IMAGE PROCESSING AND INTERPRETATION

CS474.674.1001

PROGRAMMING ASSIGNMENT NO: 1

A Report

by

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Division of Work Statement

Pratik Walunj and Jalpa Kaila divided the work for this assignment as follows:

Coding:

- Pratik handled coding for Questions 1 and 2.

- Jalpa handled coding for Questions 3 and 4.

Report Write-up:

- Pratik contributed to Section 1.1, 1.2, 2.1 and 2.2.

- Jalpa contributed to Section 1.3, 1.4, 2.3 and 2.4.

We collaborated on coding and provided mutual input for report sections to ensure balanced contribution in both aspects.

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CHAPTER 1. MOTIVATION

The motivation behind this text is to shed light on the fundamental principles and practical applications of key image processing techniques, namely image quantization, image subsampling, histogram equalization, and histogram specification. Image quantization is at the core of transforming continuous image data into discrete values, enabling efficient digital representation and manipulation, with applications like compression and storage optimization. Exploring image subsampling showcases its impact on image size and quality, emphasizing the trade-offs between resolution and computational efficiency for informed decision-making in handling extensive image datasets. Additionally, powerful techniques like histogram equalization, which enhances image contrast and detail visibility, and histogram specification, which adjusts image contrast and brightness, are explained with practical examples, enhancing comprehension in fields like medical imaging and computer vision. Throughout the text, the inclusion of figures and images not only aids understanding but also illustrates real-world applications, making image processing accessible to a broad audience in fields such as computer science, engineering, and healthcare, empowering them to manipulate and enhance digital images, thus driving progress and innovation.

CHAPTER 2. THEORY

2.1 Image Sampling

Image sampling is a fundamental process in image processing, involving the measurement of image values at discrete and finite points. This technique allows us to represent a continuous image in a digital form.

In the context of image subsampling, we reduce the image resolution by a specified factor. For instance, consider a 4x4 pixel image array. When we subsample it by a factor of 2, we effectively reduce the image size. In this case, for every 2x2 block of pixels, we select only one pixel. This selection process involves choosing one pixel from each group of four pixels, resulting in a lower-resolution representation of the original image.

Image subsampling is commonly employed to reduce data size or simplify processing while retaining essential information. It's a technique used in various image processing applications, including compression, and downscaling for efficient storage or transmission.

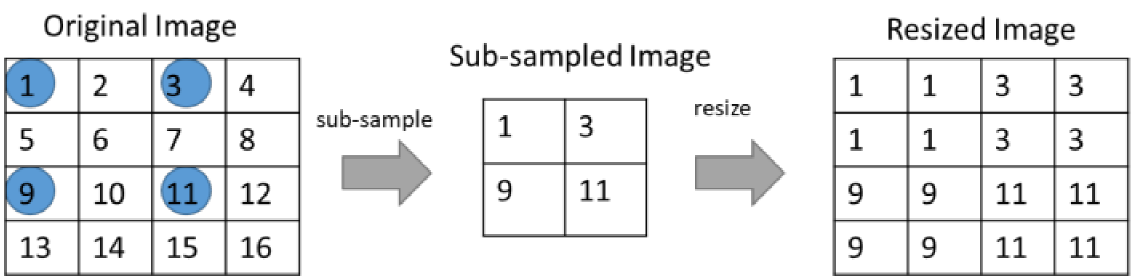


Figure 1: Figure Showing subsampling of 4x4 image by factor of 2 and then again resizing it to 4x4 image

2.2 Image Quantization

Image quantization is a crucial process in image processing where the measured values of an image at sampled locations are represented as integers. This method involves converting continuous data, typically in the form of continuous-tone images, into a discrete format suitable for digital representation and manipulation.

In the context of image quantization, one common application is the reduction of gray levels. Gray levels represent the various shades of gray in an image, often ranging from 0 (black) to 255 (white) in an 8-bit grayscale image. When gray level reduction is applied, it means reducing the number of distinct gray levels to a lower value, such as 128.

The process of quantization involves mapping the original gray levels onto the reduced set of gray levels. In the case mentioned, where the gray level range is reduced from 0-255 to 0-128, each original gray level value is reassigned to the closest matching value in the new reduced set. For instance, the original value of 64 may be mapped to 32 in the reduced set.

Image quantization is an essential technique used for various purposes, including reducing data size, simplifying image processing, and optimizing storage or transmission efficiency. It finds applications in image compression, dithering, and creating images suitable for display on devices with limited color or grayscale capabilities.

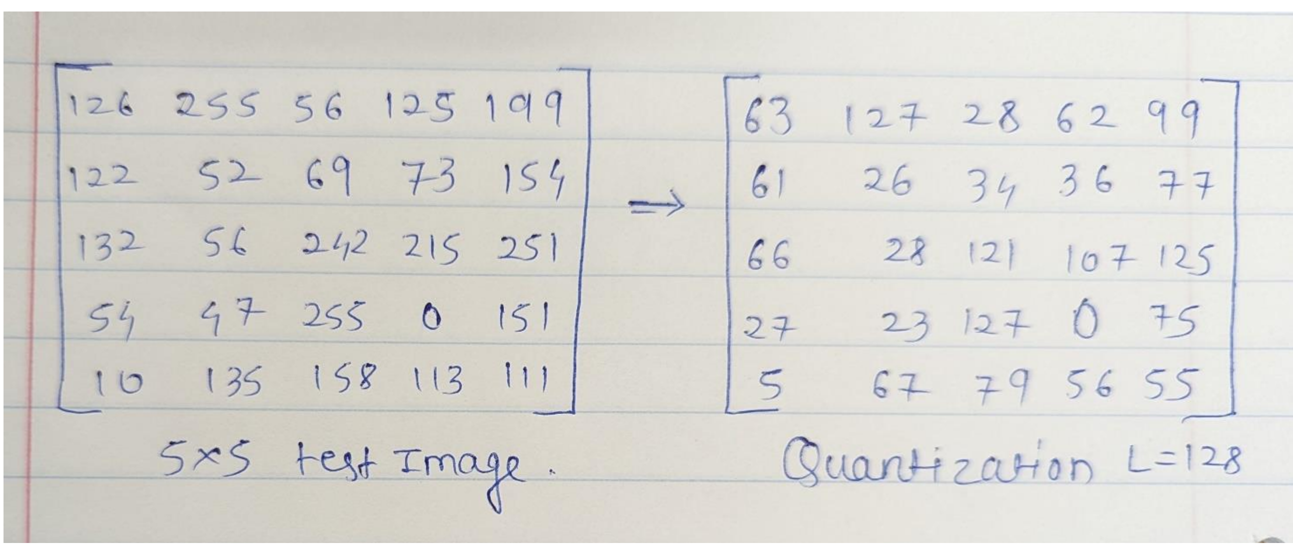


Figure 2: Figure Showing Quantization of 5x5 test image by L =128

2.3 Histogram Equalization:

In image processing, Histogram Equalization technique is used to enhance the contrast and improve the visibility of the details in image. The main task is to redistribute the gray-level values uniformly.

