CMPEN/EE455: Digital Image Processing I

Computer Project # 4:

Image Enhancement: Histogram Modification

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OBJECTIVES

The project is aimed at understanding the histogram and cumulative distribution of an image. Furthermore, techniques to enhance the contrast of an image such as gamma correction and histogram equalization are explored. The main objective of this project involves the following

1. **Understanding the histogram and CDF of an image:**
    - To build a function that would generate the histogram and CDF of an image.
    - To create the labeled plots of the histogram and CDF.
2. **Contrast modification by applying gamma correction to an image:**
    - To create a function for applying the gamma correction to an image.
    - To observe the changes in the contrast for two different gamma values.
    - To generate the histogram and CDF of the gamma corrected images.
3. **Contrast stretching of an image by histogram modification:**
    - To execute the histogram modification for contrast stretching in an image.
    - To analyze the image after histogram modification.
    - To obtain the histogram and CDF of the resultant image.
4. **Histogram equalization of an image:**
    - To execute the histogram equalization on an image using optimal contrast stretching.
    - To infer the changes in the output image after histogram equalization.
    - To generate the histogram and CDF of the equalized image.

METHODS

This project concentrates on the enhancement of an image using histogram modification. In order to perform the objectives of this project, an input image named 'truck.gif' has been utilized.

This project can be executed by running the 'main.m' file. This main.m file calls the following function: 'cdf_crr.m', 'histo_pcap.m' and 'gammatransform.m'. They execute the functions of finding the CDF, histogram and the power-law transformation respectively.

The following subsection details the method in which the project statements are solved.

1. To generate the histogram and CDF of an image:

- A function for generating the histogram and CDF is built.
- A histogram of an image gives the frequency of each intensity level in an image.
- The input image 'truck.gif' is denoted by $f(x, y)$. The image is scanned though every pixel for observing the various pixel intensities.
- The histogram function counts the number of the pixels with same intensity values.
- The histogram is denoted by $\hat{p}_r(r)$.
- The CDF quantifies the probability of observing certain pixel intensities.
- To compute the CDF, the probability density function (PDF) has to be generated.
- The PDF can be computed from the histogram of the image. The following equation gives the relation between the PDF and the histogram-

$$\boldsymbol{p(r) = (\frac{1}{N^2})\hat{p}_r(r)}$$

$$p(r) = PDF\ of\ the\ image$$
$$\hat{p}_r(r) = no.of\ pixels\ in\ image\ at\ gray\ level\ r$$
$$N\ = size\ of\ the\ image$$

- From PDF, the CDF can be computed by building a function which typically executes the following relation –

$$\boldsymbol{c(r) = \sum_0^{L-1} p(r)}$$

$$where\ c(r) = CDF\ of\ the\ image$$
$$L = \max gray\ level\ of\ the\ image$$

- The histogram and CDF are then plotted.

2. To apply the gamma correction to the image:

- The gamma correction is used to enhance the contrast of the image. The intensity of the pixels of the image are mapped to new intensity levels.
- The transformation is executed using the following relation-

$$\boldsymbol{S = (255) * \left(\frac{f(x,y)}{255}\right)^{\gamma}}$$

where $\mathrm{S} = \text{new pixel intesities}$
$f(x, y) = original\ pixel\ intensities$
$\boldsymbol{\gamma} = correction\ factor$

- The abovementioned relation is executed as a function. The image is gamma corrected for $\gamma = 0.20$ and $\gamma = 5$.
- The histogram and CDF are generated using the concepts discussed in the above method section.

3. **To implement contrast stretching by histogram modification:**
   - The contrast stretching is implemented by the piece wise linear transformation on the original image.
   - For executing this, the following algorithm is followed –
     (a) Set all pixels with gray levels below 10% in the CDF to black(zero).
     (b) Set all pixels with gray levels above 90% in the CDF to white(L-1).
     (c) Linearly stretch the range between the 10% and 90% gray levels to cover the range 0 to 255.
   - To set the pixels with gray level below 10% in the CDF to zero, an optimal L1 is chosen such that up to L1 gray level every pixel intensity is set to zero. The L1 can be found out by -

     $$\boldsymbol{L1 = argmin\{c(r) \geq 0.1\}}$$

   - To set the pixels with gray level below 90% in the CDF to *L-1*, an optimal L2 is chosen such that up to L1 gray level every pixel intensity is set to zero. The L2 can be found out by -

     $$\boldsymbol{L2 = argmax\{1 - c(r) \geq 0.9\}}$$

   - To linearly stretch the range between the 10% and 90% gray levels to cover the range 0 to 255, the following transformation is used-

     $$\boldsymbol{S = mr + b}$$

     $where\ S = new\ intensity\ levels$
     $r = original\ intensity\ levels$

     Here,

     $$\boldsymbol{m = \frac{L-1}{L2-L1}} \quad and \quad \boldsymbol{b = -mL1}$$

   - Hence, the overall transformation can be depicted by the following equations,

     $$\boldsymbol{S} = \begin{cases} \boldsymbol{0}\ ; & 0 \leq r \leq L1 \\ \boldsymbol{mr + b}; & L1 < r \leq L1 \\ \boldsymbol{L - 1}; & L2 < r \leq L - 1 \end{cases}$$

   - The histogram and CDF of the new image are plotted accordingly.

4. **To implement Histogram Equalization using Contrast Stretching:**
   - Histogram Equalization is the procedure used to adjust the image intensities to improve its contrast, and is implemented here by stretching its contrast.
   - Histogram equalization helps in spreading out the intensity values over all the levels, thus improving the overall image contrast.

- For implementing the histogram equalization, optimal transformation of the pixels has to be performed. The transformation is given by-

$$\boldsymbol{S = T(r)}$$

- The optimal transformation function for achieving histogram equalization is the CDF of the original image itself.

$$\boldsymbol{S = T(r) = nearest(CDF(r) * 255)}$$

Where S – new intensity level

r – original intensity level

- The histogram and the CDF of the resultant image is plotted using the functions discussed in the method section 1.

RESULTS

This section details all the images that are obtained after completing each of the objectives. Firstly, the image that is considered as the input image for the image enhancement i.e. ‘truck.gif’ is as shown in Fig 1.

Figure 1: Input Image

The abovementioned objective’s results are documented as follows.

1. To generate the histogram and CDF of an image:

The histogram is plotted for the input image, and the pdf and cdf are calculated and thus plotted. These figure are as shown in Fig 2, Fig 3 and Fig 4 respectively.

