ASSIGNMENT - 2

GROUP-7

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ASSIGNMENT – 2
HISTOGRAM EQUALIZATION & MATCHING

Aim:

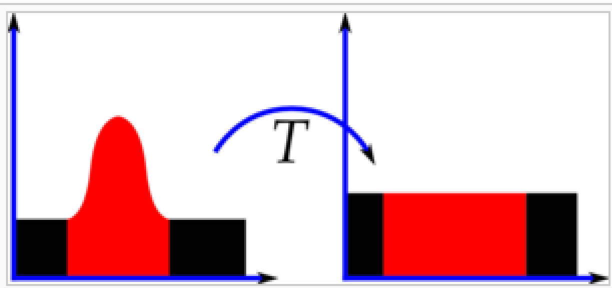
Write C++/Image-J modular functions -

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

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

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. 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.



Histograms of an image before and after equalization.

Implementation – Grayscale Image:

Consider a discrete grayscale image {x} and let ni be the number of occurrences of gray level i. The probability of an occurrence of a pixel of level i in the image is

$$p_x(i) = p(x = i) = \frac{n_i}{n}, \quad 0 \le i < L$$

L being the total number of gray levels in the image (typically 256), n being the total number of pixels in the image, and $p_x(i)$ being in fact the image's histogram for pixel value i, normalized to [0,1].

Let us also define the cumulative distribution function corresponding to px as

$$cdf_x(i) = \sum_{j=0}^{i} p_x(j),$$

which is also the image's accumulated normalized histogram.

We would like to create a transformation of the form y = T(x) to produce a new image {y}, with a flat histogram. Such an image would have a linearized cumulative distribution function (CDF) across the value range, i.e.

$$cdf_y(i) = iK$$

for some constant K. The properties of the CDF allow us to perform such a transform (see Inverse distribution function); it is defined as

$$cdf_y(y') = cdf_y(T(k)) = cdf_x(k)$$

where k is in the range [0,L). Notice that T maps the levels into the range [0,1], since we used a normalized histogram of {x}. In order to map the values back into their original range, the following simple transformation needs to be applied on the result:

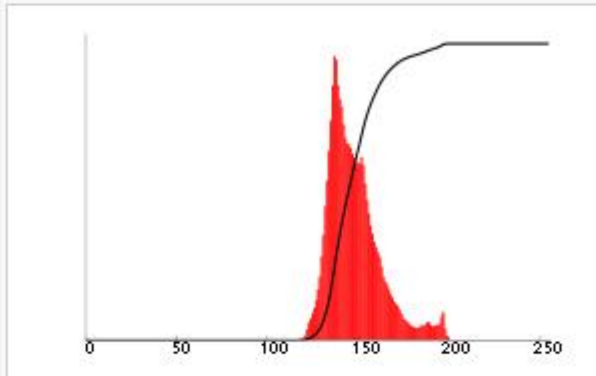
$$y' = y \cdot (\max\{x\} - \min\{x\}) + \min\{x\}$$

Histogram equalization of color images:

The above describes histogram equalization on a grayscale image. However it can also be used on color images by applying the same method separately to the Red, Green and Blue components of the RGB color values of the image. However, applying the same method on the Red, Green, and Blue components of an RGB image may yield dramatic changes in the image's color balance since the relative distributions of the color channels change as a result of applying the algorithm. However, if the image is first converted to another color space, Lab color space, or HSL/HSV color space in particular, then the algorithm can be applied to the luminance or value channel without resulting in changes to the hue and saturation of the image.