The histogram equalization process performs computing of cumulative density functions (cdf) of the original image's histogram, and it maps each pixel intensity value to new value based on cdf.

The new image has improved contrast and detail visibility of the image because of balanced distribution of pixel values.

Following steps are required to compute histogram equalization:

1. Compute Histogram
2. Compute probability density function (pdf) which means Normalize the histogram by diving each pixel value with total number of pixels.
3. Compute cumulative distribution function by taking integral of all values of pdf. It represents the cumulative probability of pixels intensities of an image.
4. Map pixel intensity of original image with new intensity value using cdf.
5. Generate equalized image by replacing the pixels in original image with its corresponding new intensity value obtained.

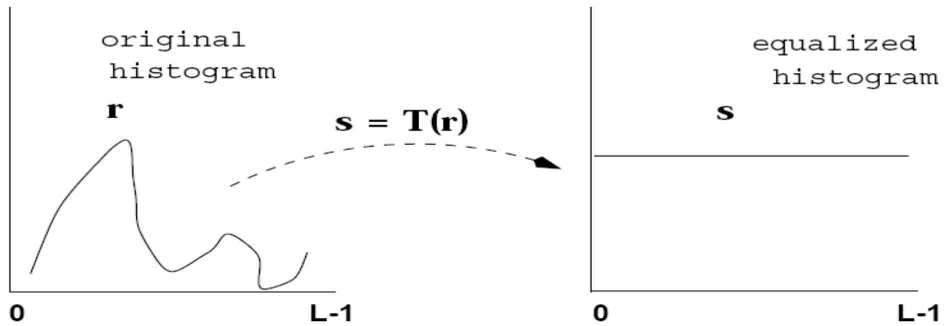


Figure 3: Figure presents the histogram of an original image and after applying the transformation function s=T(r) it will generate the equalized histogram.

2.4 Histogram Specification:

Histogram specification is a technique in image processing to manipulate the histogram of an image so that it matches a predefined reference histogram. Histogram specification is also known as histogram matching. Histogram equalization yields an image with uniform pdf. Sometimes an image with non-uniform pdf gives better results. So that histogram specification technique makes that possible by distributing the pixels non-uniformly.

Histogram specification involves two histogram equalizations and one inverse function to get the final image. For that, the calculation of cdf function on both input image and reference histogram. Then matching the pixel intensity of input image to new value based on relationship between these cdfs.

Following steps are required to compute histogram specification:

1. Calculate the histogram of input image.
2. Calculate the histogram of reference image if input is an image not a histogram.
3. Calculate the cumulative density function on both histogram of input image and reference image for the histogram equalizations.
4. Perform mapping for each pixel in input image, map its original intensity to a new intensity value based on the relationship between the cdf of the input and reference image.
5. Create the final image by replacing each pixel in the input image with corresponding new intensity value.
6. The histogram of the final image and reference input image should be same as a result.

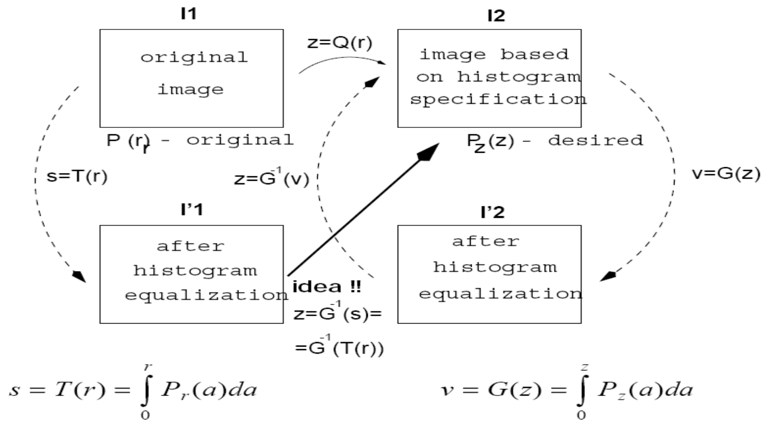


Figure 4: Figure presents an original image I1 and histogram of a reference image. Histogram equalization is applied on both s=T(r) and v=G(z). The inverse function is applied on T(r) to get final image I2 after histogram specification.

CHAPTER 3. RESULTS AND DISCUSSION

3.1 Image Sampling

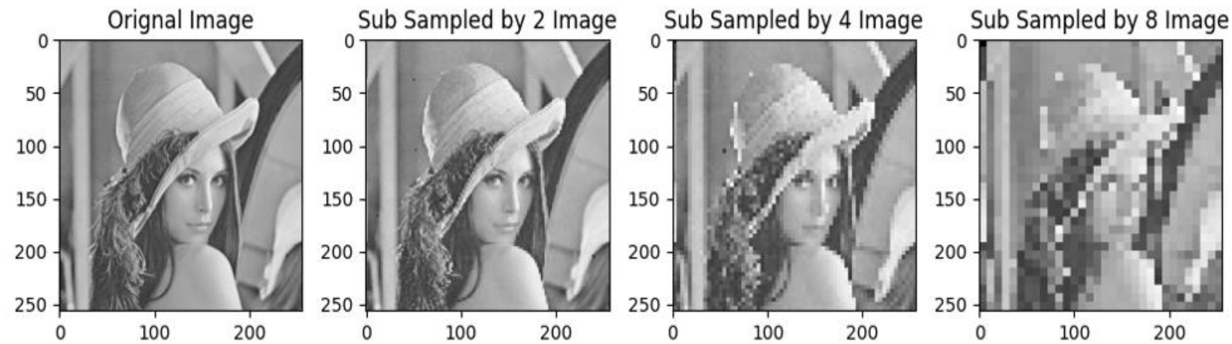


Figure 5: A figure illustrating image subsampling at factors of 2, 4, and 8 is presented, demonstrating the reduction in image resolution at each step

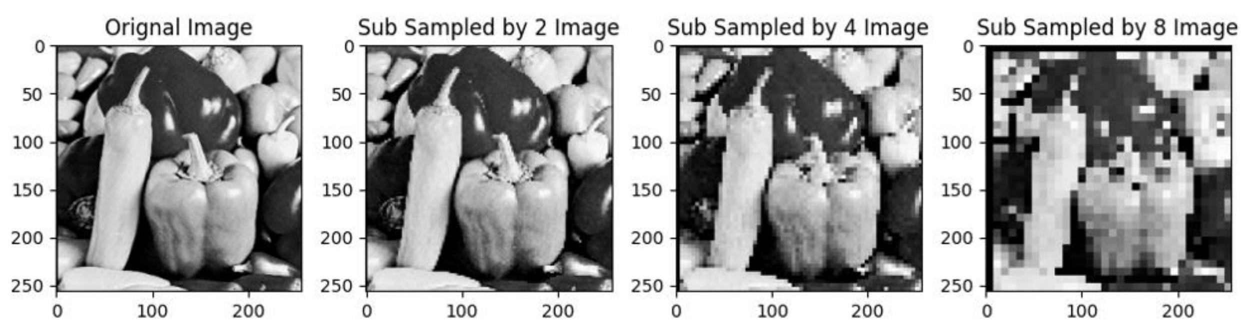


Figure 6: A figure illustrating image subsampling at factors of 2, 4, and 8 is presented, demonstrating the reduction in image resolution at each step

In Figures 5 and 6, we can observe the effects of sub-sampling the original image at different rates: 2x, 4x, and 8x. Sub-sampling is a technique used to reduce the size of an image by retaining only a fraction of the original pixels. While it can be an efficient way to decrease computational load and storage requirements, it often results in a noticeable distortion of the image.

