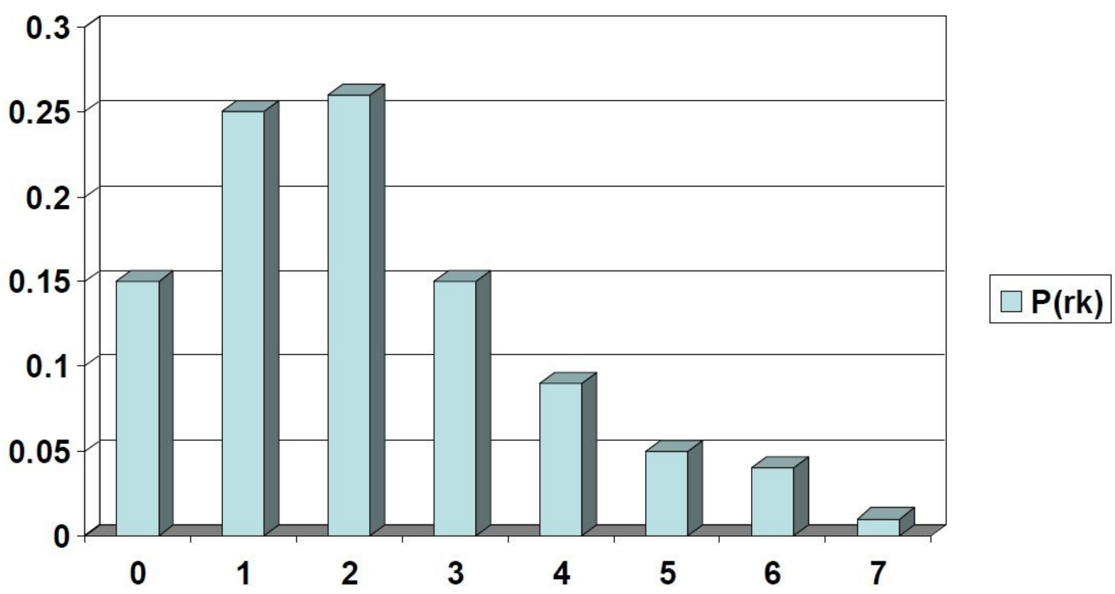
How exactly: Let's compute z_k*

$z_k - s_k = 0 - 0.15 = -0.15 >! 0$ (not greater than zero) increase z_k and keep $s_k$as is until you satisify the criteria.

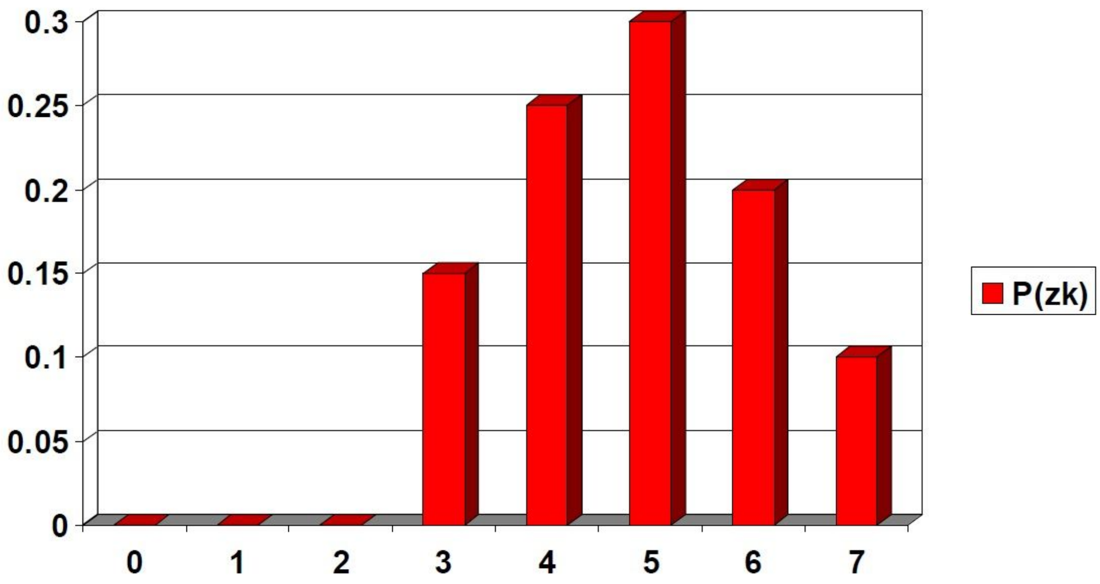
Until you reach: $0.15 - 0.15 = 0 >= 0$(check) Then $z_k* = z_k$ $n = r_k$

r_k	s_k	z_k	z^*	n
0	0.15	0	0.15	3
1	0.4	0	0.4	4
2	0.66	0	0.7	5
3	0.81	0.15	0.9	6
4	0.9	0.4	0.9	6
5	0.95	0.7	1.0	7
6	0.99	0.9	1.0	7
7	1.0	1.0	1.0	7