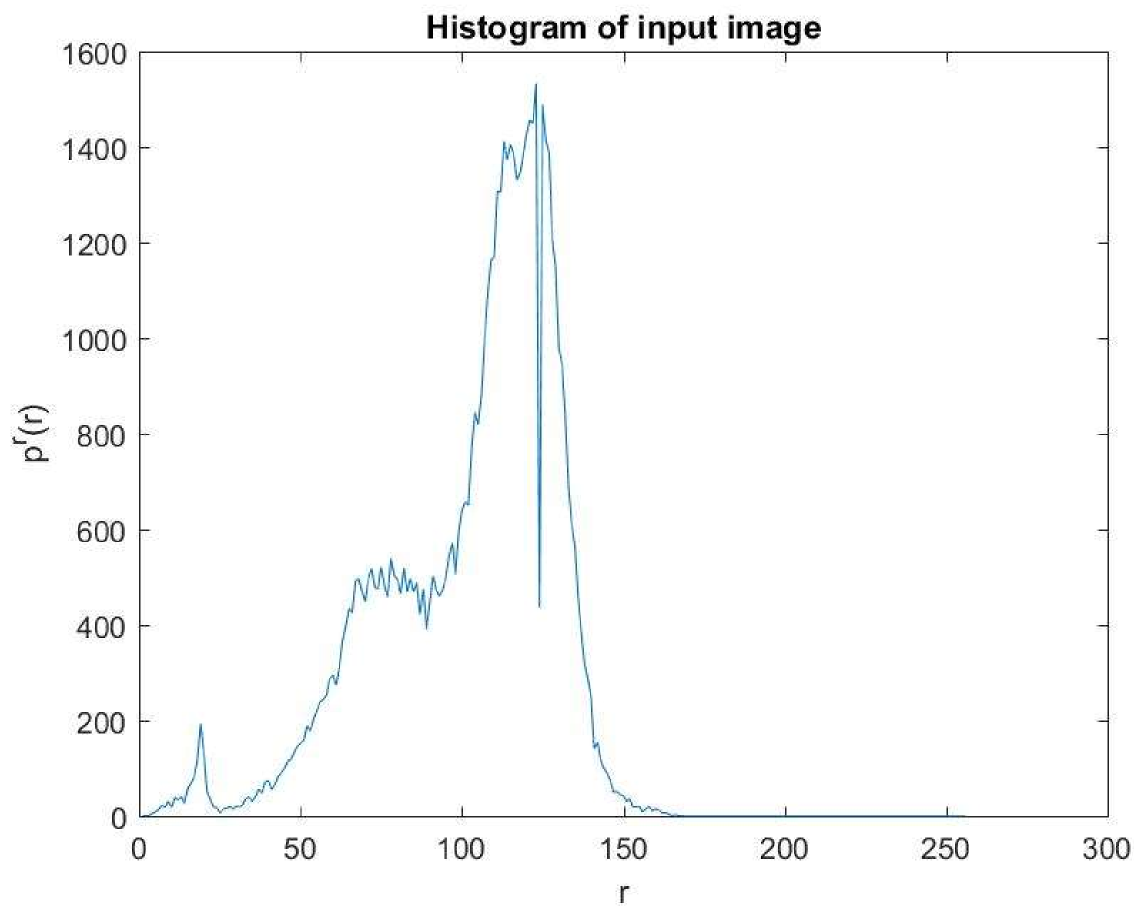


Figure 2: Histogram of input image

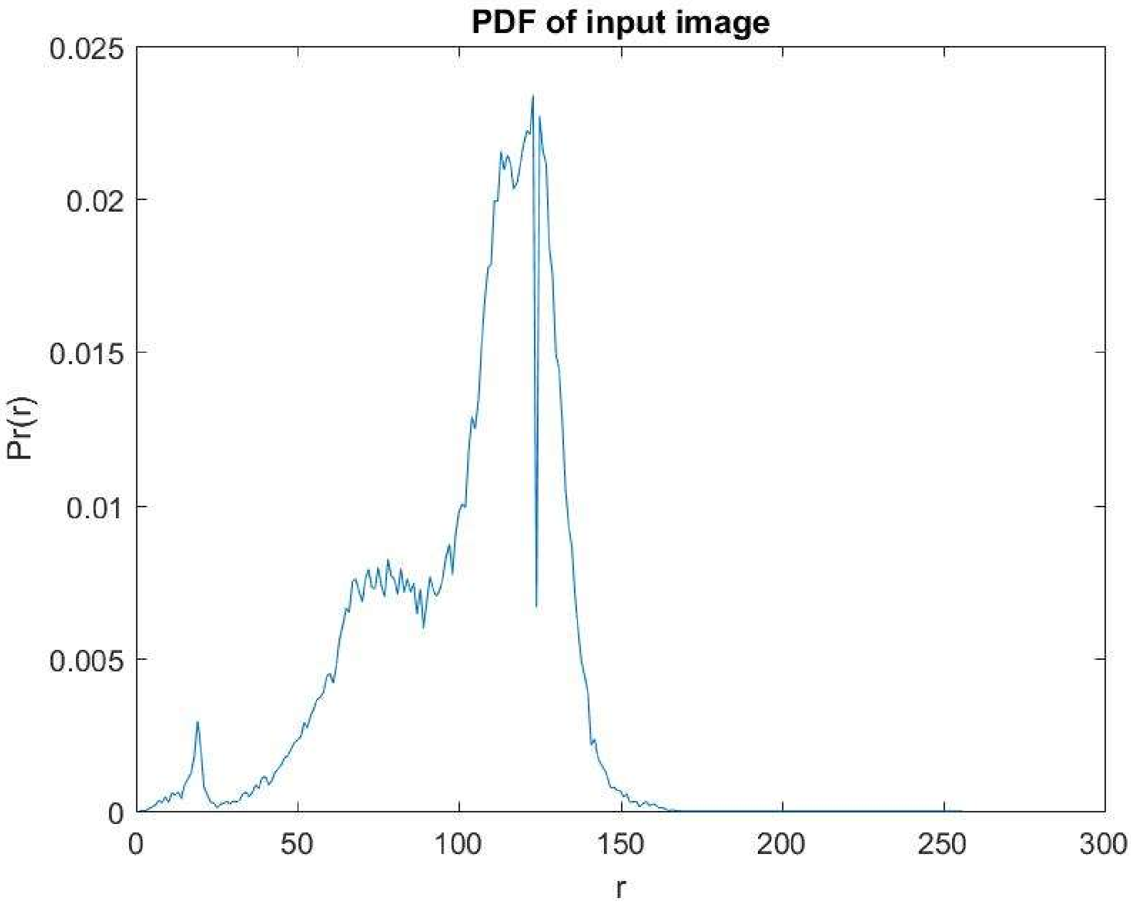


Figure 3: PDF of input image

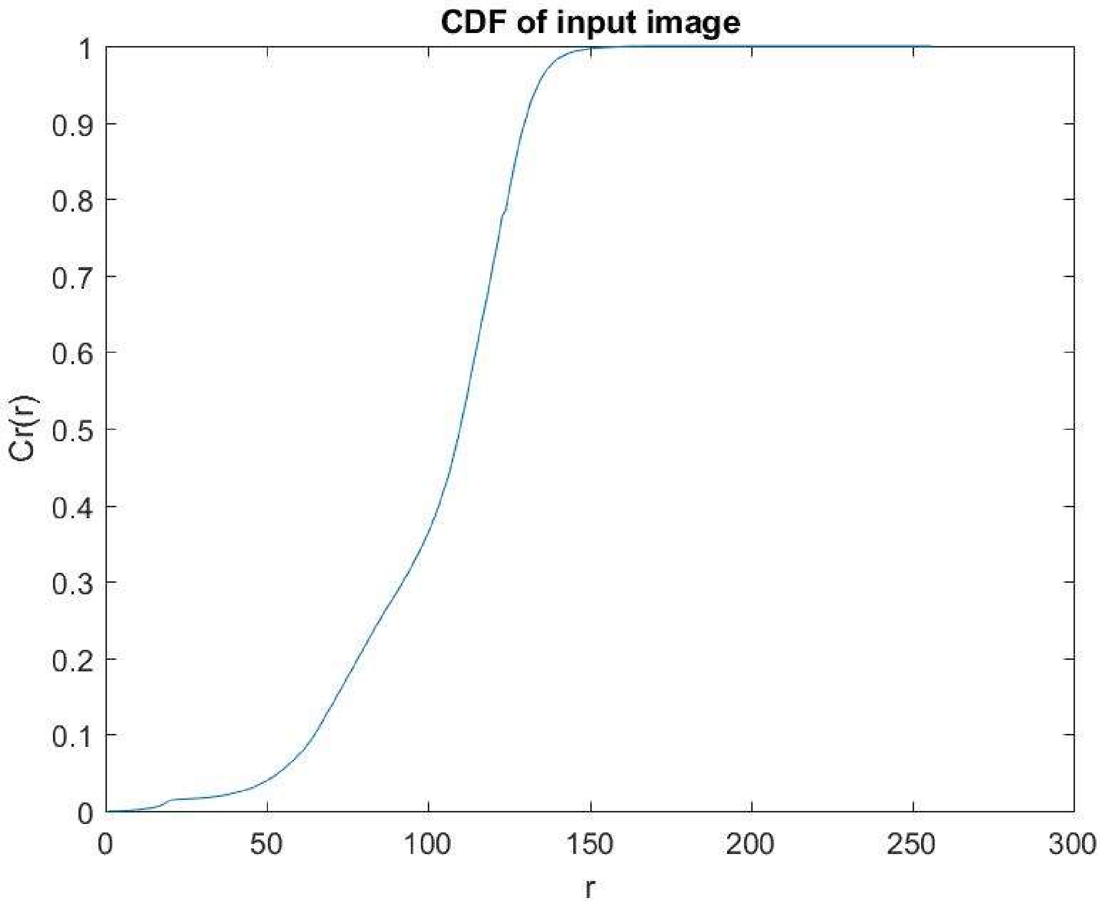


Figure 4: CDF of input image

2. **To apply the gamma correction to the image:**