As we increase the sub-sampling rate, the image becomes progressively more distorted and loses fine details. This distortion occurs because, with higher sub-sampling rates, we retain fewer pixels to represent the same area of the original image. Consequently, the image appears more pixelated and less smooth, with the individual pixels becoming more prominent.

The distortion becomes particularly pronounced at an 8x sub-sampling rate, where only a fraction of the original pixels is retained, causing the image to lose much of its visual fidelity. This reduction in quality is a trade-off between image size and image clarity, and the choice of sub-sampling rate depends on the specific requirements of the application.

In summary, sub-sampling can be a useful tool for reducing the size of an image, but it comes at the cost of image distortion and loss of detail. The choice of sub-sampling rate should be made carefully, considering the balance between image size and image quality required for a particular task or application.

3.2 Image Quantization

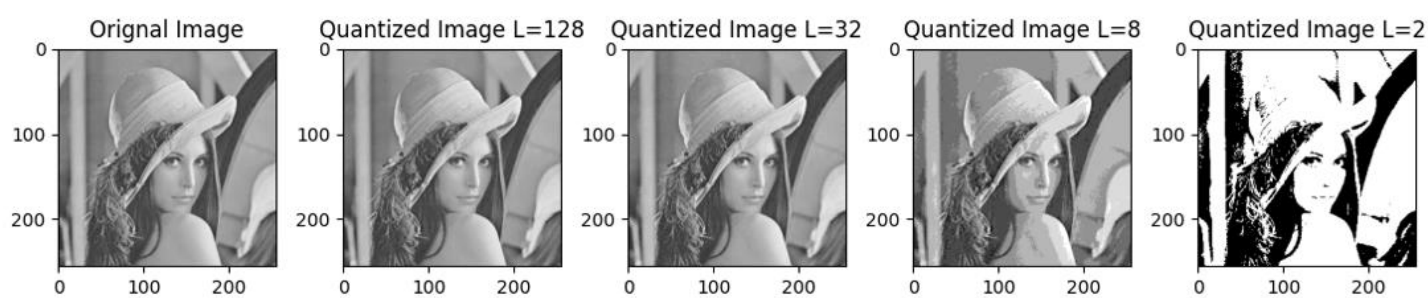


Figure 7: A figure depicting image quantization at different levels, specifically at quantization levels of 128, 32, 8, and 2, showcases the gradual reduction in the number of distinct color or intensity values used to represent the image, leading to a loss of detail and smoothness as the level decreases.

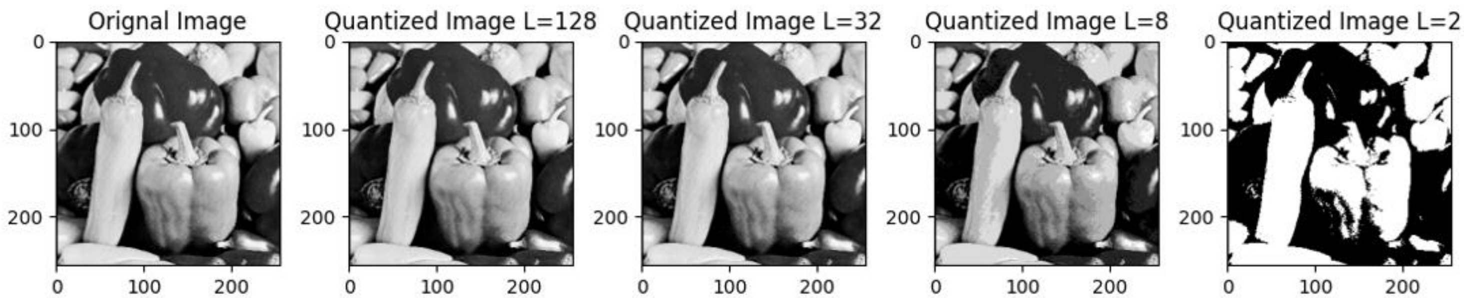


Figure 8: A figure depicting image quantization at different levels, specifically at quantization levels of 128, 32, 8, and 2, showcases the gradual reduction in the number of distinct color or intensity values used to represent the image, leading to a loss of detail and smoothness as the level decreases.

In Figures 7 and 8, we can observe the impact of quantization on the original image, with varying levels of quantization factors: 128, 32, 8, and 2. Quantization is a process in which the number of distinct gray levels or colors in an image is reduced, essentially simplifying the image's color or gray-scale representation.

As the quantization factor decreases, meaning that fewer distinct gray levels are used, the image progressively transitions towards a black and white appearance. This happens because with a lower quantization factor, there are fewer possible values for each pixel's intensity, resulting in a coarser representation of the original image's color or gray-scale information.

At a quantization factor of 128, the image retains a relatively high level of detail and maintains many distinct shades of gray. As we reduce the factor to 32, 8, and 2, the image becomes increasingly simplified, with fewer shades of gray and colors. At a quantization factor of 2, the image essentially becomes binary, with only two levels of intensity, typically black and white, which gives it a stark, high-contrast appearance.

This effect is often used in image processing to reduce the amount of data required to represent an image while sacrificing color or gray-scale detail. It can be particularly useful in scenarios where memory or bandwidth constraints are important considerations.

In summary, as the quantization factor decreases, an image loses its color or gray-scale richness and approaches a black and white appearance. The choice of quantization factor depends on the specific requirements of the application and the trade-off between image fidelity and data reduction.

3.3 Histogram Equalization:

3.3.1 Histogram equalization on 5x5 test image

This section 2.3.1 shows the result of histogram equalization applied on 5x5 test image. As you can see in Figure 9, First we input the 5x5 test image with different intensity values at each pixel level. We calculate the probability at each pixel level by dividing the total number of pixel values. Then we calculate the cumulative probability density function by taking the sum of all pixel values of 5x5 test image. The mapping is performed by Map pixel intensity of original image with new intensity value using the calculated cdf.

The purpose of the Image equalization is to improve the contrast of an image. Here the darker region becomes darker and bright region becomes brighter. This presents a more visuality of certain feature or pattern of an image compared to original image.

We applied image equalization on 5x5 test image. As we can see in figure 3 left side is the input 5x5 image and right side is the resultant equalized test image. The top row of the image having the darker region after equalization becomes more darker. The bottom or last row of the image has brighter pixels so after equalization it becomes more brighter.

