CMPEN 455: Digital Image Processing

Project 4 – Image Enhancement: Histogram Modification

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A. Objectives

The goal of this project is to create a histogram – probability distribution function (**pdf**) and cumulative distribution function (**cdf**) of the given image, 'truck.gif'. Once this is complete, the next objective is to apply different degrees of gamma correction to the image, and obtain the **pdfs** and **cdfs** of the gamma-corrected images. The other main goals of the project are to modify the image based on criteria applied to the histogram, as well as applying histogram equalization to the image.

B. Methods

For question 1, we used the for loop to obtain each pixel's gray level. And obtain the number of pixels which has same gray value. We use the number of pixels which has an identify gray level divided by the total pixel number, thus we can get the probability distribution function (**pdf**) of each identified gray level.

$$p_r(r) = \frac{1}{N^2} \times h_r(r)$$

The Cumulative Distribution Function (**cdf**) of a random variable r, is the probability that a given value will be less than or equal to r. For instance, the CDF of gray level 20 would be the sum of the probabilities of gray level 0 to gray level 20 (inclusive).

$$c_r(r) = \sum_{i=0}^{r} p_r(i)$$

We divided the data into 8 bins; each containing 32 gray level values. This was done to view the data in a basic form, to get an idea of the distribution. The PDF and CDF are plotted using Matlab's bar function and 'histc' style.

However, to obtain a more accurate histogram and CDF of the image, we repeated the process without bins, representing all 256 gray levels. The result can be seen in Figure 3 & 4.

For question 2, we used the function below to gamma-correct the image:

$$s = cr^{\gamma},\ c > 0$$

As for an 8-bit gray-scale, we used equation:

$$s = T(r) = 255(\frac{r}{255})^{\gamma}$$

where c and γ are positive constants. c is equal to 1 (255/255), γ is equal to 5 and 0.2.

For question 3, contrast stretching, we used the formula below to apply histogram-modification.

$$T(r) = \begin{cases} 0 & 0 \le r < L_1 \\ mr + b & L_1 \le r \le L_2 \\ L-1 & L_2 < r \le L-1 \end{cases}$$

$$m = \frac{L-1}{L_2 - L_1}\ b = -mL_1$$

According to the question, we got the parameters L1, L2 using “min(find(cr>0.1))-1” and “max(find(cr<0.9))-1”

$$L_1 = argmin(c_r(r) \ge 0.1) - 1 = 64$$

$$L_2 = argmax(c_r(r) \le 0.9) - 1 = 128$$

So the mathematical transformation s=T(r) become:

$$s = T(r) = \begin{cases} 0 & 0 \le r < 64 \\ \frac{255}{64}r - 255 & 64 \le r < 128 \\ 255 & 128 \le r < 255 \end{cases}$$

Question 4 is about histogram equalization, we got the equalized gray-levels for several steps:

1. Obtain the **cdf** of the original image: Cr(r);

2. Lmax(255) * Cr(r)

3.T(r) = nint [Lmax*Cr(r)];

4. Equalized image: fn(x,y)= T[f(x,y)];

Like when we found the function s=T(r) that equalized the original image's PDF, we will create a similar function to linearize the original PDF, distributing the gray levels of the image as close to linear as possible.

C. Results

For Q1, the PDF and CDF with 8 bins are shown below. It is obvious that the contrast is low because most of the gray levels are within the lower half of the possible values that the pixels can take.

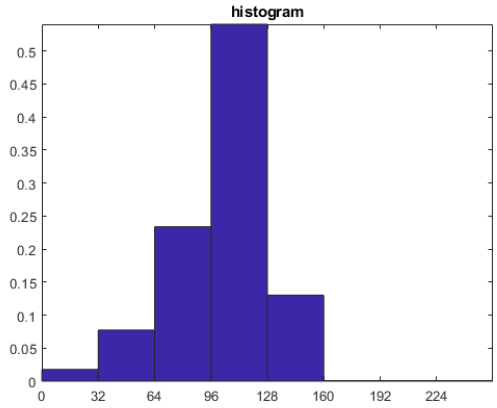

Figure 1 – PDF with 8 bins.