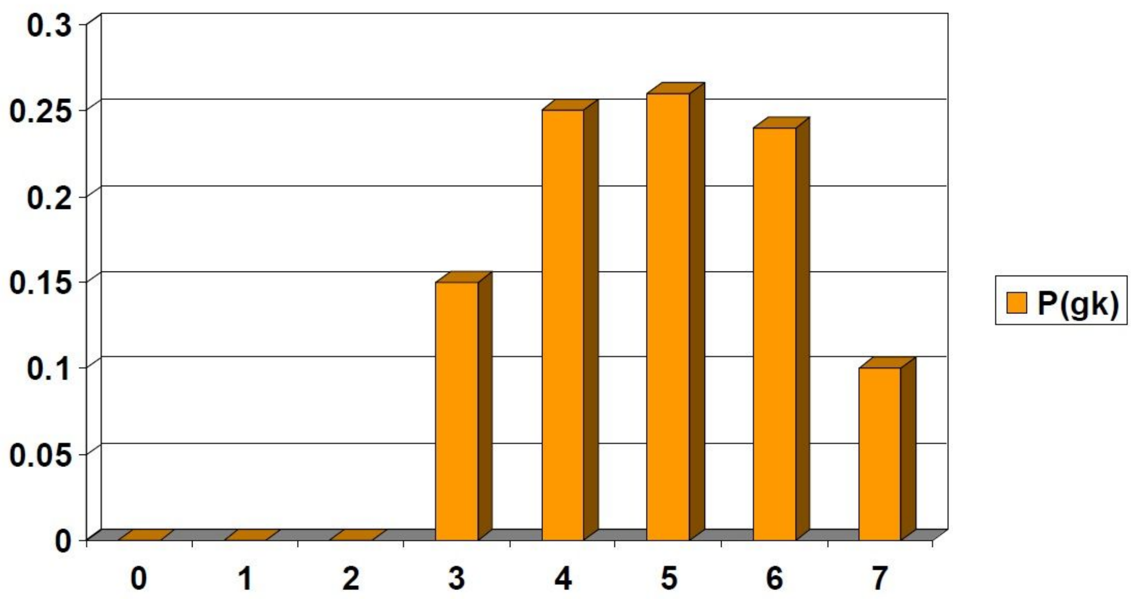
Original Histogram



Specified Histogram



Resulting Histogram



The images which we use are 8-bit i.e having 256 different intensity levels as opposed to 8 levels in the above example, but the implementation is the same.

This algorithm is for Histogram matching, but Histogram Equalization is carried out as well by using the same algorithm by using a reference image with Uniform PDF. This way matching the input image with an image with Uniform PDF results in a Histogram Equalized image.

Algorithm

On execution, the code prompts the user to select between the two operations:

1. Histogram Equalization
2. Histogram Matching

After selecting the desired operation, it prompts the user to input the name of the input test image.
If Histogram Matching was chosen, name of the reference image is also asked as input.

After getting all these inputs the code proceeds by reading the above images using ***imread()*** function of OpenCV library.

Subsequent analysis involves processing of the images and producing the outputs, which are illustrated by the below mentioned functions.

The functions described with their **Pseudocode** are as follows:

getHistogram:

Input: Input image
Output: Histogram of input image

- `for i = 0...HEIGHT-1`
    - `for j = 0...WIDTH-1`
        - `histIntensity[img[i,j]]++;`

getCumulativeHistogramNormalized:

Input: Input image

Output: Cumulative Distribution Histogram of input image

- `Check for number of channels in image (Grayscale or RGB)`
- `if(channels == 1)`
    - `Ret = getHistogram(input_img)`
- `Else if(channels == 3)`
    - `Convert BGR image to HSV format.`
    - `Take the intensity value 'V'`
    - `Ret = getHistogram(V channel of image)`
- `Integrate the above obtained PDF to get the CDF.`
- `Normalize the CDF`
- `Return the obtained CDF`