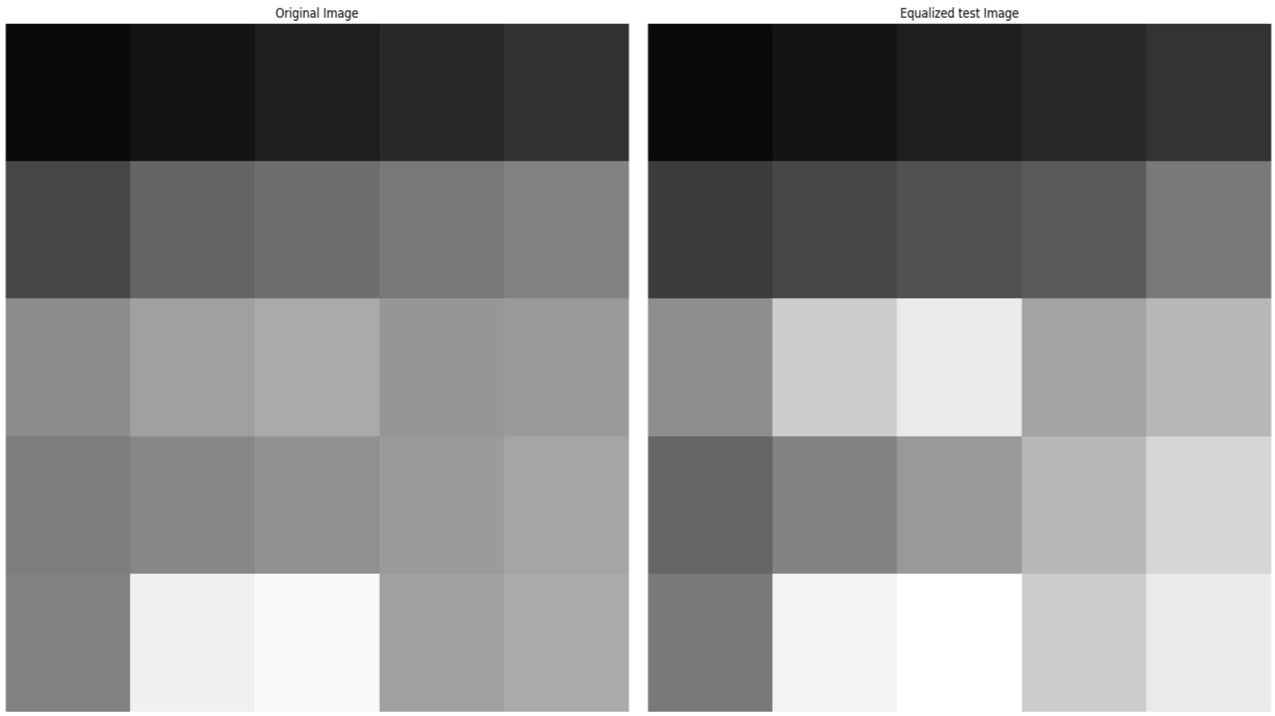


Figure 9: Left: Input image with size 5x5. **Right:** Equalized image after performing image equalization on input image.

3.3.2 Histogram Equalization on boat and f_16 image

This section 2.3.2 shows the result of histogram equalization applied on boat and f_16 images. As you can see in Figure 10, First we input the boat and f_16 image. We calculate the probability at each pixel level by dividing the total number of pixel values. Then we calculate the cumulative probability density function by taking the sum of all pixel values for boat and f_16 test images. The mapping is performed by Map pixel intensity of original boat and f_16 image with new intensity value using the calculated cdf for boat and f_16 images.

The purpose of the Image equalization is to improve the contrast of an image. Here the darker region becomes darker and bright region becomes brighter. This presents a more visuality of certain feature or pattern of an image compared to original image. As the contrast increases, the histogram will spread out and details in the images become more visible. This is the benefit of image equalization when we have images with poor lighting condition or where certain details are hidden due to limited dynamic range.

We applied the image equalization on boat and f_16. The Top left corner of figure 10 shows the original image of the boat and f_16. Top right corner of figure 10 shows the resultant equalized image after applying the equalization technique. As we can see in the figure it increases the contrast of the image and darker regions becomes darker such as some part of tree in boat image and some part of mountains in f_16 image. The brighter regions become brighter such as right side of the tree in boat image and right side of the mountain in f_16 image.