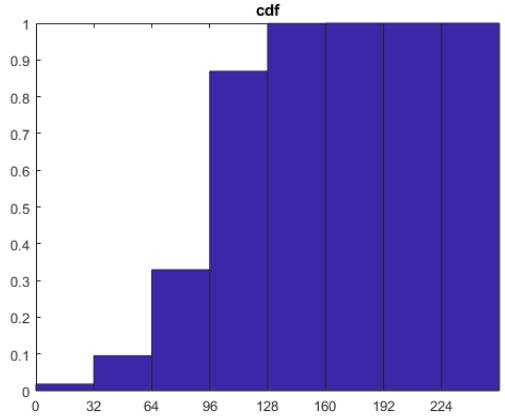

Figure 2 – CDF of Figure 1.

The more accurate PDF and CDF are shown below (not separated into bins):

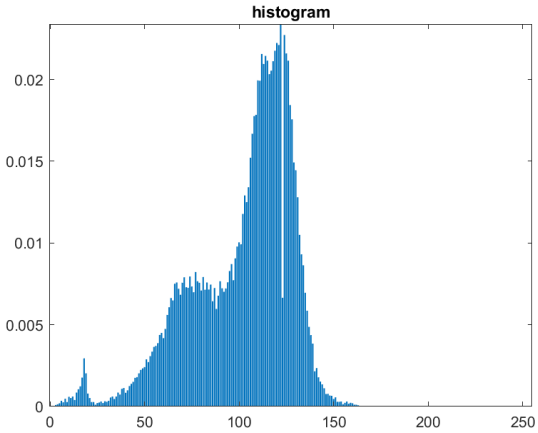

Figure 3 – PDF of Original image.

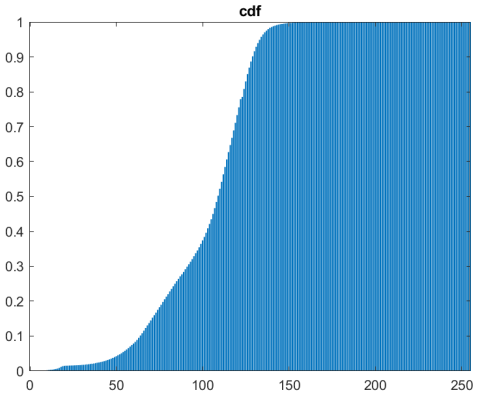

Figure 4 – CDF of Original image.

For Q2, gamma correction with gamma = 5 (Figure 5) makes the image dimmer and lower the contrast, it is hard to see many of the details that the original image had. With gamma = 0.2 (Figure 6), the image is lighter in appearance than the original, however; some detail is still not easily visible due to the contrast.

