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Batch: A-4 **Roll No.:** 16010122151

Experiment No. 7

Grade: AA / AB / BB / BC / CC / CD /DD

Signature of the Staff In-charge with date

Title: Write a program to apply the global processing technique: Histogram equalization.on a digital image

Objective: To learn and understand the concept of histogram stretching and equalization in image enhancement operations.

Expected Outcome of Experiment:

CO	Outcome
CO4	Design & implement algorithms for digital image enhancement, segmentation & restoration.

Books/ Journals/ Websites referred:

1. http://www.mathworks.com/support/
2. www.math.mtu.edu/~msgocken/intro/intro.html.
3. R. C.Gonsales R.E.Woods, “Digital Image Processing”, Second edition, Pearson Education
4. S.Jayaraman, S Esakkirajan, T Veerakumar “Digital Image Processing “Mc Graw Hill.
5. S.Sridhar,”Digital Image processing”, oxford university press, 1st edition."

Pre Lab/ Prior Concepts:

Image histogram

In an image processing context, the histogram of an image normally refers to a histogram of the pixel intensity values. This histogram is a graph showing the number of pixels in an image at each different intensity value found in that image. For an 8-bit greyscale image there are 256 different possible intensities, and so the histogram will graphically display 256 numbers showing the distribution of pixels amongst those greyscale values. Histograms can also be taken of color images either individual histogram of red, green and blue channels can be taken, or a 3-D histogram can be produced, with the three axes representing the red, blue and green channels, and brightness at each point representing the pixel count. The exact output from the operation depends upon the implementation it may simply be a picture of the required histogram in a suitable image format, or it may be a data file of some sort representing the histogram statistics.

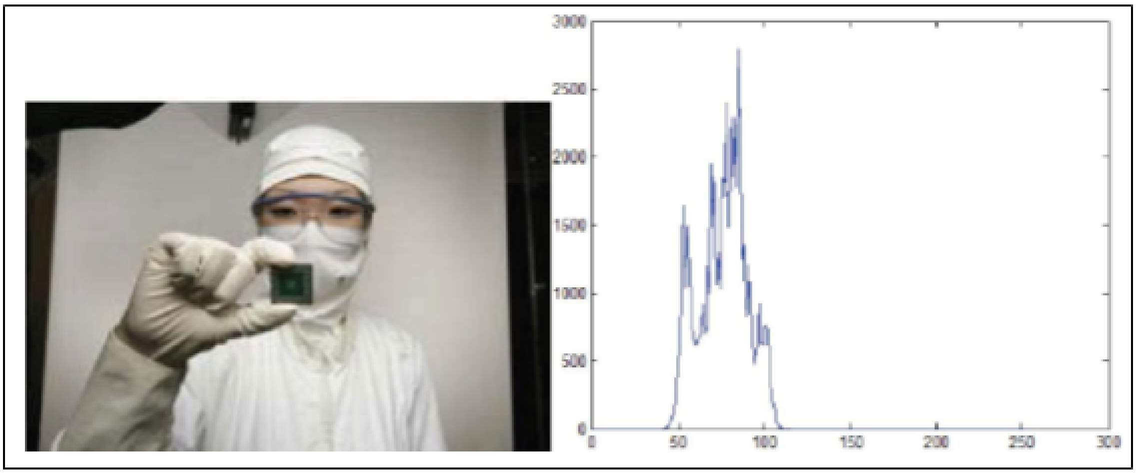


Fig. 1 An image and its histogram Histogram Equalization:

A perfect image is one which has equal number of pixels in all its grey levels. hence our objective is not only to spread the dynamic range , but also to have equal pixels in all the grey levels. This technique is known as histogram equalization.

Basically the histogram equalization spreads out intensity values along the total range of values in order to achieve higher contrast. This method is especially useful when an image is represented by close contrast values, such as images in which both the background and foreground are bright at the same time, or else both are dark at the same time. For example, the result of applying histogram equalization to the image in figure 1 is presented in figure 2.