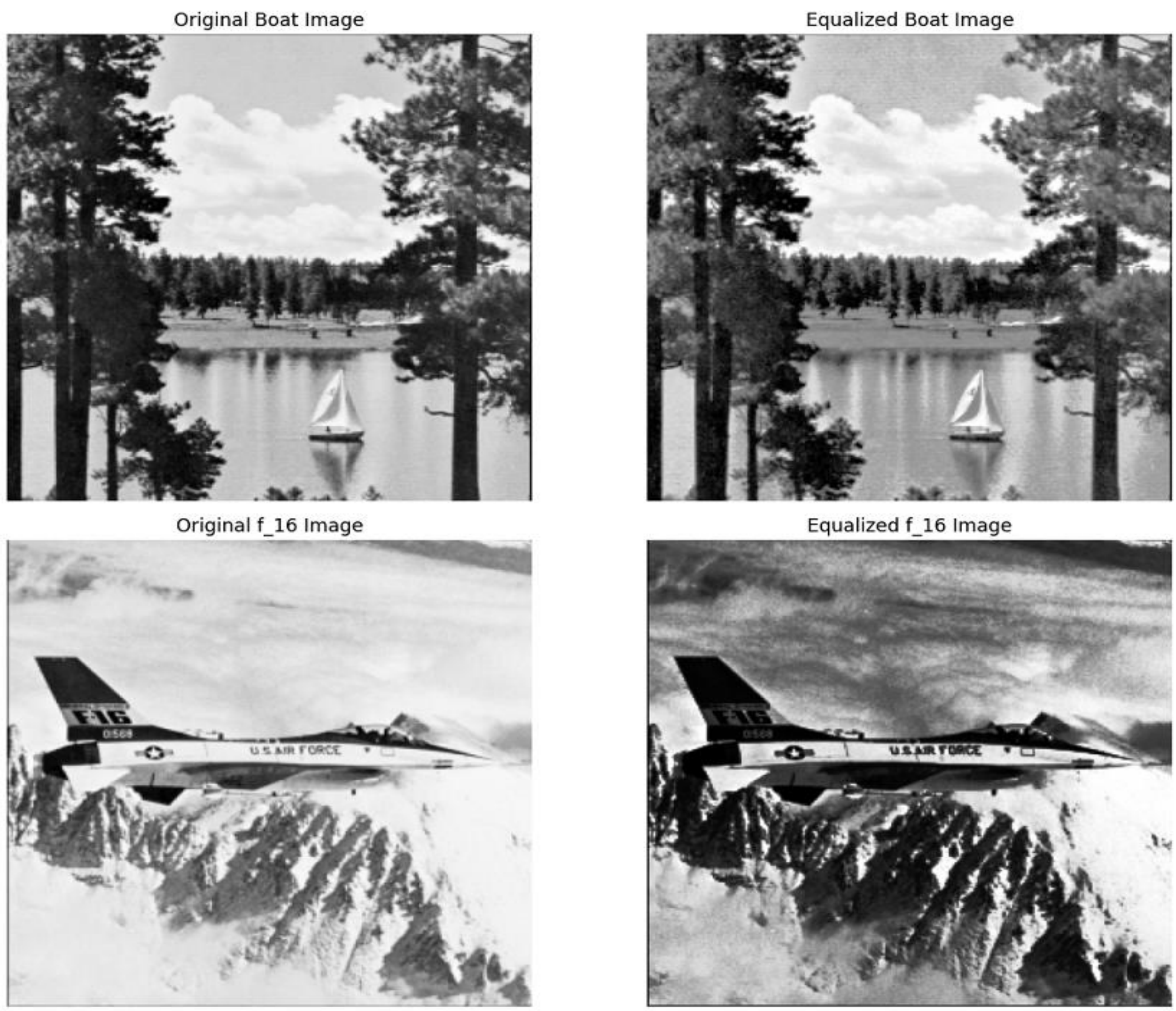


Figure 10: Top Left: Input image Boat image. **Top Right:** Equalized Boat image after performing image equalization on input image. **Bottom Left:** Input image f_16 image. **Bottom Right:** Equalized f_16 image after performing image equalization on input image.

3.3.3 All Histograms before and after equalization on boat and f_16 image

This section 2.3.3 shows the result of All histograms before and after equalization applied on boat and f_16 images. As you can see in Figure 11, First we input the boat and f_16 image. We calculate the probability at each pixel level by dividing the total number of pixel values. Then we calculate the cumulative probability density function by taking the sum of all pixel values for boat and f_16 test images. The mapping is performed by Map pixel intensity of original boat and f_16 image with new intensity value using the calculated cdf for boat and f_16 images.

We applied the image equalization on boat and f_16. The Top 1 of figure 11 shows the original image of the boat, Top 2 of figure 11 shows the equalized image of boat, Top 3 of figure 11 shows the histogram of boat image, Top 4 of figure 11 shows the histogram of equalized boat image. Bottom 1 of figure 11 shows the original image of the f_16, Bottom 2 of figure 11 shows the equalized image of f_16, Bottom 3 of figure 11 shows the histogram of f_16 image, Bottom 4 of figure 11 shows the histogram of equalized f_16 image.

As we can see in the figure 10 and 11 it increases the contrast of the image and darker regions becomes darker such as some part of tree in boat image and some part of mountains in f_16 image. The brighter regions become brighter such as right side of the tree in boat image and right side of the mountain in f_16 image.

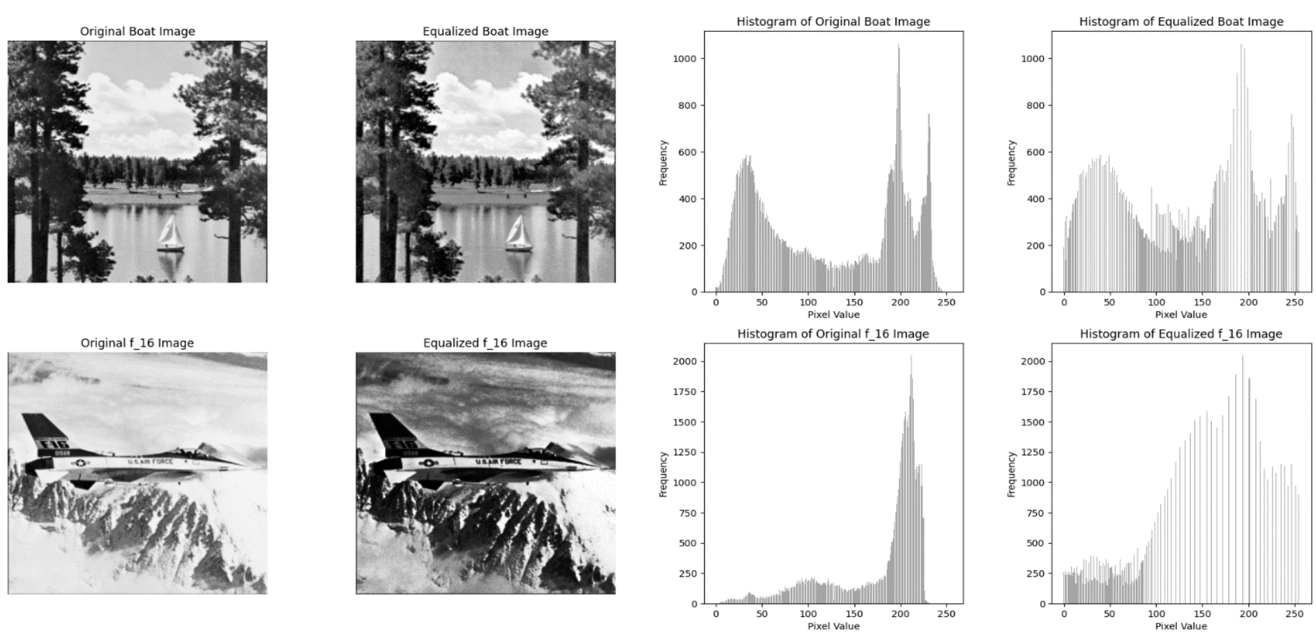


Figure 11: Top 1: Input Boat image. **Top 2:** Equalized Boat image after performing image equalization on input image. **Top 3:** Histogram of Input boat image. **Top 4:** Histogram of Equalized boat image. **Bottom 1:** Input f_16 image. **Bottom 2:** Equalized f_16 image after performing image equalization on input image. **Bottom 3:** Histogram of Input f_16 image. **Bottom 4:** Histogram of Equalized f_16 image.