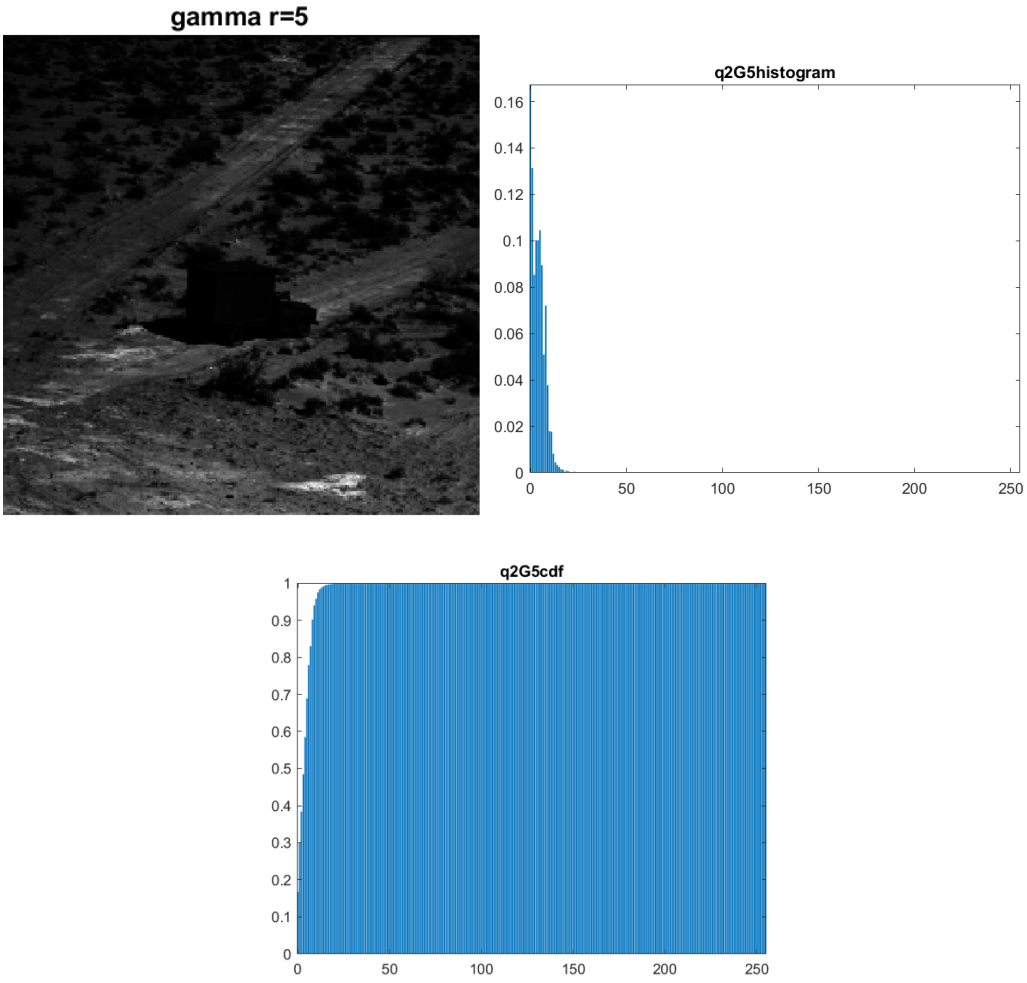

Figure 5 – (Left) Gamma-corrected image with γ = 5. (Right) histogram with γ = 5. (Down) cdf with γ = 5.