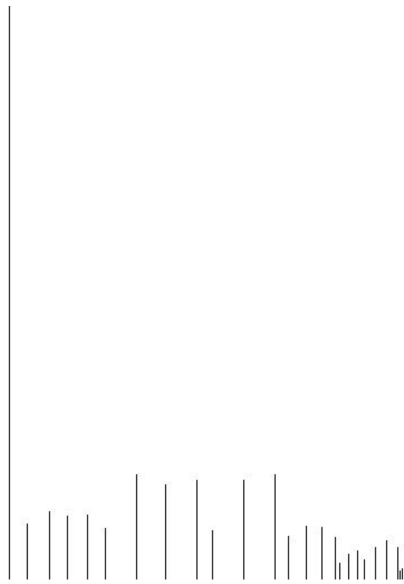
matchHistogram:

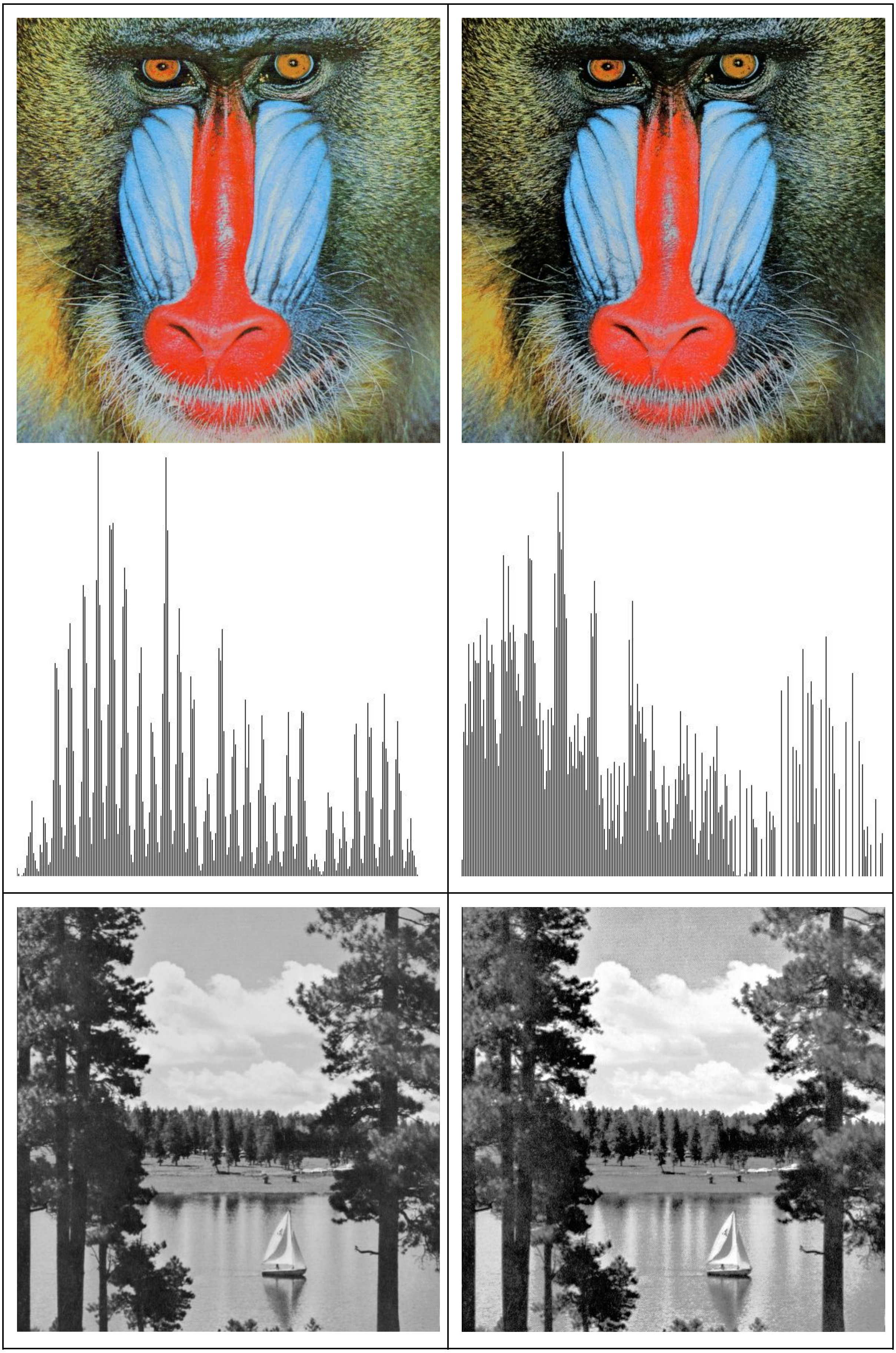
Input: Input Image, Reference Image, CDF of Reference image
Output: Matched image