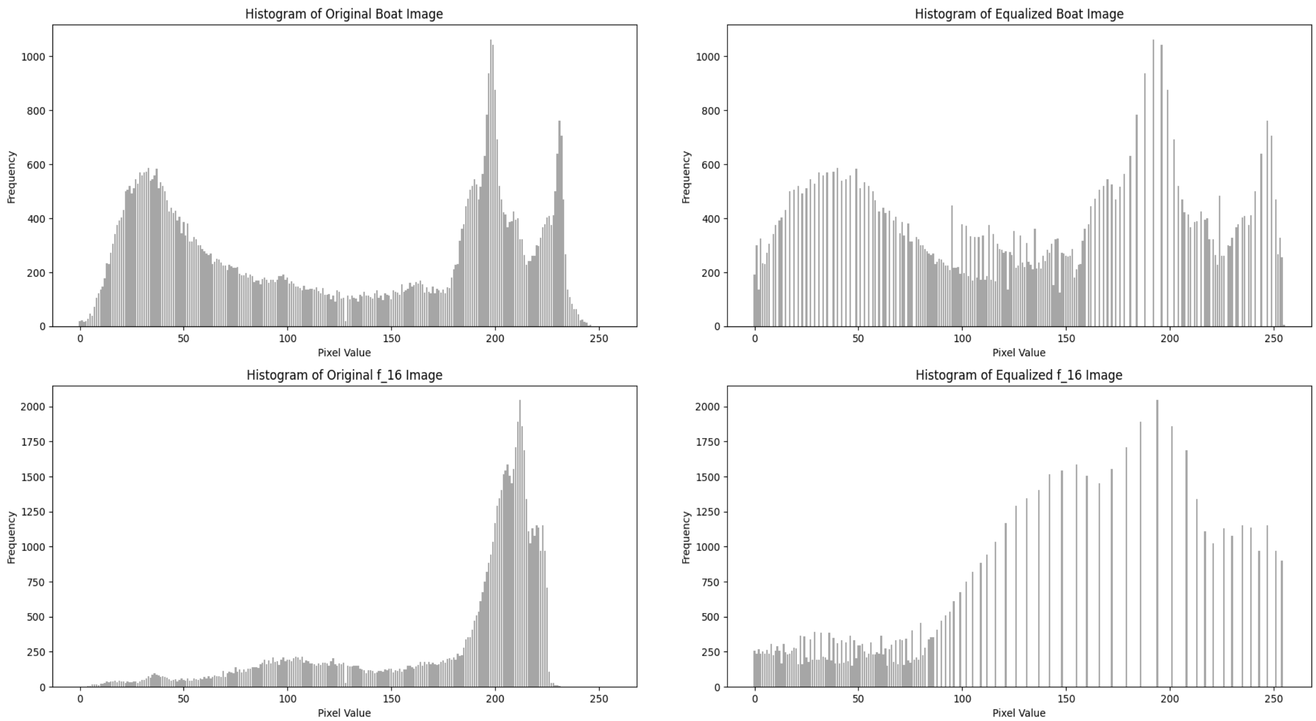


Figure 12: Top 1: Histogram of Input Boat image. **Top 2:** Histogram of Equalized Boat image after performing image equalization on input image. **Bottom 1:** Histogram of Input f_16 image. **Bottom 2:** Histogram of Equalized f_16 image after performing image equalization on input image.

The histogram of the original boat image and equalized boat image are different. As we can see, in figure 12, the histogram of equalized boat image is broader than histogram of the original boat image. Same thing we can see in f_16 image. The histogram of f_16 after equalization is broader than histogram of original f_16 image.

The Effectiveness of the image equalization can vary depending on the specific image and intended application. For the boat and f_16 image, we applied the same equalization techniques on both, but we can see more visibility in f_16 image compared to boat image after the equalization. From analysis of histograms, we can say that the equalized histogram of f_16 image gives more details compared to its original f_16 image and same thing for equalized Histogram of boat image is broader and gives more details than original histogram of boat image.

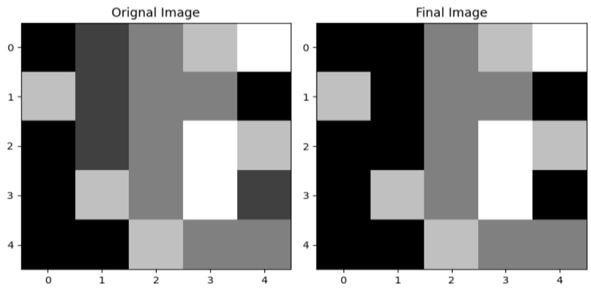
3.4 Histogram Specification:

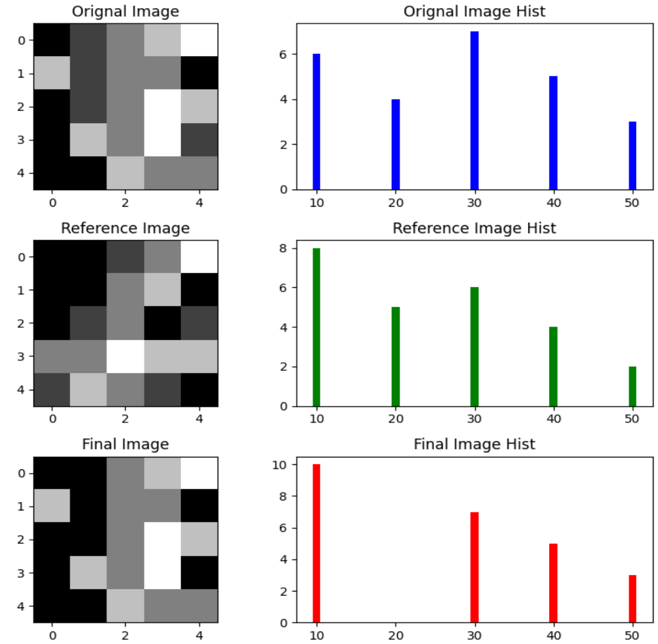
3.4.1 Histogram Specification on 5x5 test image

This section 2.4.1 shows the result of histogram specification applied on 5x5 test image. As you can see in Figure 13, First we input the 5x5 test image with different intensity values at each pixel level and reference image with same size. We calculated the histogram of both images then histogram equalization is applied on both images. The mapping is performed by Map pixel intensity of original image with new intensity value using corresponding calculated cdf and reference image. Then inverse function is applied to get final image which have same contrast and brightness level as given reference image.

The purpose of the Image specification is to change the distribution of pixel value of an image and make it similar to reference image. It is like adjusting the brightness and contrast of an image similar to reference image. So the final image have the same contrast and brightness as reference image.

We applied image specification on 5x5 test image. As we can see in figure 13 (a) is the input 5x5 image and final image after specification (b) All image and Histogram of original, reference, and final image after histogram specification. The contrast and brightness level of final image is set to contrast and brightness level of reference image and histogram of the final image is similar to histogram of reference image.





(a) **(b)**

Figure 13: (a) Input image with size 5x5 and Final image after specification. **(b)** All images and histogram of all images after performing image Specification on input image 5x5.

3.4.2 Histogram Specification on boat and f_16 image

This section 2.4.2 shows the result of histogram specification applied on boat and f_16 image. As you can see in Figure 14, First we input the boat and f_16 image with different intensity values at each pixel level and reference images sf and peppers correspondingly. We calculated the histogram of boat and f_16 images then histogram equalization is applied on both images. The mapping is performed by Map pixel intensity of original boat and f_16 image with new intensity value using corresponding calculated cdf for boat and f_16 images and reference images sf and peppers. Then inverse function is applied to get final image of boat and f_16 which have same contrast and brightness level as corresponding given reference images sf and peppers.

The purpose of the Image specification is to change the distribution of pixel value of boat and f_16 image and make it similar to corresponding reference images sf and peppers. It is like adjusting the brightness and contrast of boat and f_16 image similar to corresponding reference image sf and peppers. So, the final image of boat and f_16 have the same contrast and brightness as corresponding reference image sf and peppers.