   A function 'gammatransform.m' is created in order to obtain the power-law transformation using gamma correction factor 5 and 0.2.

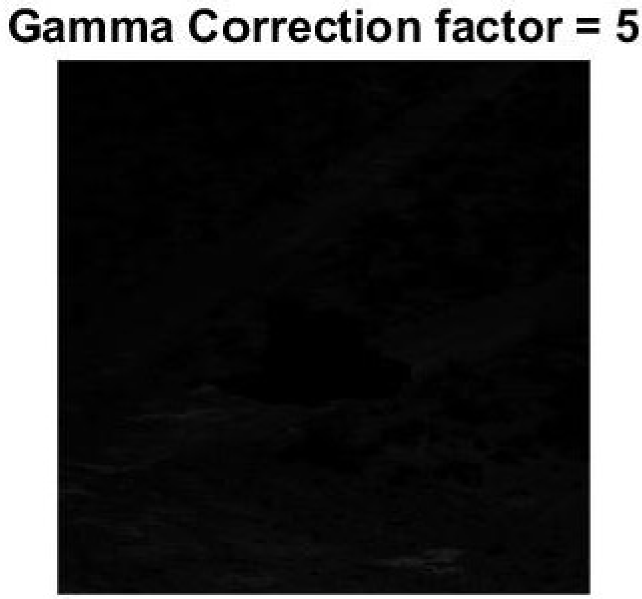


Figure 5: Gamma = 5 transformed image

Figure 6: Gamma =0.2 transformed image

The respective histogram and CDFs are as shown in figure 7 through 10.