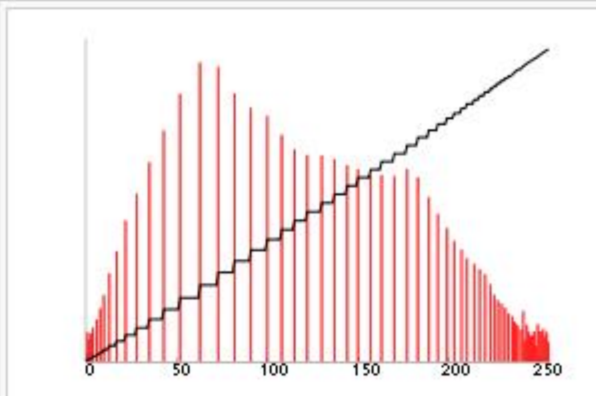
Histogram equalization Example (Source - Wikipedia):

An unequalized image



Corresponding histogram (red) and cumulative histogram (black)

The same image after histogram equalization

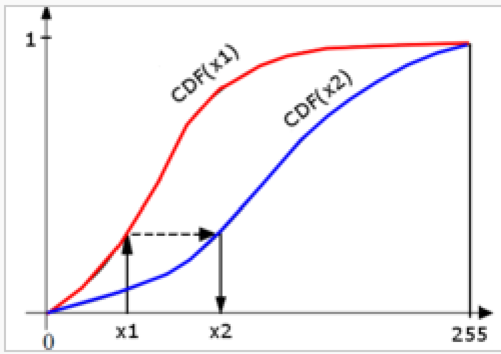


Corresponding histogram (red) and cumulative histogram (black)

The above describes Histogram Equalization performed on an example Grayscale Image (Source – Wikipedia). The same has been performed and observations are recorded for reference.

Histogram Matching:

Histogram matching is a process where an image, or higher dimension scalar data is modified such that its histogram matches that of another (reference) dataset. A common application of this is to match the images from two sensors with slightly different responses, or from a sensor whose response changes over time



An example of histogram matching

Algorithm:

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 – $F_1()$ for the reference image and $F_2()$ for the target image. Then for each gray level $G_1 \in [0, 255]$, we find the gray level G_2 for which $F_1(G_1) = F_2(G_2)$, and this is the result of histogram matching function: $M(G_1) = G_2$. Finally, we apply the function $M()$ on each pixel of the reference image

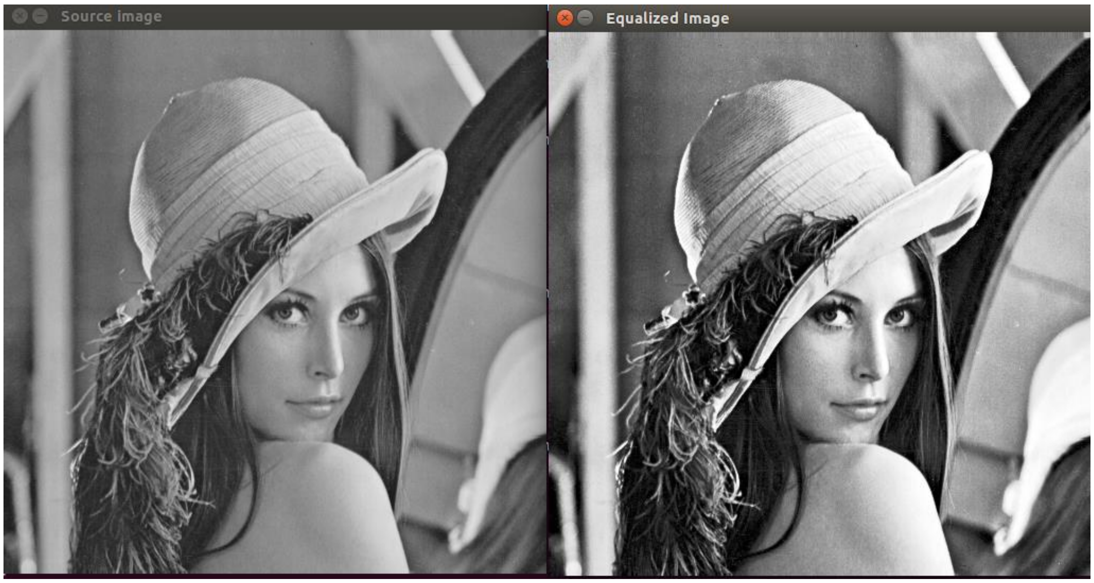
Exact histogram matching:

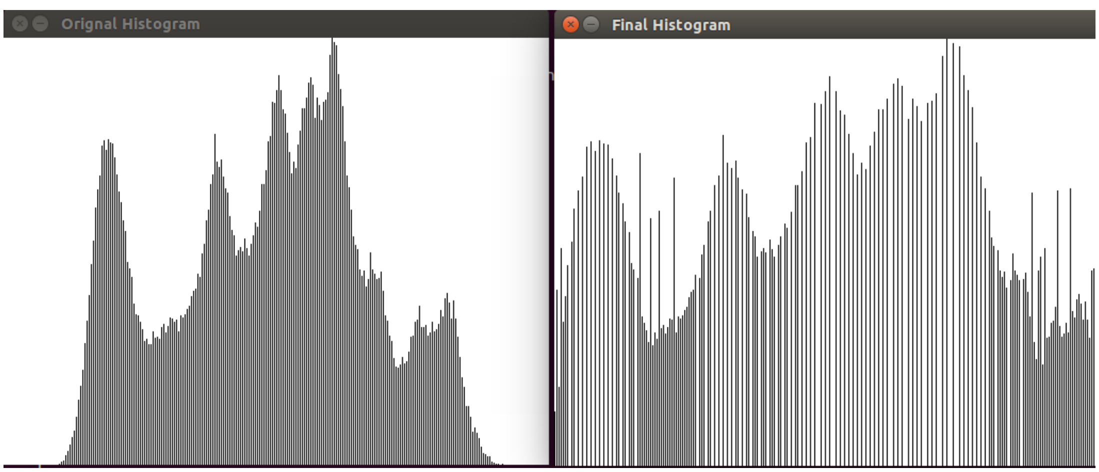
In typical real-world applications, with 8-bit pixel values (discrete values in range [0, 255]), histogram matching can only approximate the specified histogram. All pixels of a particular value in the original image must be transformed to just one value in the output image.

Exact histogram matching is the problem of finding a transformation for a discrete image so that its histogram *exactly* matches the specified histogram.[3] Several techniques have been proposed for this. One simplistic approach converts the discrete-valued image into a continuous-valued image and adds small random values to each pixel so their values can be ranked without ties. However, this introduces noise to the output image.