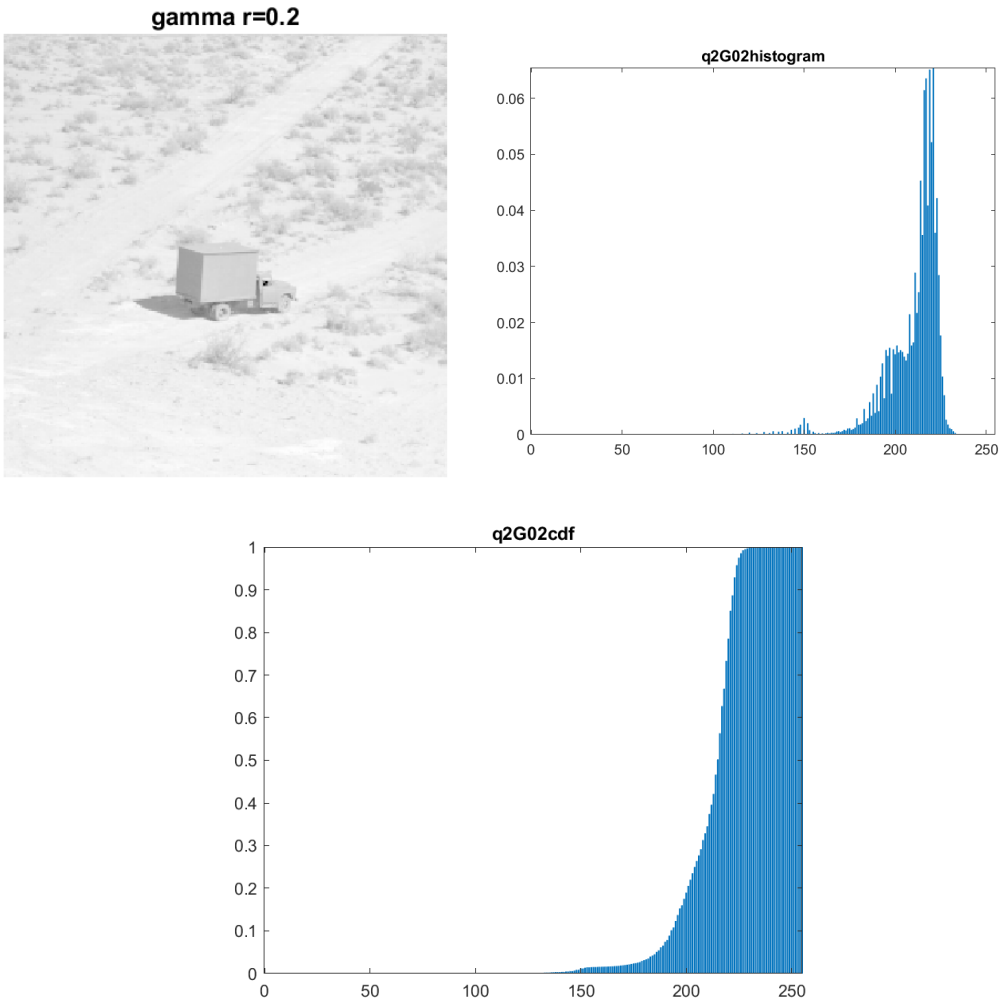

Figure 6 – Gamma-corrected image with $\gamma = .20$. (Right) histogram with $\gamma = 0.2$. (Down) cdf with $\gamma = 0.2$.

For Q3, after applying modifying the histogram, the contrast of the image increased, and more details are visible.

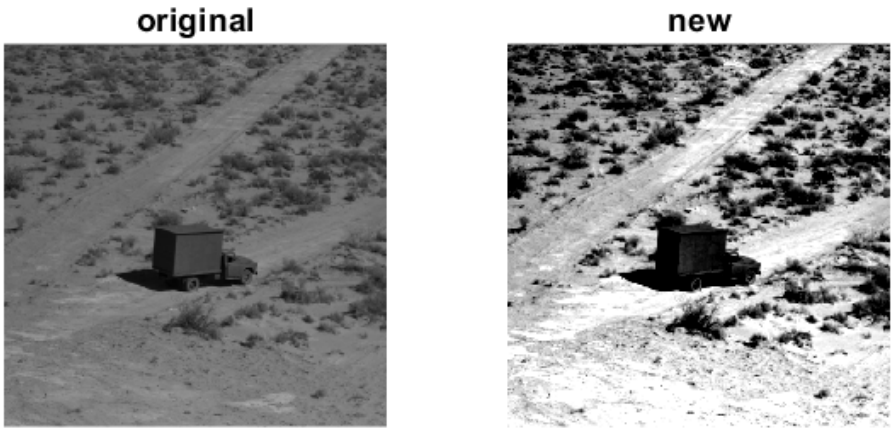

Figure 7 – Original image contrasted with the image of the modified histogram.

The corrected image has a histogram and cdf as below:

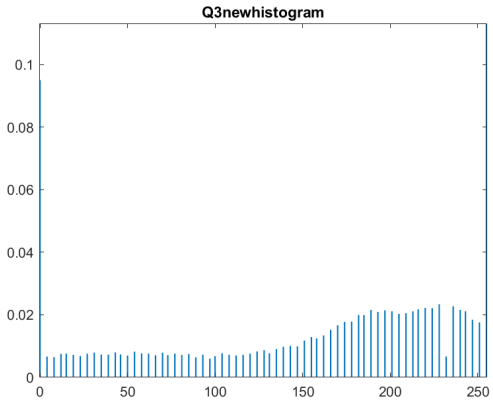

Figure 8 – PDF after Histogram Modification is applied.

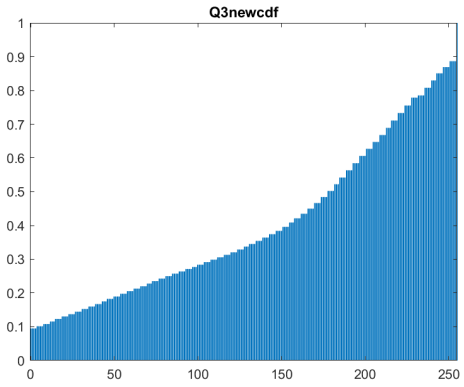

Figure 9 – CDF after Histogram Modification is applied.

For Q4, Histogram equalization is the non-linear stretching of the image and the redistribution of the pixel value so that the number of pixels within a certain gray-level is roughly the same (Figure 12) and increase the local contrast of the image (Figure 11). The equivalent mathematical transformation is shown in Figure 10.