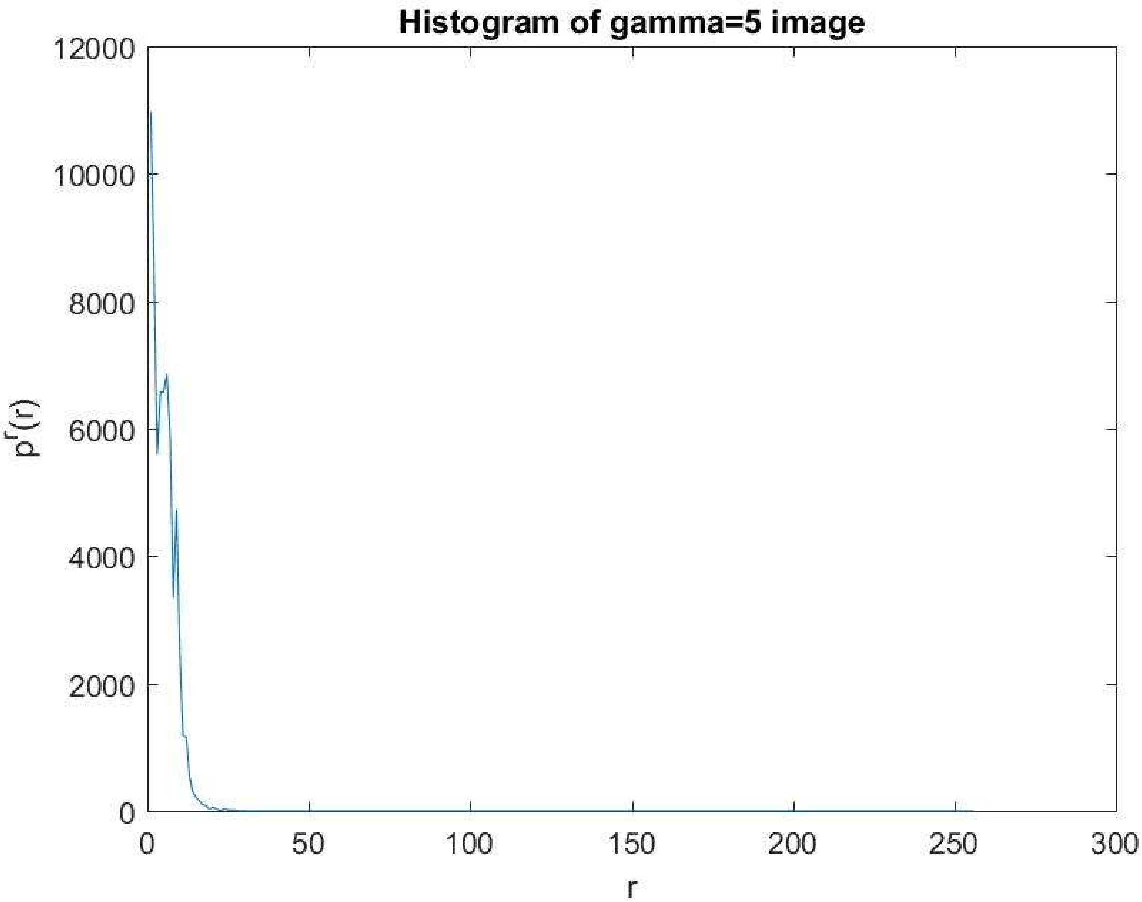


Figure 7: Histogram of gamma=5

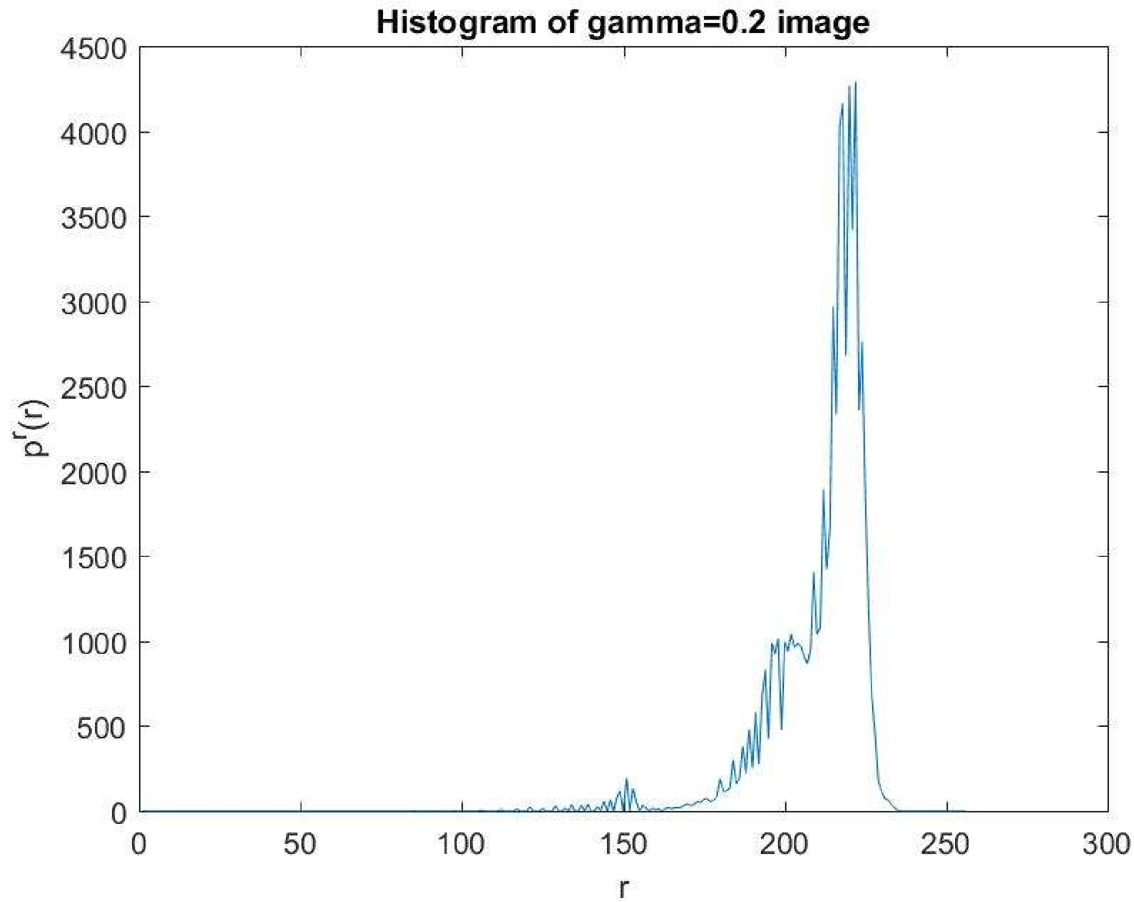


Figure 8: Histogram of gamma=0.2

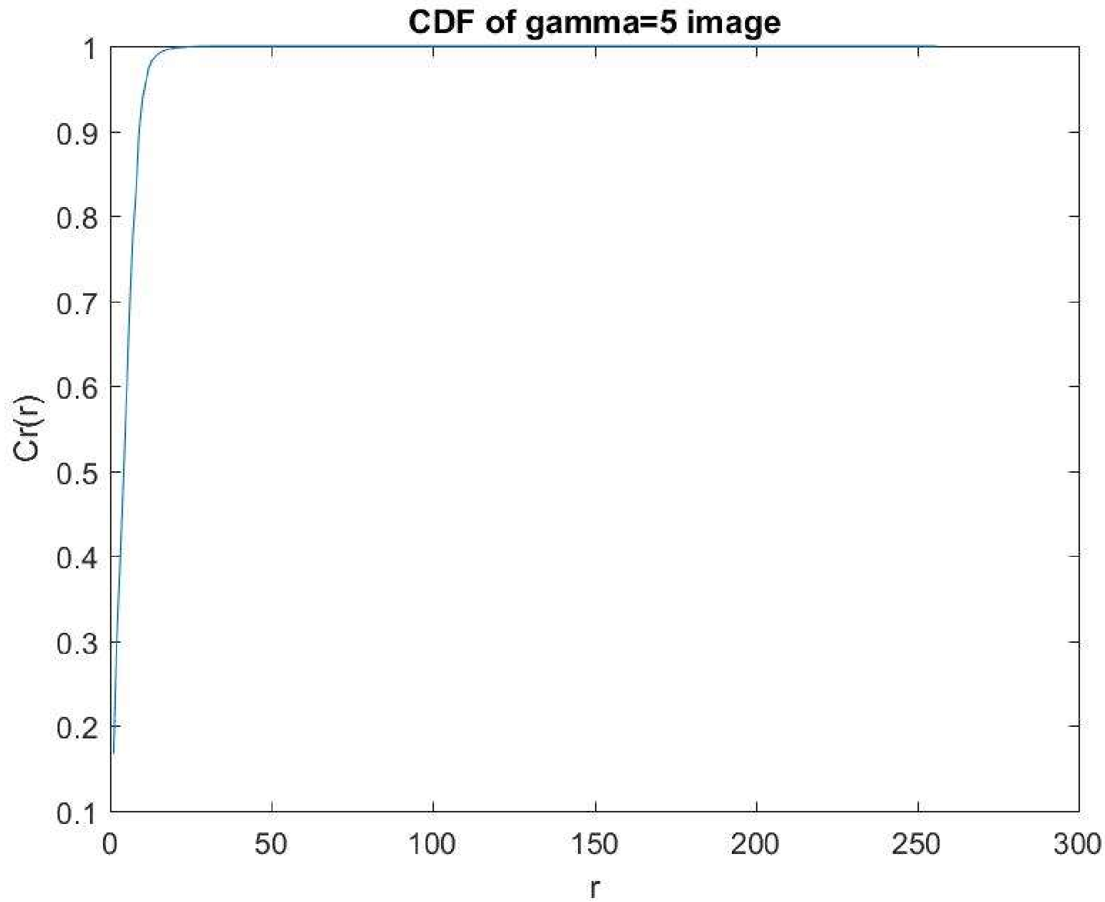


Figure 9: CDF of gamma=5

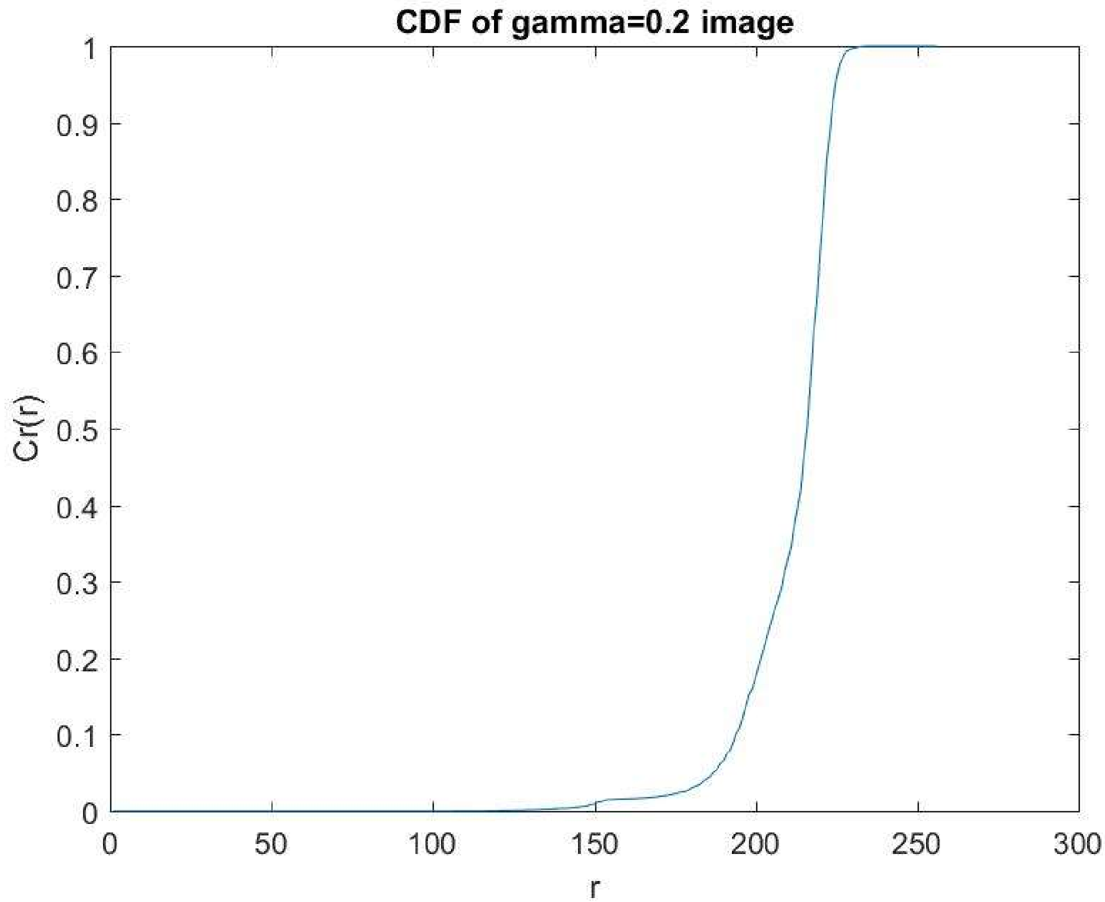


Figure 10: CDF of gamma=0.2