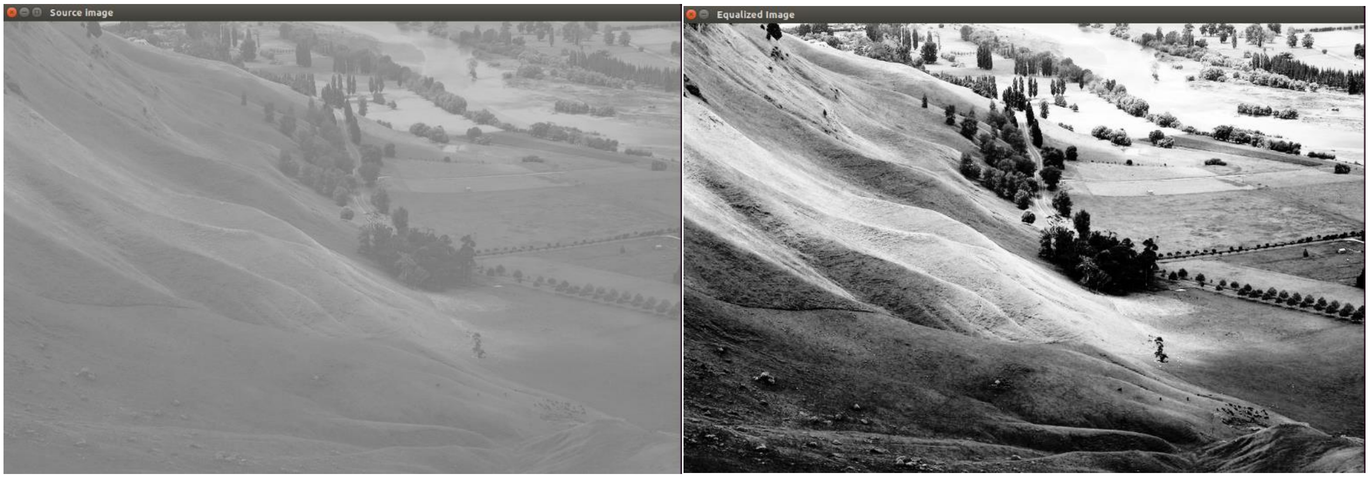
Observations –

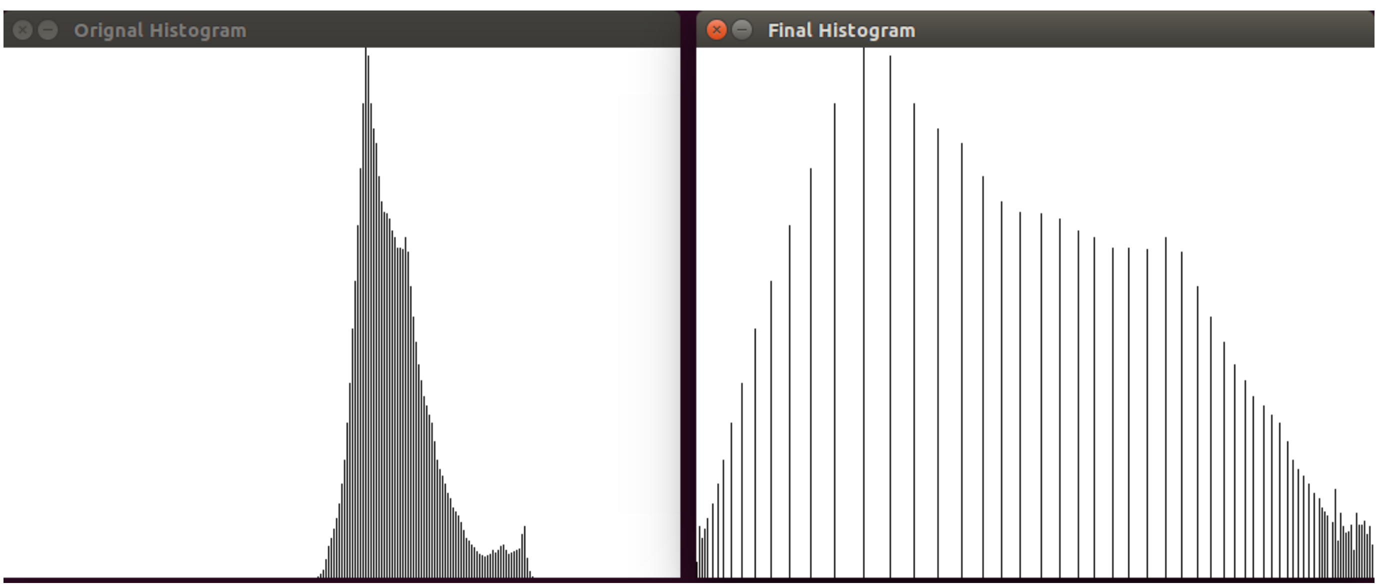
1) **Histogram equalization – Lena Grayscale Image**