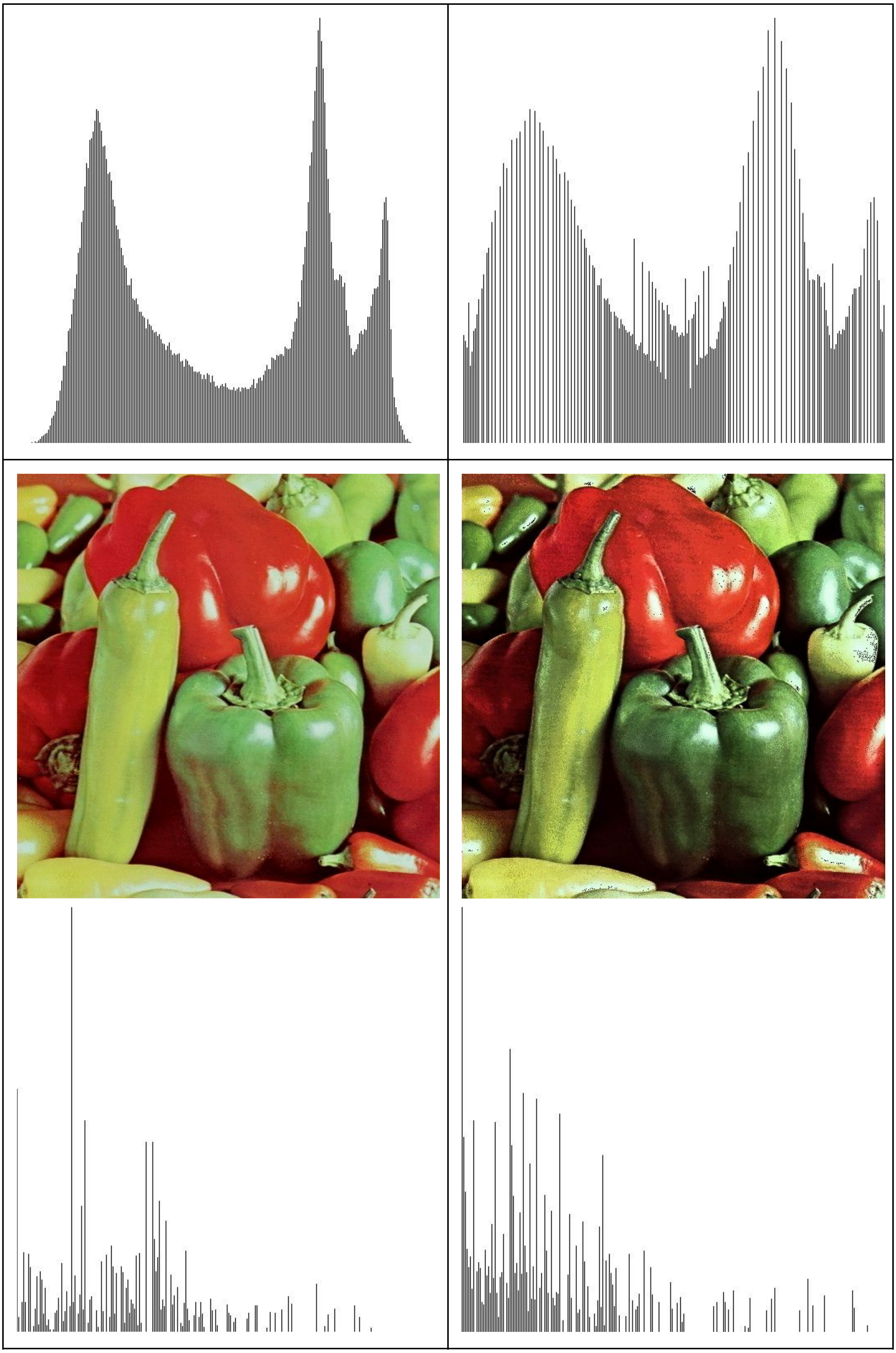
- `Get Normalized CDF of input image using getCumulative HistogramNormalized() function.`
- `for i = 0...HEIGHT-1`
    - `for j = 0...WIDTH-1`
        - `For k = 0...255`
            - `If CDF_refHist[k] >= CDF_inputHist(pixel value at [i,j])`
                - `Out_img[i,j] = k`
                - `break;`