3. **To implement contrast stretching by histogram modification:**

The CDF of the image before contrast stretching is implemented is as shown in figure 11.

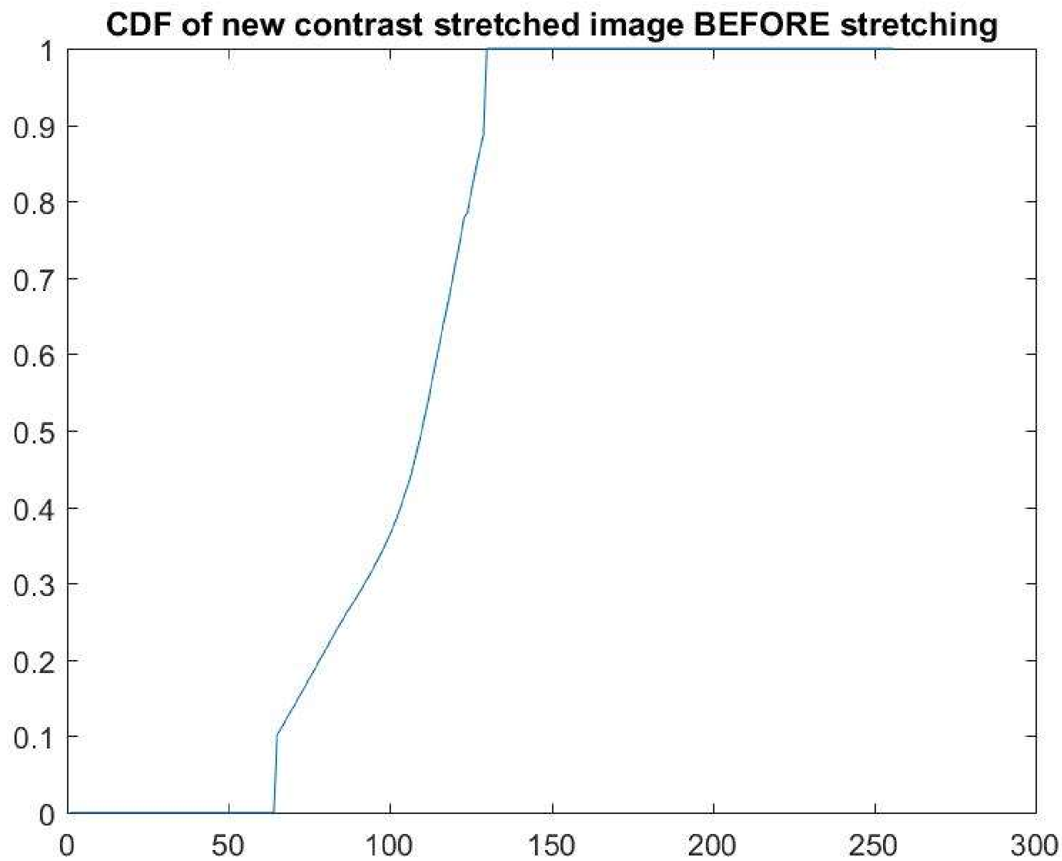


Figure 11

After the algorithm for contrast stretching is implemented, the output image and its histogram, PDF and CDF is as shown in figure 12 through 15.