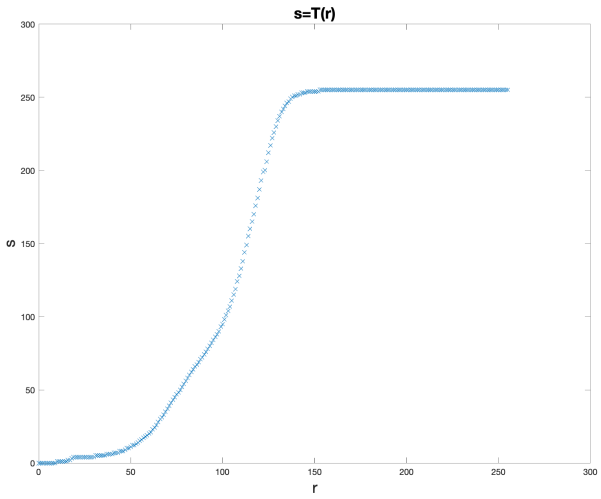

Figure 10 – Mathematical Transformation s=T(r)

Figure 11 – Image after Histogram Equalization.

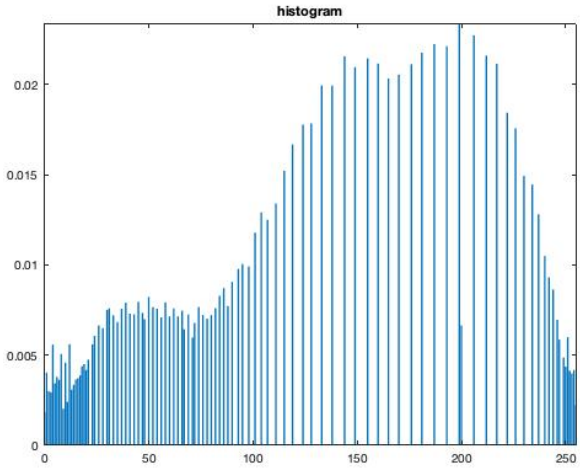

Figure 12 – PDF of image after Histogram Equalization.

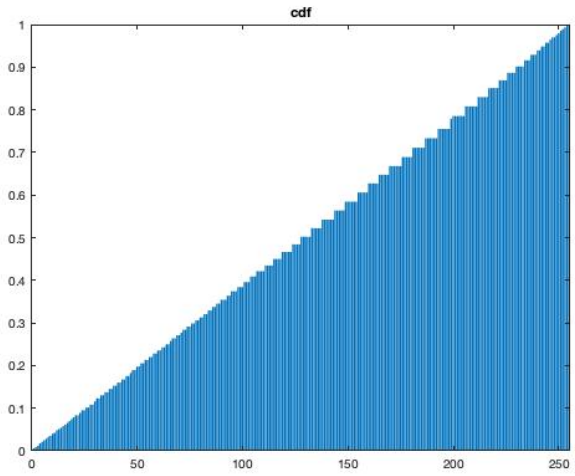

Figure 13 – CDF of image after Histogram Equalization.

Observation Q5:

The histogram modification will affect the brightness and contrast of a picture. Brightness is reflected by the magnitude of gray level, while contrast is reflected by the range distribution of the gray level. The original picture is dark and has low contrast. And its histogram showed all the pixels' gray level are below 160. In Question 2, we used the gamma correction to modify the original image. With a $\gamma = 5$, the pdf shift to left and the region of the pdf become smaller. As shown in picture, this modification made the image darker and lower the contrast. With $\gamma = 0.2$, the pdf shift to right and the region of the pdf become smaller. As shown in picture, this modification makes the image lighter and lower the contrast. In Question 3, after contrast stretching, the range distribution of the gray levels is expanded, as shown in histogram. The contrast increased after this modification. In Question4, the idea of histogram equalization is to change the gray-level histogram of the original image from a relatively concentrated gray-level range to a uniform distribution within the whole gray range.

D. Conclusion

In this project, we modified the image through gamma correction, linear stretching and histogram equalization. Gamma correction changes the brightness and alter the contrast of the original image. Linear stretching offered a vast improvement of contrast, but Equalizing the image's histogram made the most favorable changes. Retaining most if not all of the detail of the original image, while providing a higher contrast between objects in the image. In general, changing the histogram affects the contrast and perceived brightness of an image. While some methods would offer different benefits in various situations, these methods are all useful when trying to show more detail or adjust the brightness of a picture.