As the contrast increases the histogram will spread out and details in the images become more visible. This is the benefit of image equalization when we have images with poor lighting condition or where certain details are hidden due to limited dynamic range.

We applied the image specification on boat and f_16. The Top and bottom left corner of figure 14 shows the original image of the boat and f_16. The top and bottom right corner of figure 14 shows the resultant final image after applying the specification technique. As we can see in the figure it set the contrast and brightness level of boat image to given reference sf image and f_16 image to peppers image.

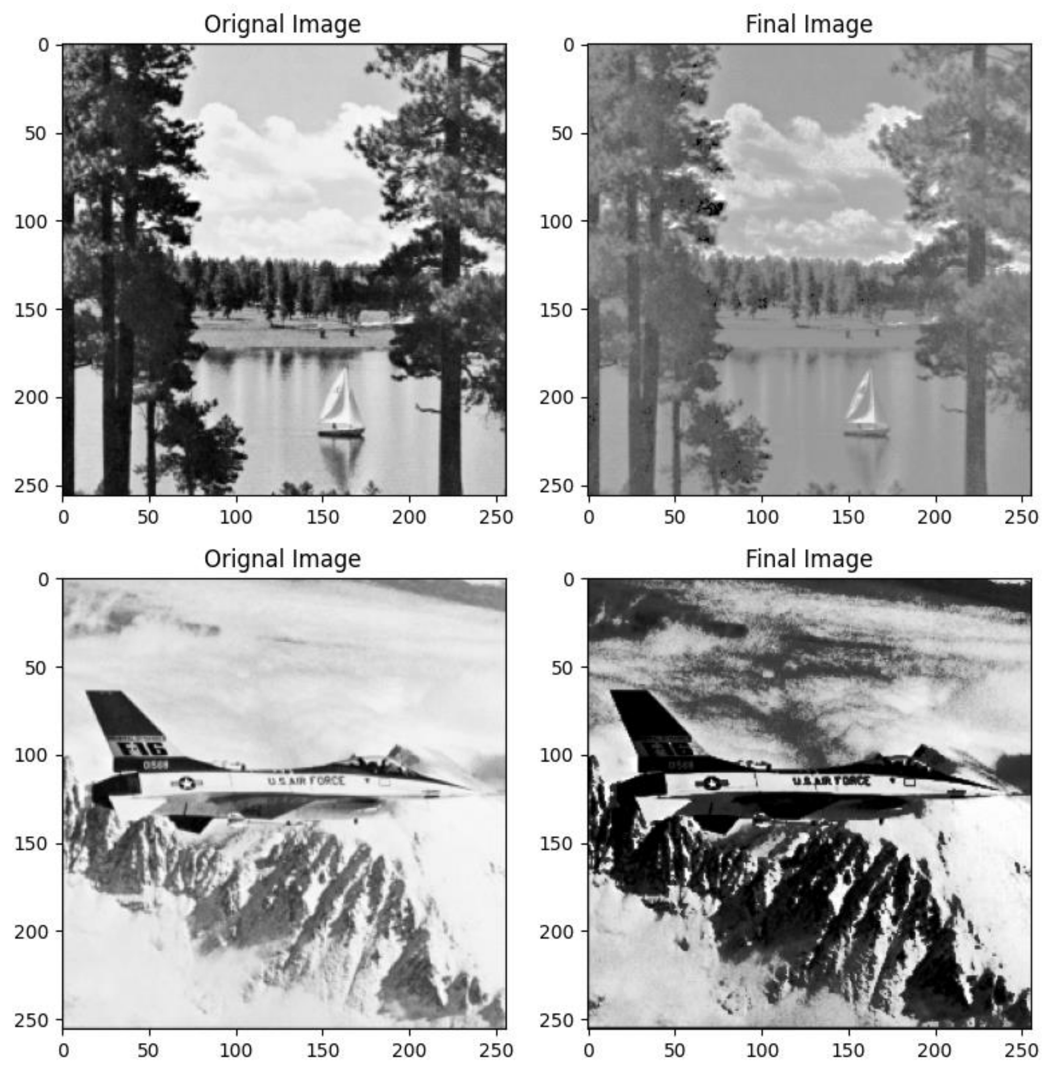


Figure 14: Top Left: Input image Boat image. **Top Right:** Final Boat image after performing histogram specification on input Boat image. **Bottom Left:** Input image f_16 image. **Bottom Right:** Final f_16 image after performing histogram specification on input f_16 image.

3.4.3 All Histograms before and after specification on boat and f_16 image

This section 2.4.3 shows the result of All histograms before and after specification applied on boat and f_16 images. As you can see in Figure 15, First we input the boat and reference sf image. We calculated the histogram of boat and sf images then histogram equalization is applied on both images boat and sf images. The mapping is performed by Map pixel intensity of original boat image with new intensity value using corresponding calculated cdf for boat image and reference sf image. Then inverse function is applied to get final image of boat which have same contrast and brightness level as corresponding given reference image sf.

We applied the image specification on boat and sf. The Top 1 of figure 15 shows the original image of the boat, Top 2 of figure 15 shows the histogram of an original image of boat. Middle 1of figure 15 shows the original image of sf, Middle 2 of figure 15 shows the histogram of an original image of sf, Bottom 1 of figure 15 shows the final image of the boat, Bottom 2 of figure 15 shows the histogram of the final image of boat.

The histogram of the original boat image and specified boat image are different. As we can see in the previous Equalization section, the histogram of equalized boat image is broader than histogram of the original boat image. After applying the specification, we get the final image of boat with same contrast and brightness level as reference sf image. The histogram of the final boat image is similar to the reference sf image.