Figure 12: Contrast Stretched image

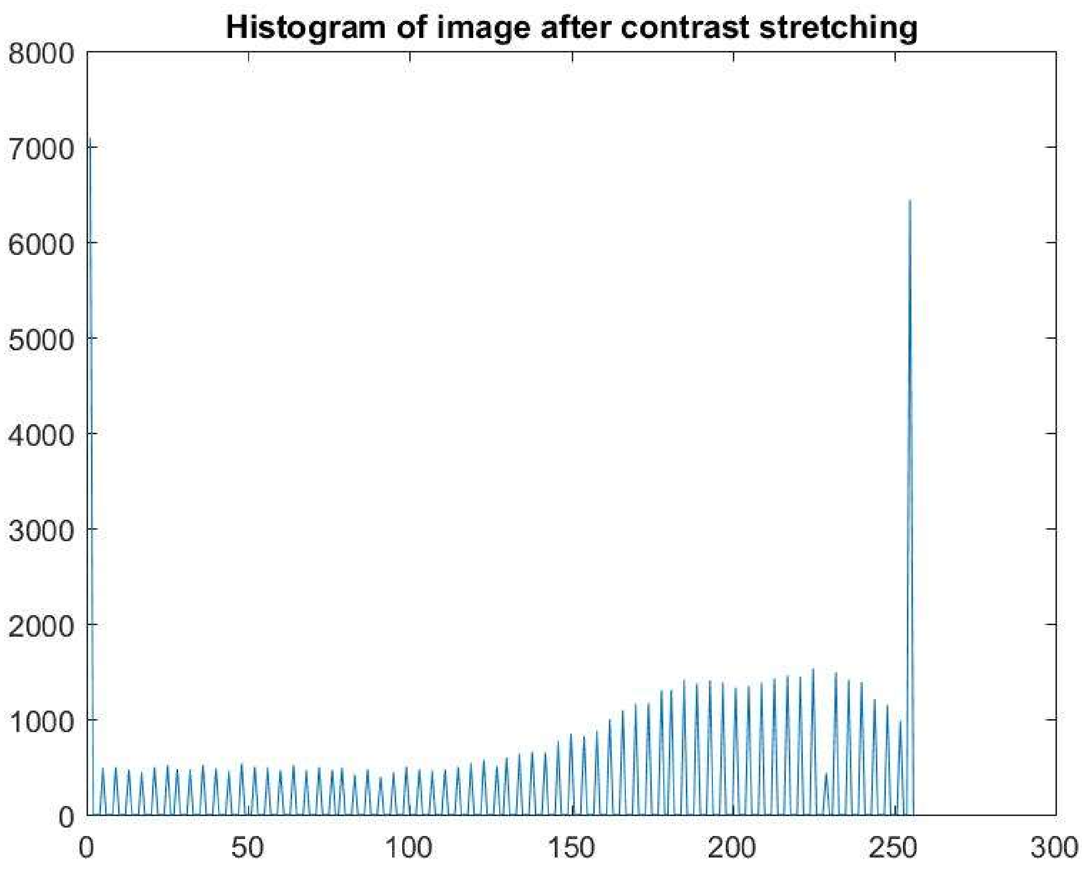


Figure 13

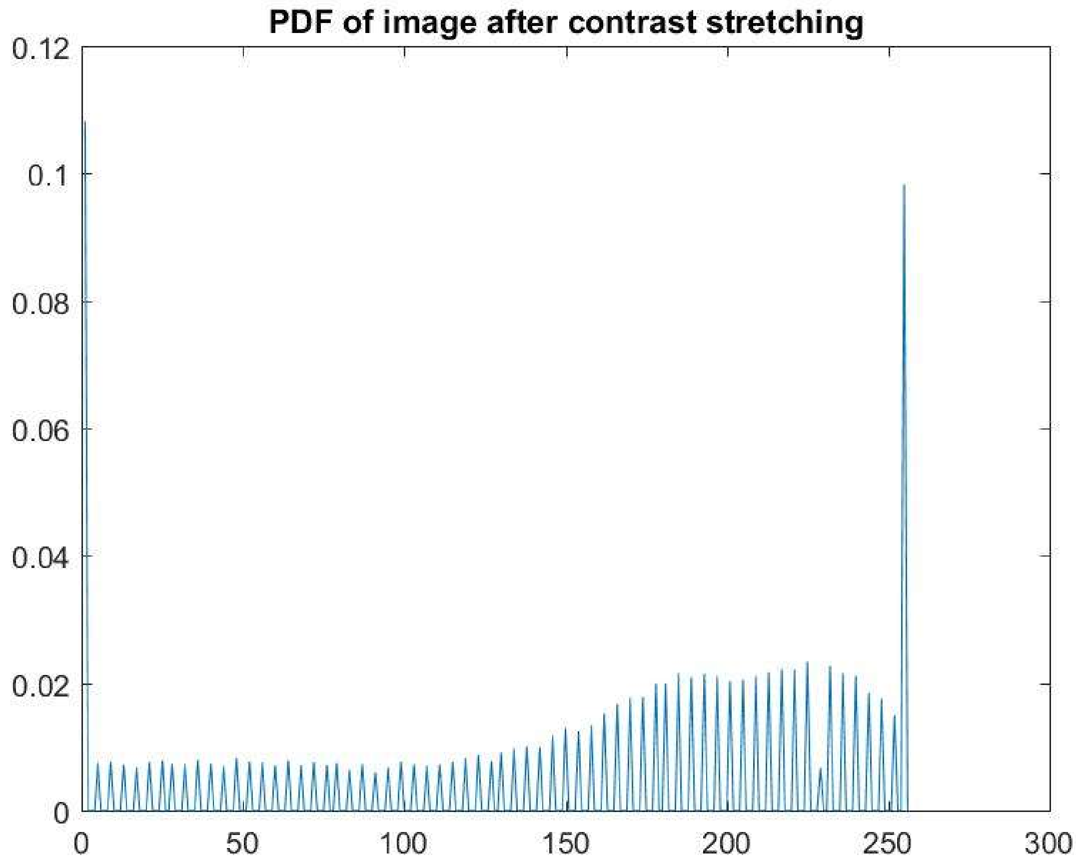

PDF of image after contrast stretching
0.12
0.1
0.08
0.06
0.04
0.02
0
0
50
100
150
200
250
300