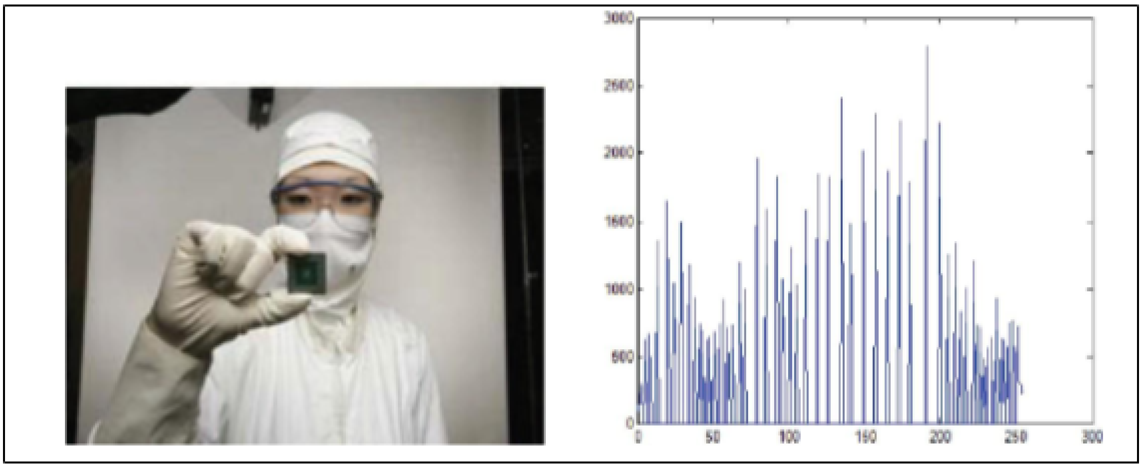


Fig. 2 New image and its equalized histogram

Description of cumulative histogram equalization:

Here are the steps for implementing this algorithm.

1. Create the histogram for the image.
2. Calculate the cumulative distribution function histogram.
3. Calculate the new values through the general histogram equalization formula.
4. Assign new values for each gray value in the image.

Thus processed image is obtained by mapping each pixel with level rk into a corresponding pixel with level sk in o/p image. This transformation is called Histogram equalization

Resources Used: Matlab

Implementation Details:

Write Algorithm and Matlab commands used

ALGORITHM:

1. **Read the Image**: Load the input image.
2. **Convert to Grayscale (if necessary)**: If the image is in RGB format, convert it to grayscale.
3. **Compute Histogram**: Calculate the frequency of each intensity level (0–255).
4. **Compute Probability Distribution**: Normalize the histogram by dividing by the total number of pixels.
5. **Compute Cumulative Distribution Function (CDF)**: Compute the cumulative sum of the probability distribution.
6. **Equalize Intensities**: Map the original pixel intensities to new intensities using the CDF.
7. **Construct the Equalized Image**: Replace each pixel intensity in the original image with the corresponding intensity from the equalized mapping.
8. **Compute Histogram of Equalized Image**: Verify the contrast enhancement.
9. **Display Results**: Show the original grayscale image, histogram, equalized image, and its histogram.

CODE:

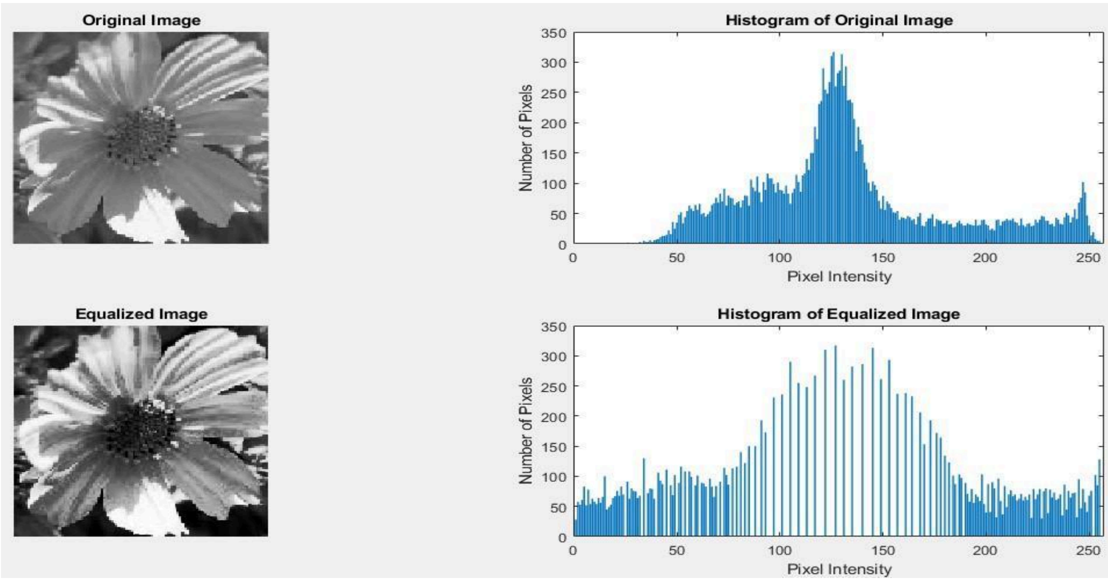
```
img = imread('cosmos.jpg');
if ndims(img) == 3
   gray_img = rgb2gray(img);
else
   gray_img = img;
end
[num_rows, num_cols] = size(gray_img);
hist_vals = zeros(1, 256);
prob_dist = zeros(1, 256);
for row = 1:num_rows
   for col = 1:num_cols
       pixel_intensity = gray_img(row, col);
       hist_vals(pixel_intensity + 1) = hist_vals(pixel_intensity + 1)+ 1;

   end

   end
prob_dist = hist_vals / (num_rows * num_cols);
cum_dist = zeros(1, 256);
cum_sum = 0;
for intensity = 1:256
   cum_sum = cum_sum + prob_dist(intensity);
   cum_dist(intensity) = round(cum_sum * 255);
```

```
end
equalized_image = uint8(zeros(num_rows, num_cols));
for row = 1:num_rows
for col = 1:num_cols
       pixel_intensity = gray_img(row, col);
       equalized_image(row, col) = cum_dist(pixel_intensity + 1);
   end
   end
equalized_hist_vals = zeros(1, 256);
for row = 1:num_rows
   for col = 1:num_cols
       pixel_intensity = equalized_image(row, col);
equalized_hist_vals(pixel_intensity+1)= equalized_hist_vals(pixel_intensity
+ 1) + 1;
   end end
figure;
subplot(2, 2, 1);
imshow(gray_img);
title('Original Image');
subplot(2, 2, 2);
bar(hist_vals);
xlabel('Pixel Intensity');
ylabel('Number of Pixels');
title('Histogram of Original Image');
subplot(2, 2, 3);
imshow(equalized_image);
title('Equalized Image');
subplot(2, 2, 4);
bar(equalized_hist_vals);
xlabel('Pixel Intensity');
ylabel('Number of Pixels');
title('Histogram of Equalized Image');
disp('Histogram Values of Original Image:');
disp(hist_vals);
disp('Probability Distribution Function:');
disp(prob_dist);
disp('Cumulative Distribution Function:');
disp(cum_dist);
disp('Histogram Values of Equalized Image:');
```

```
disp(equalized_hist_vals);
```

OUTPUT:

Image:



Command Window :Tabulation of Numerical Computations used in code :

```
Command Window
New to MATLAB? See resources for Getting Started.
>> untitled
Histogram Values of Original Image:
  Columns 1 through 17

     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0

  Columns 18 through 34

     0     0     0     0     0     0     0     0     2     0     0     0     1     0     3     2     5

  Columns 35 through 51

     3     3     6     3     6     7     8    11    13    13    15    22    16    36    25    35    48

  Columns 52 through 68

    52    34    44    54    63    58    54    64    56    66    49    51    45    49    53    64    67

  Columns 69 through 85

    76    68    83    70    91    63    80    76    75    64    68    70    60    72    80    79    63

  Columns 86 through 102

   106    93    87   111    85    69   102    89   116   108   108    99    85   101    89    88    83

  Columns 103 through 119

    96    83    66    84    91   114   102    86   113   116   140   122   150   150   193   173   231

  Columns 120 through 136

   236   290   255   248   267   310   317   260   282   286   313   261   293   237   238   233   206
```

```
  Columns 137 through 153

   153   193   172   164   134   123   101    87   103    97    89    71    58    79    56    70    66

  Columns 154 through 170

    59    52    51    54    40    44    43    41    46    44    39    41    32    45    51    30    29

  Columns 171 through 187

    37    42    42    49    29    41    39    38    33    34    38    32    33    27    28    35    38

  Columns 188 through 204

    33    30    30    34    32    31    30    40    30    31    39    40    32    30    23    25    22

  Columns 205 through 221

    39    40    30    37    38    41    39    39    42    36    35    30    42    31    28    33    34

  Columns 222 through 238

    29    30    40    35    40    46    45    38    38    32    33    29    43    40    33    32    44

  Columns 239 through 255

    51    47    35    44    57    41    68    76   102    85    47    30    14    19     8     5     5

  Column 256

     0

Probability Distribution Function:
  Columns 1 through 10

         0         0         0         0         0         0         0         0         0         0

  Columns 11 through 20

         0         0         0         0         0         0         0         0         0         0

  Columns 21 through 30

         0         0         0         0         0    0.0001         0         0         0    0.0001

  Columns 31 through 40

         0    0.0002    0.0001    0.0003    0.0002    0.0002    0.0004    0.0002    0.0004    0.0004

  Columns 41 through 50

    0.0005    0.0007    0.0008    0.0008    0.0009    0.0013    0.0010    0.0022    0.0015    0.0021

  Columns 51 through 60

    0.0029    0.0032    0.0021    0.0027    0.0033    0.0038    0.0035    0.0033    0.0039    0.0034

  Columns 61 through 70

    0.0040    0.0030    0.0031    0.0027    0.0030    0.0032    0.0039    0.0041    0.0046    0.0042

  Columns 71 through 80

    0.0051    0.0043    0.0056    0.0038    0.0049    0.0046    0.0046    0.0039    0.0042    0.0043

  Columns 81 through 90

    0.0037    0.0044    0.0049    0.0048    0.0038    0.0065    0.0057    0.0053    0.0068    0.0052
```

```
Columns 91 through 100

  0.0042    0.0062    0.0054    0.0071    0.0066    0.0066    0.0060    0.0052    0.0062    0.0054

Columns 101 through 110

  0.0054    0.0051    0.0059    0.0051    0.0040    0.0051    0.0056    0.0070    0.0062    0.0052

Columns 111 through 120

  0.0069    0.0071    0.0085    0.0074    0.0092    0.0092    0.0118    0.0106    0.0141    0.0144

Columns 121 through 130

  0.0177    0.0156    0.0151    0.0163    0.0189    0.0193    0.0159    0.0172    0.0175    0.0191

Columns 131 through 140

  0.0159    0.0179    0.0145    0.0145    0.0142    0.0126    0.0093    0.0118    0.0105    0.0100

Columns 141 through 150

  0.0082    0.0075    0.0062    0.0053    0.0063    0.0059    0.0054    0.0043    0.0035    0.0048

Columns 151 through 160

  0.0034    0.0043    0.0040    0.0036    0.0032    0.0031    0.0033    0.0024    0.0027    0.0026

Columns 161 through 170

  0.0025    0.0028    0.0027    0.0024    0.0025    0.0020    0.0027    0.0031    0.0018    0.0018

Columns 171 through 180

  0.0023    0.0026    0.0026    0.0030    0.0018    0.0025    0.0024    0.0023    0.0020    0.0021

Columns 181 through 190

  0.0023    0.0020    0.0020    0.0016    0.0017    0.0021    0.0023    0.0020    0.0018    0.0018

Columns 191 through 200

  0.0021    0.0020    0.0019    0.0018    0.0024    0.0018    0.0019    0.0024    0.0024    0.0020

Columns 201 through 210

  0.0018    0.0014    0.0015    0.0013    0.0024    0.0024    0.0018    0.0023    0.0023    0.0025

Columns 211 through 220

  0.0024    0.0024    0.0026    0.0022    0.0021    0.0018    0.0026    0.0019    0.0017    0.0020

Columns 221 through 230

  0.0021    0.0018    0.0018    0.0024    0.0021    0.0024    0.0028    0.0027    0.0023    0.0023

Columns 231 through 240

  0.0020    0.0020    0.0018    0.0026    0.0024    0.0020    0.0020    0.0027    0.0031    0.0029

Columns 241 through 250

  0.0021    0.0027    0.0035    0.0025    0.0042    0.0046    0.0062    0.0052    0.0029    0.0018

Columns 251 through 256

  0.0009    0.0012    0.0005    0.0003    0.0003         0
```

```
Cumulative Distribution Function:
  Columns 1 through 17

     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0

  Columns 18 through 34

     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0

  Columns 35 through 51

     0     0     0     0     1     1     1     1     1     1     2     2     2     3     3     4     4

  Columns 52 through 68

     5     6     6     7     8     9    10    11    12    13    14    14    15    16    17    18    19

  Columns 69 through 85

    20    21    22    23    25    26    27    28    29    30    31    33    33    35    36    37    38

  Columns 86 through 102

    40    41    42    44    46    47    48    50    51    53    55    56    58    59    61    62    63

  Columns 103 through 119

    65    66    67    68    70    72    73    74    76    78    80    82    84    87    90    92    96

  Columns 120 through 136

   100   104   108   112   116   121   126   130   134   139   144   148   152   156   160   163   167

  Columns 137 through 153

   169   172   175   177   179   181   183   184   186   187   189   190   191   192   193   194   195

  Columns 154 through 170

   196   197   197   198   199   200   200   201   202   202   203   203   204   205   205   206   206

  Columns 171 through 187

   207   208   208   209   210   210   211   211   212   212   213   213   214   214   215   215   216

  Columns 188 through 204

   216   217   217   218   218   219   219   220   220   221   222   222   223   223   224   224   224

  Columns 205 through 221

   225   225   226   227   227   228   228   229   230   230   231   231   232   232   233   233   234

  Columns 222 through 238

   234   235   235   236   237   237   238   239   239   240   240   241   241   242   242   243   244

  Columns 239 through 255

   244   245   246   246   247   248   249   250   252   253   254   254   254   255   255   255   255
```

```
  Column 256

   255

Histogram Values of Equalized Image:
  Columns 1 through 17

    28    58    53    61    83    52    78    54    63    58    54    64    56    66   100    45    49

  Columns 18 through 34

    53    64    67    76    68    83    70     0    91    63    80    76    75    64    68     0   130

  Columns 35 through 51

     0    72    80    79    63     0   106    93    87     0   111     0    85    69   102     0    89

  Columns 52 through 68

   116     0   108     0   108    99     0    85   101     0    89    88    83     0    96    83    66

  Columns 69 through 85

    84     0    91     0   114   102    86     0   113     0   116     0   140     0   122     0   150

  Columns 86 through 102

     0     0   150     0     0   193     0   173     0     0     0   231     0     0     0   236     0

  Columns 103 through 119

     0     0   290     0     0     0   255     0     0     0   248     0     0     0   267     0     0

  Columns 120 through 136

     0     0   310     0     0     0   317     0     0     0   260     0     0     0   282     0

  Columns 137 through 153

     0     0     0   286     0     0     0     0   313     0     0     0   261     0     0     0   293

  Columns 154 through 170

     0     0     0   237     0     0     0   238     0     0   233     0     0     0   206     0   153

  Columns 171 through 187

     0     0   193     0     0   172     0   164     0   134     0   123     0   101    87     0   103

  Columns 188 through 204

    97     0    89    71    58    79    56    70    66    59   103    54    40    87    41    90    80

  Columns 205 through 221

    32    96    59    37    84    49    70    77    67    70    60    63    71    60    66    61    70

  Columns 222 through 238
```

```
  31    79    62    70    79    30    75    80    39    78    65    73    61    63    70    35    86

 Columns 239 through 255

  45    76    65    72    73    32    95    47    79    57    41    68    76     0   102    85   128

 Column 256

   0
```