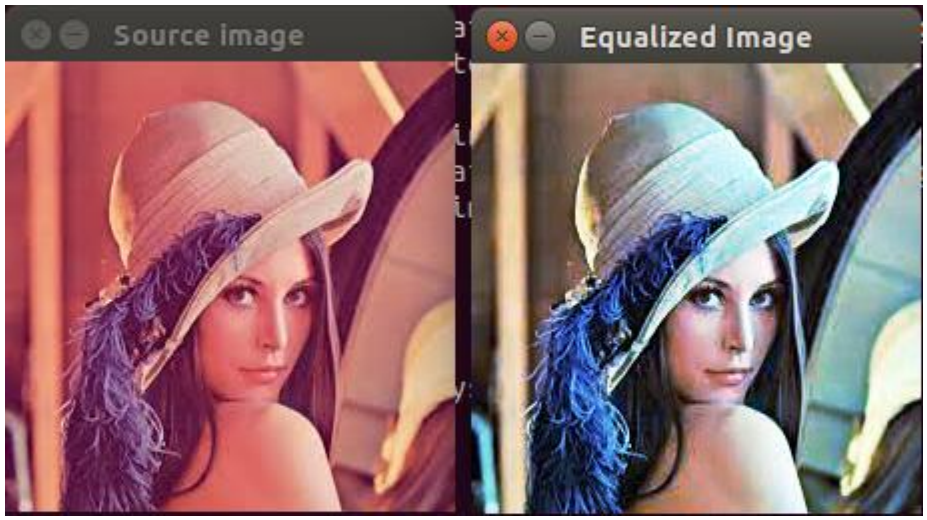


2) Histogram equalization – Wikipedia Example Image



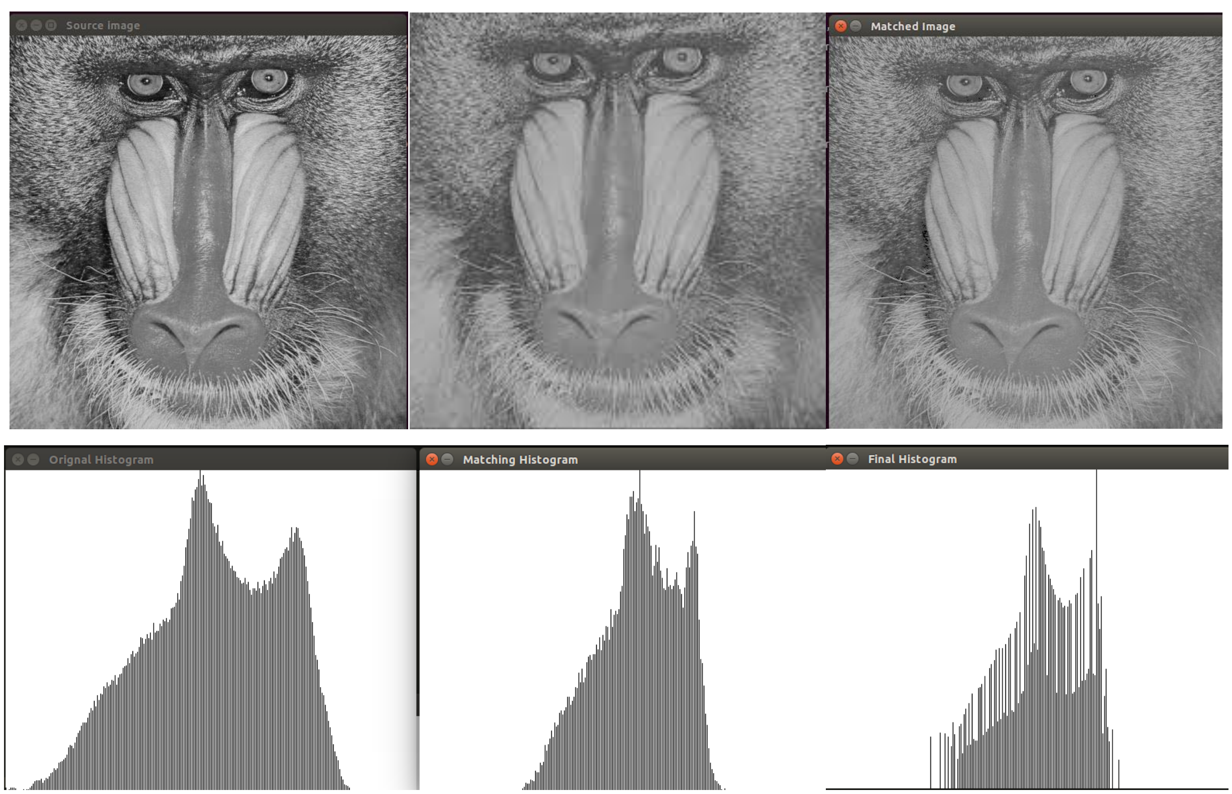


3) Histogram equalization – Color Image



4) Histogram Matching – Grayscale Image

Histogram Matching done with respect to Baboon Dull (Center Image)



5) Histogram Matching – Color Image

Histogram Matching done with respect to Lena (Center Image)