Figure 14

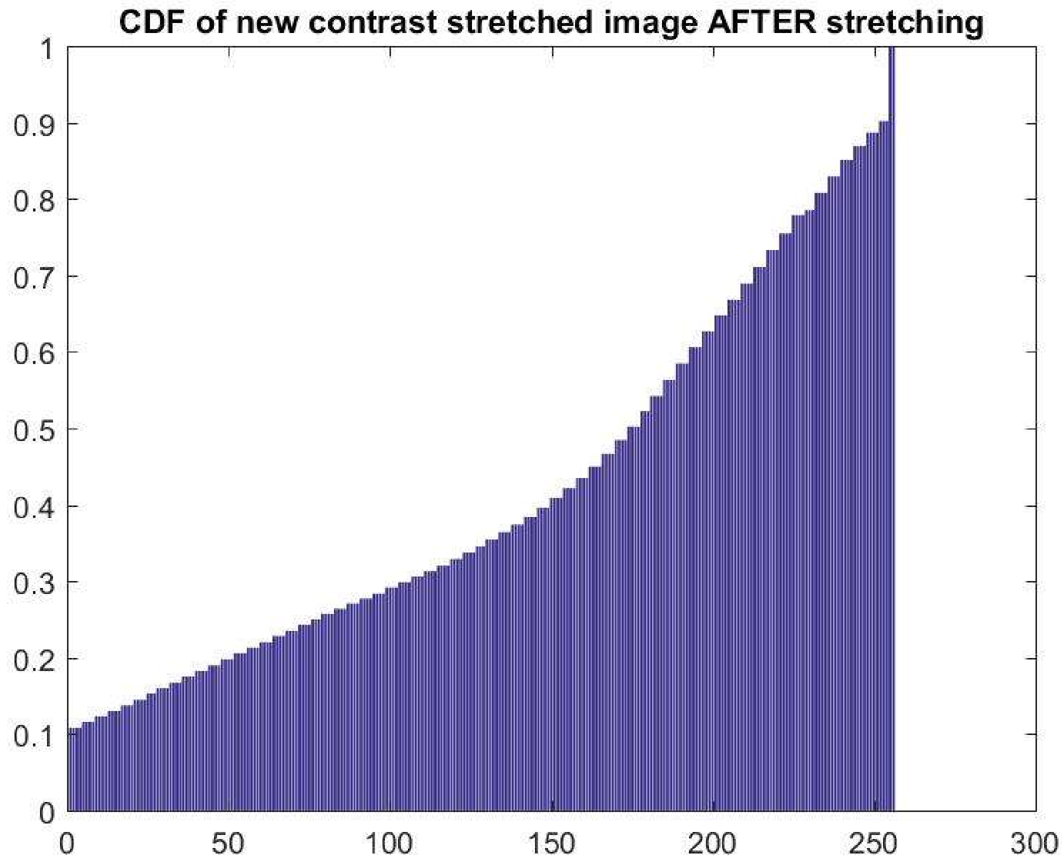

CDF of new contrast stretched image AFTER stretching
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
50
100
150
200
250
300

Figure 15

4. To implement Histogram Equalization using Contrast Stretching:

The equalization of the input image using an optimal contrast stretching algorithm is as shown in figure 16. Their histogram, pdf and cdf are shown in figure 17 through 19.

Figure 16: Output image after Histogram Equalization

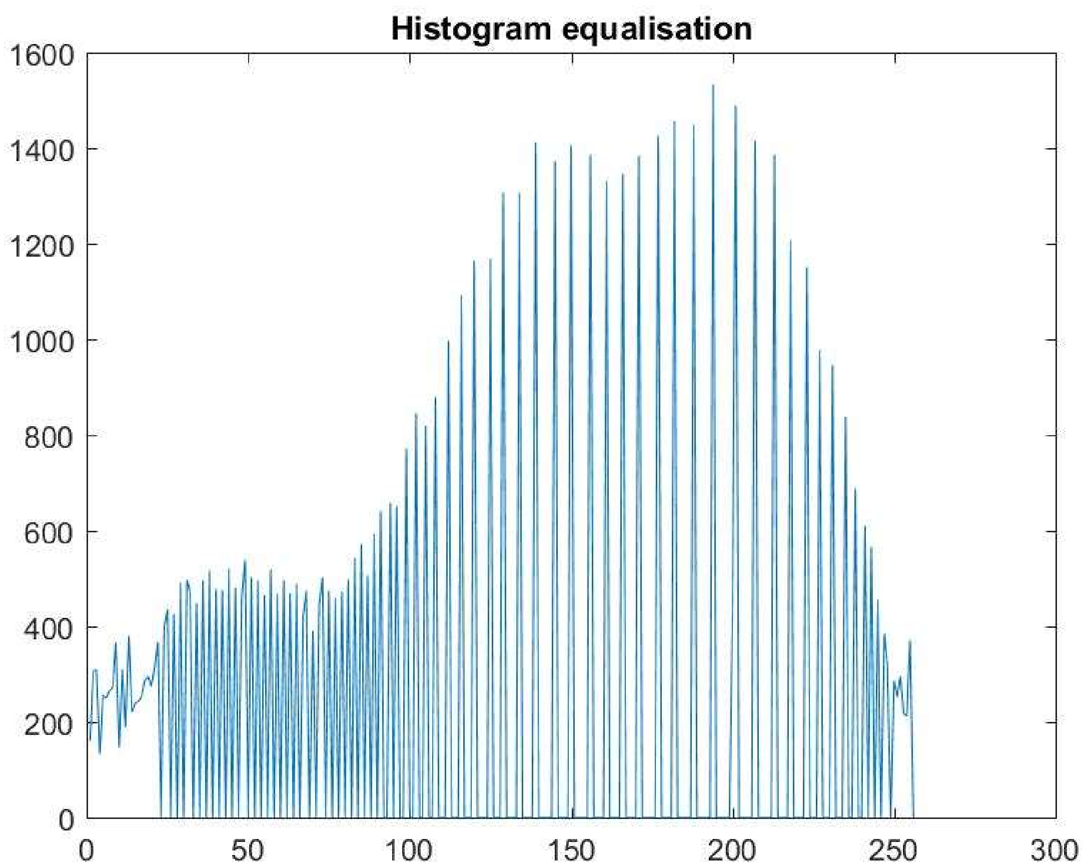
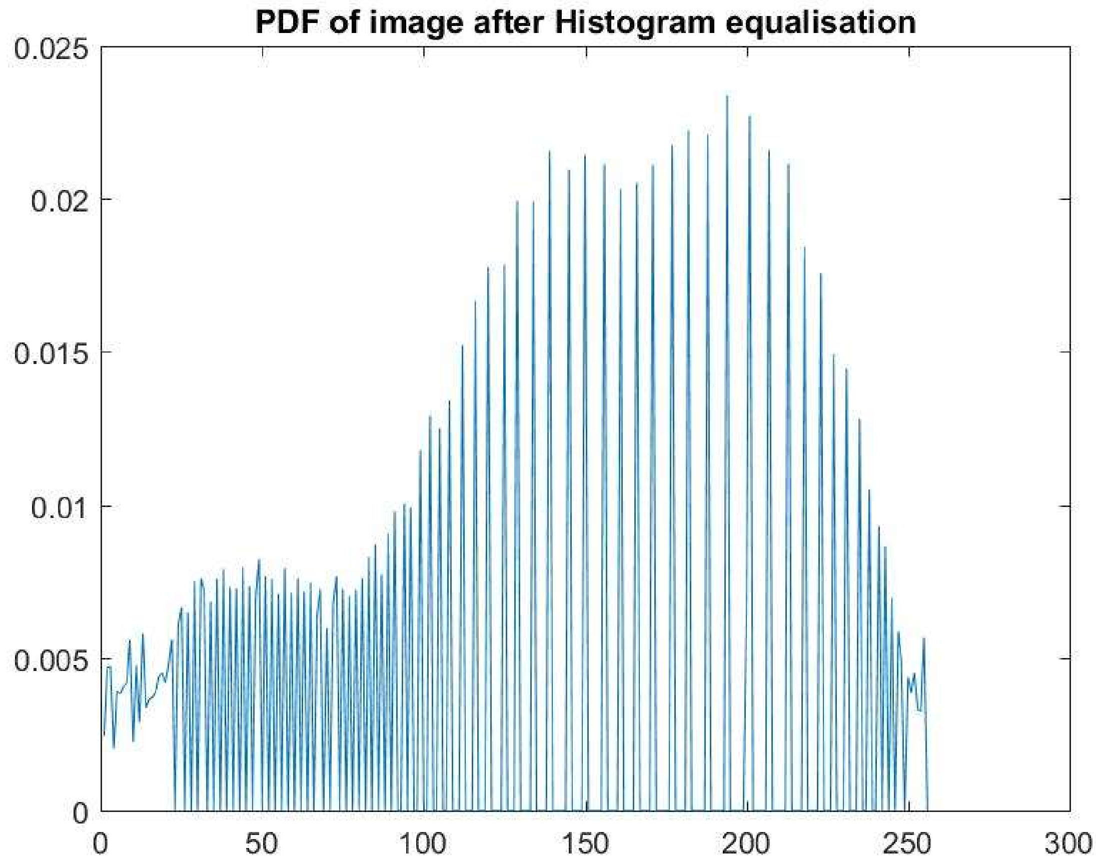