Conclusion:- In this experiment, we first learnt what a histogram for an image refers to, then histogram equalization, got a demonstration of a live problem-solving for the same using an example, and finally implemented the concept for a given image using MATLAB.

Date: _02/04/2025 **Signature of faculty in-charge**

Post Lab Descriptive Questions

Compare between contrast stretching and histogram equalization.

ANS.:

Feature	Contrast Stretching	Histogram Equalization
Definition	Expands the range of pixel intensities by stretching them linearly across the available dynamic range.	Redistributes pixel intensities based on the cumulative distribution function (CDF) to achieve a more uniform histogram.
Method	Uses a piecewise linear function to adjust pixel intensities.	Uses cumulative probability distribution to remap intensity values.
Effect on Image	Enhances contrast by making dark regions darker and bright regions brighter.	Enhances contrast adaptively by redistributing pixel intensities.
Mathematical Approach	$I_{new} = \frac{(I - Imin)}{Imax - Imin} \times (L-1)$	$I_{new} =$ CDF(I) x (L-1)
Preservation of Image Details	Preserves relative intensity differences but may not enhance all details.	Can lose some details in highly concentrated intensity ranges.

Computational Complexity	Low (simple linear transformation).	Higher (requires computing histogram, PDF, and CDF).
Best Used When	The image has well-defined minimum and maximum intensity values but lacks contrast.	The image has an uneven distribution of intensities,leading to poor visibility of details.
Visual Effect	Improves global contrast without drastically altering the appearance	Can introduce excessive contrast in some areas, leading to unnatural effects
Example Use Cases	Medical imaging, satellite images, and low-contrast photos with known intensity limits.	X-rays, remote sensing images, and images with non-uniform illumination.