Results

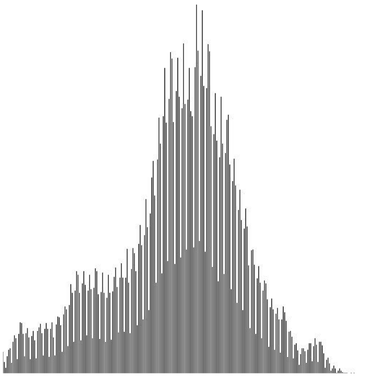
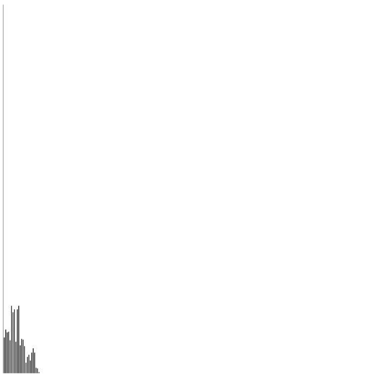
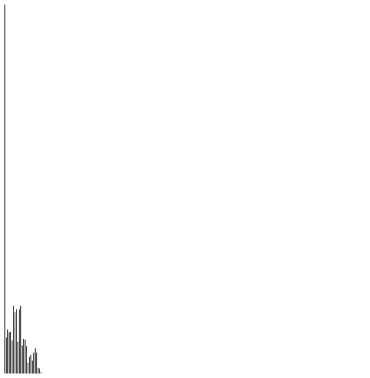
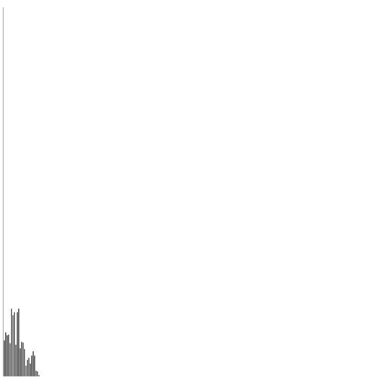
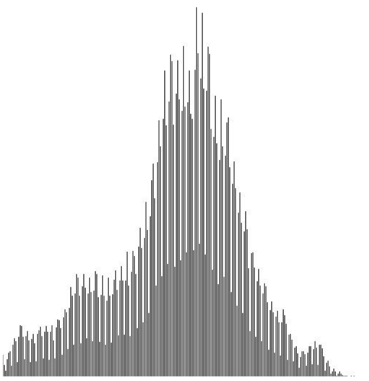
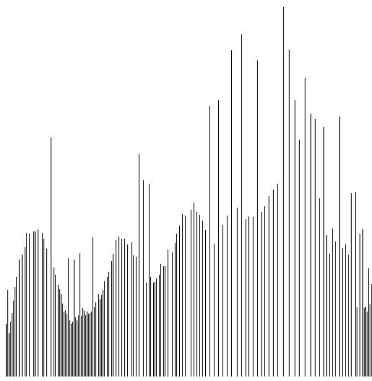
Histogram Equalization

Input Image	Histogram Equalized Image
 	 





Histogram Matching

Input Image	Reference Image	Histogram Matched Image
 	 	 
 	 	 

Analysis Aditya Narayan [13EC35010]

1. Histogram equalization method is used to improve an image's contrast by stretching its histogram. The target histogram is one that closely resembles a uniform distribution.
   Histogram matching is the method of modifying an image's histogram to match that of a reference histogram.

2. Histogram equalization is a special case of histogram matching wherein the reference histogram is a uniform histogram.

3. Histogram equalization is of great use to correct overexposed or underexposed images, wherein the image pixels are either too bright or too dull. Histogram matching is used in case of image outputs from similar sensors, to correct aberrations within them.

4. Camera today have a *High Dynamic Range* feature wherein the image is successively captured with increasing amount of light entering the lens (by varying the aperture). The final image is formed by the superimposition of all these images after histogram equalization. This allows the camera to capture details that are visible in both high-lighting and low-lighting conditions.

Analysis

Adarsh Kumar Kosta

[13EC35008]

1. Histogram Equalization is useful in extracting faded information from an image by enhancing its contrast over the entire color scale. By this, distinct boundaries in the image can be identified very well.

2. Histogram Matching is a technique to manipulate the histogram of an input image to match with the histogram of a reference image. It is a special case of Histogram equalisation wherein the histogram of the input image is transformed in conjunction with the reference image rather than getting evenly distributed over the entire color plane.

3. Thus, we can see that Histogram Equalization is equivalent to Histogram Matching with the reference image having a uniform distribution PDF.

4. These transformations along with many other useful effects are integrated in today’s digital cameras to output an enhanced version of the image.

5. Due to rounding off, during equalization and matching the obtained output histogram is not identical to the reference histogram but differs by a small amount for each intensity value. The profile is however similar.