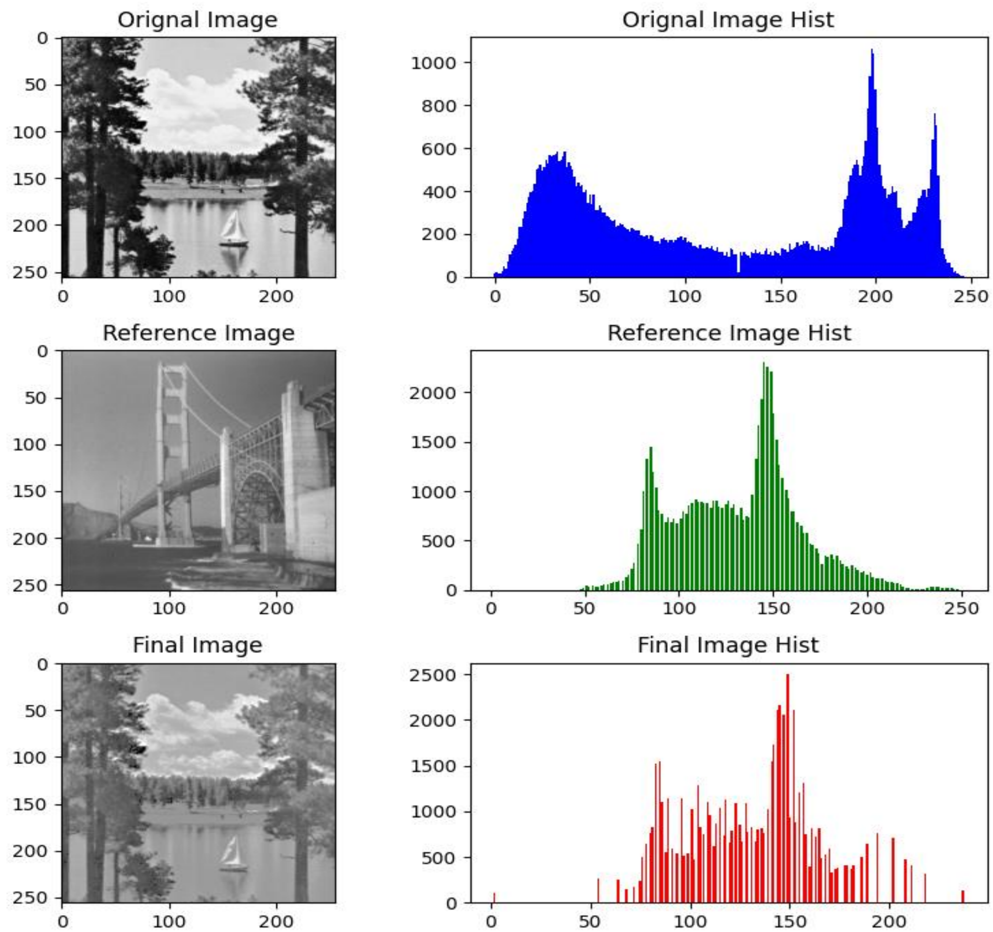


Figure 15: Top 1: Input Boat image. **Top 2:** Histogram of an original boat image. **Middle 1:** Reference sf image. **Middle 2:** Histogram of a sf image. **Bottom 1:** Final image after specification. **Bottom 2:** Histogram of a final image after specification.

As you can see in Figure 16, First we input the f_16 and reference peppers image. We calculated the histogram of f_16 and peppers images then histogram equalization is applied on both images f_16 and peppers images. The mapping is performed by Map pixel intensity of original f_16 image with new intensity value using corresponding calculated cdf for f_16 image and reference peppers image. Then inverse function is applied to get final image of f_16 which have same contrast and brightness level as corresponding given reference image peppers.

We applied the image specification on f_16 and peppers. The Top 1 of Figure 16 shows the original image of the f_16, Top 2 of Figure 16 shows the histogram of an original image of f_16, Middle 1of Figure 16 shows the original image peppers, Middle 2 of Figure 16 shows the histogram of an original image of peppers, Bottom 1 of Figure 16 shows the final image of the f_16, Bottom 2 of Figure 16 shows the histogram of the final image of f_16.

The histogram of the original f_16 image and specified f_16 image is different. As we can see in the previous equalization section, the histogram of equalized f_16 image is broader than histogram of the original f_16 image. After applying the specification, we get the final image of f_16 with same contrast and brightness level as reference peppers image. The histogram of the final f_16 image is similar to the reference peppers image.

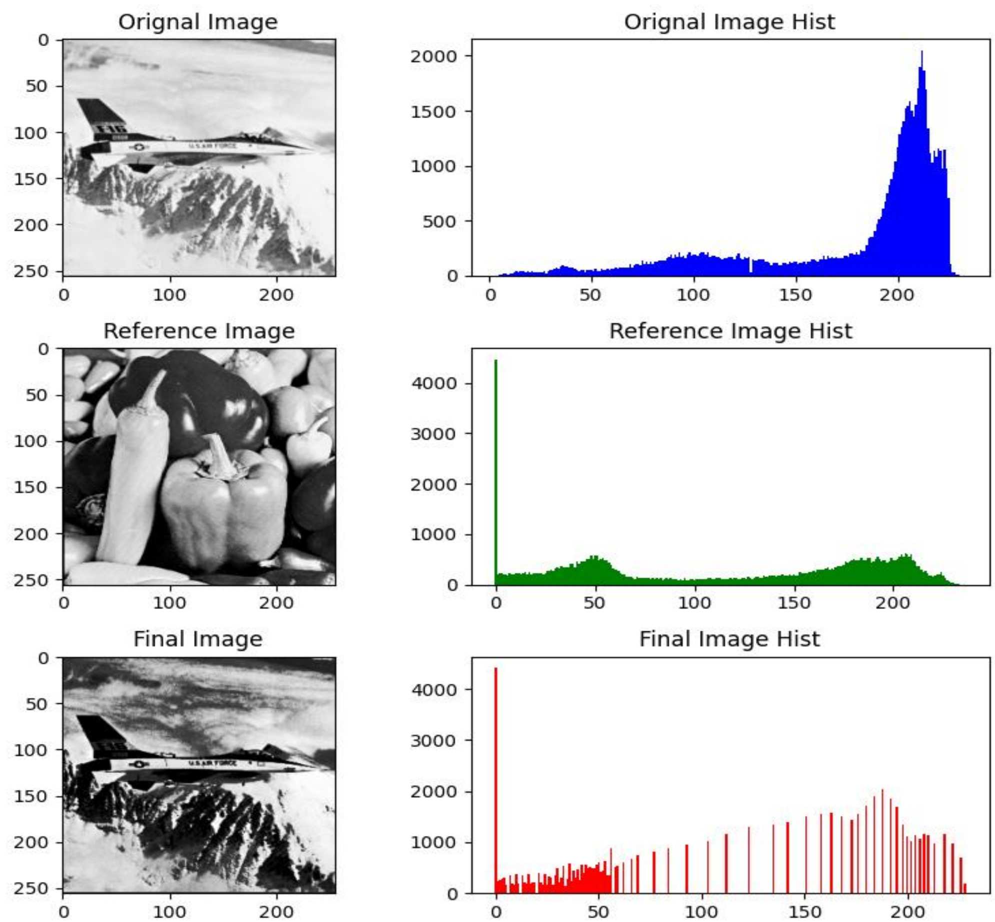


Figure 16: Top 1: Input f_16 image. **Top 2:** Histogram of an original f_16 image. **Middle 1:** Reference peppers image. **Middle 2:** Histogram of a peppers image. **Bottom 1:** Final image after specification. **Bottom 2:** Histogram of a final image after specification.

From the results of figures 16 and 17 we can say that the result image after Histogram Specification has a histogram that is similar to the histogram of the reference image. The pixel intensities of the original image changed according to reference image. Now we have result images with the same intensity level as reference image.

For the boat image the reference image is sf image which has low contrast so after applying specification the contrast of boat image is similar to sf image. For the f_16 image the reference image is peppers image which has high contrast so after specification the contrast of f_16 image is similar to peppers image.

In a result of figure 15 and 16, The histogram of final boat image after specification is similar to sf image and the histogram of final f_16 image after specification is similar to peppers image.

CHAPTER 4. REFRENCES

1) https://www.cse.unr.edu/~bebis/CS474/