Figure 17



PDF of image after Histogram equalisation
0.025
0.02
0.015
0.01
0.005
0
0
50
100
150
200
250
300

Figure 18

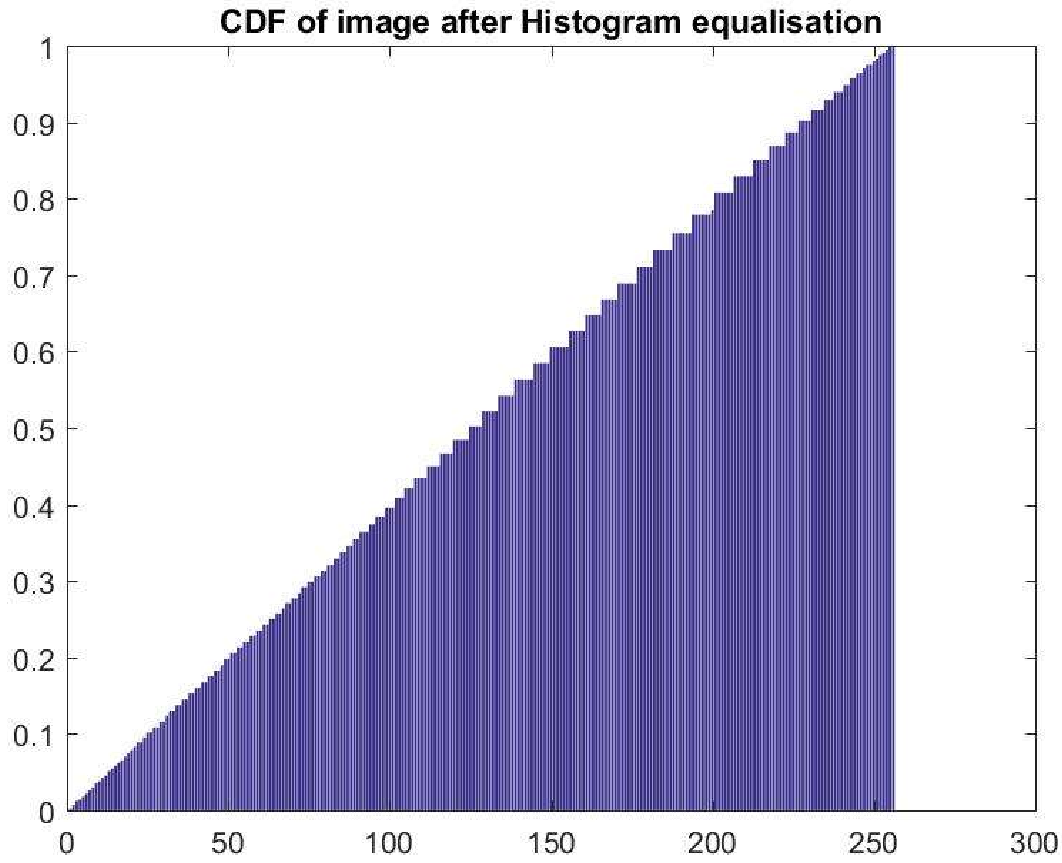

CDF of image after Histogram equalisation
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
50
100
150
200
250
300

Figure 19

OBSERVATION

This section provides the observations that one can notice from the first to the fourth objective, and thus answers the question 5 of the project.

It can be seen from the results of the first objective that the max number of pixels are concentrated between 70 to 150 approximately. This can be noticed in the sudden rise in the graph of the CDF at that region. The slope changes abruptly from being close to 0 to almost infinity and then back to 0 at the points 70 and 150 respectively.

From the second objective of making a gamma correction, it can be noticed that this sort of transformation is used in order to brighten or darken an image thereby suitable for further operation. It can be observed that when gamma was greater than 1, the image got darker and when gamma was less than 1, the image got brighter and brighter. It can be seen from its histogram that the majority of intensity level is closer to 0(black and hence dark) for gamma=5, and for gamma=0.2, they are closer to 255 (white and hence bright).

From the results in the third objective, it can be observed that before contrast stretching is done, the pixels are concentrated between 70-150. Once contrast stretching algorithm is implemented, the intensity levels are seemed to be spread out between 0-255 and the region in between seem to have an equal share of intensity levels. Therefore, the CDF appears to be almost linearly increasing, and thus is justified. It can be observed from the output image that the input image seems to have been slightly darkened.

Having performed the fourth objective, we can observe from its CDF that there is more linearity when compared to the result of objective 3. This is due to equalization of the histogram. There is a somewhat uniform distribution of the change in intensity levels. From the output image, it can be observed that, to our eye, this image seems more appreciable than the input image. This is due to the change in contrast where the distribution of intensity is even and when moving from one intensity level to another, there is a gradual change and not a sudden jump.

CONCLUSION

After completing the necessary tasks to meet the objectives of this project, we can come to a set of following conclusions:

- While performing contrast enhancement using power law transformation, it can be concluded that variation in the value of γ varies the enhancement of the images. For all values of $\gamma < 1$, the transformation mapping is weighted towards brighter intensity and for $\gamma > 1$, the mapping is weighted towards darker intensity. For $\gamma = 1$, the mapping is linear and there is no difference.
- Contrast stretching can be more favorable if there is a wide range of intensity values to be stretched i.e. if the input image has only say 10 intensity values, then contrast stretching these 10 to 256 intensity levels would not be as favorable as stretching 100 intensity levels to 255. This term favorable is with respect to quality as observed by human eye.
- Histogram equalization is qualitatively more favorable than contrast stretching because in the latter case, there is a gradual change in the intensity level and the CDF tends to be linear.
- This sort of enhancement is done in order to be able to provide a better qualitative output with reference to the human eye. Contrast enhancement is also done in order to be able to observe certain areas of interest such as in medical imaging, any sort of recognition algorithms.