Al-Mustaqbal University
College of Healthcare and Medical Techniques
Fourth stage
Medical Physical Department

جامعة المستقبل
AL MUSTAQBAL UNIVERSITY

Medical Imaging Processing

Image Histogram

By

Asst. Prof. Dr. Mehdi Ebady Manaa

Image Histogram

The histogram of an image is a plot of the gray _levels values versus the number of pixels at that value. A histogram appears as a graph with "brightness" on the horizontal axis from 0 to 255 (for an 8-bit) intensity scale) and "number of pixels "on the vertical axis. The histogram gives us a convenient –easy –to –read representation of the concentration of pixels versus brightness of an image, using this graph we able to see immediately:

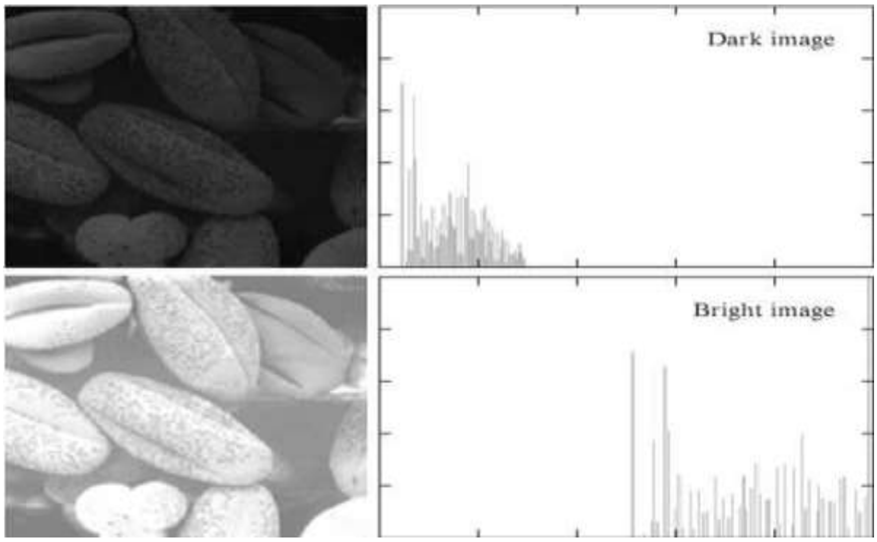
1- Whether an image is basically dark or light and high or low contrast.

2- Give us our first clue a bout what contrast enhancement would be appropriately applied to make the image more subjectively pleasing to an observer, or easier to interpret by succeeding image analysis operations.

So the shape of histogram provide us with information about nature of the image or sub image if we considering an object within the image. For example:

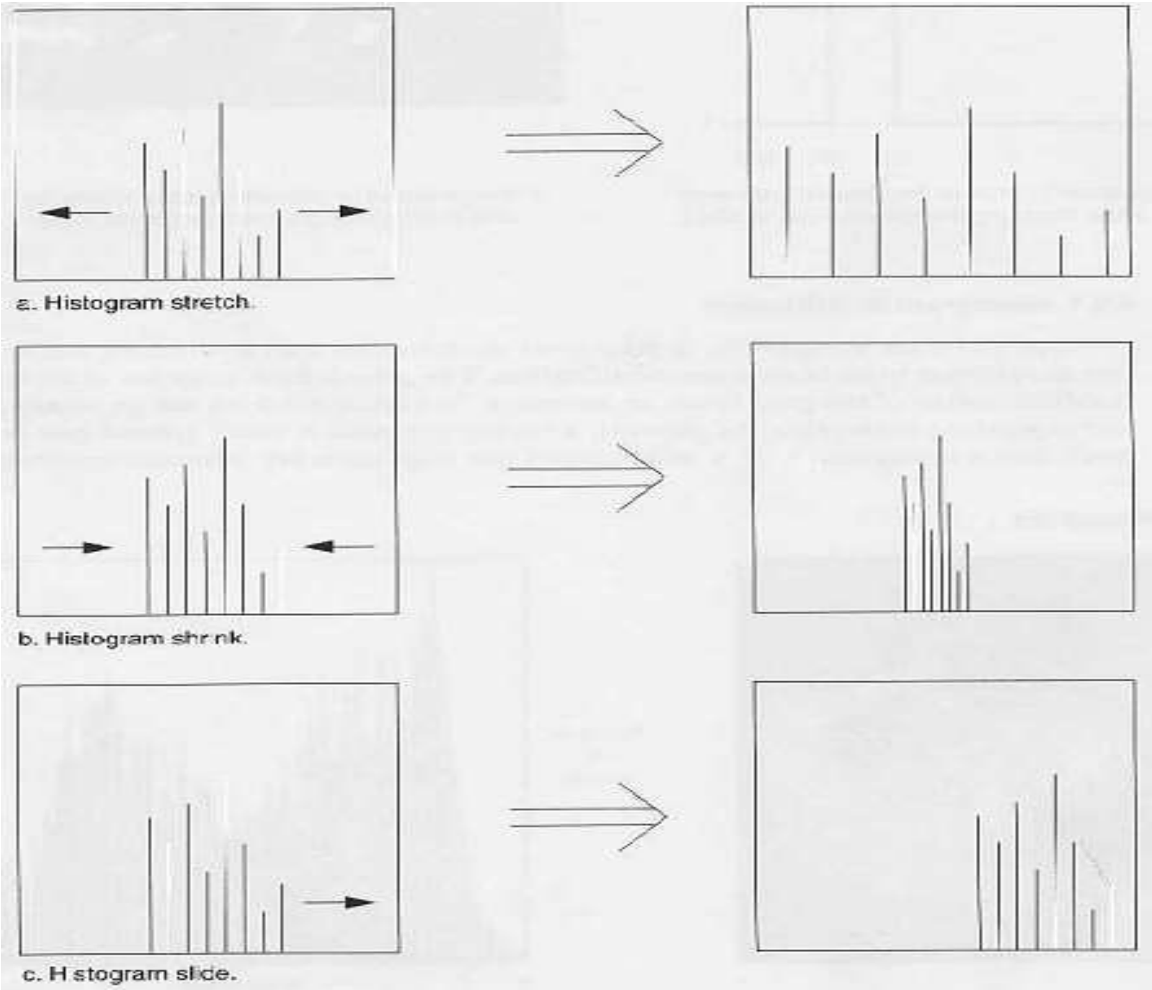
- Very narrow histogram implies a low-contrast image
- Histogram skewed toward the high end implies a bright image
- Histogram with two major peaks , called bimodal, implies an object that is in contrast with the background

As shown in figures below:



Histogram Modifications

The gray level histogram of an image is the distribution of the gray level in an image is the distribution of the gray level in an image. The histogram can be modified by mapping functions, which will stretch, shrink (compress), or slide the histogram. Figure below illustrates a graphical representation of histogram stretch, shrink and slide.



Histogram stretching (Contrast stretching):

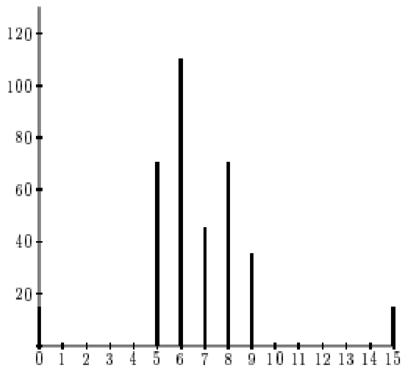
The mapping function for **histogram stretch** can be found by the following equation:

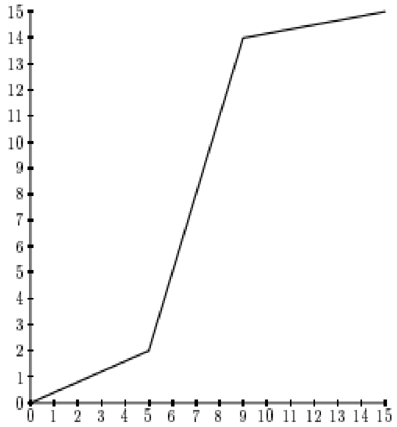
$$\text{Stretch}\,(I\,(r,\,c)) = \left[\frac{I(r,c)-I(r,c)_{\min}}{I(r,c)_{\max}-I(r,c)_{\min}}\right][MAX\text{-}MIN] + MIN.$$

Where, I(r,c) max is the largest gray- level in the image I(r,c). (r,c) min is the smallest gray- level in the image I(r,c). MAX and MIN correspond to the maximum and minimum gray _level values possible (for an 8-bit image these are 255 and 0). This equation will take an image and stretch the histogram a cross the entire gray-level range which has the effect of increasing the contrast of a low contrast image .

Example: Suppose an image with the histogram shown in the table and figure below:

Gray level	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
n_i	15	0	0	0	0	70	110	45	70	35	0	0	0	0	0	15



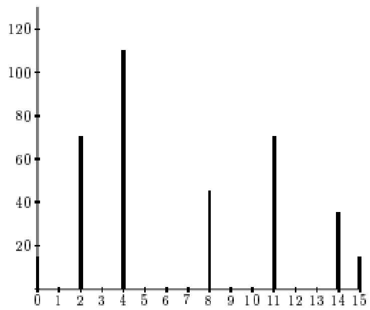


A histogram of a poorly contrasted image, and a stretching function.

The gray level 5−9 according the gray level 2−14. Apply the equation to get the new gray level. $J=[(14-2)/(9-5)](i-5)+2$ where i is the original grey level and j its result after the transformation

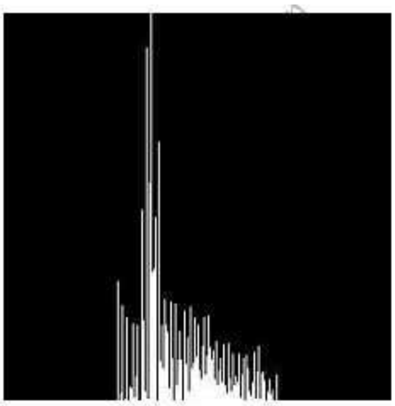
I	5	6	7	8	9
j	2	5	8	11	14

and the corresponding histogram in the figure below.



Another example:

Low-contrast image



Histogram of low-contrast image

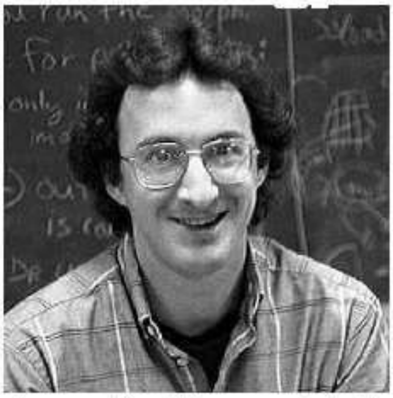
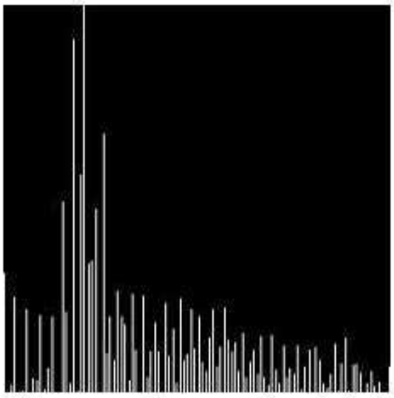


Image after histogram stretching



Histogram of image after stretching

Histogram Shrink

The opposite of a histogram stretch is a histogram shrink, which will decrease image contrast by compressing the gray levels. The mapping function for a **histogram shrinking** can be found by the following equation:

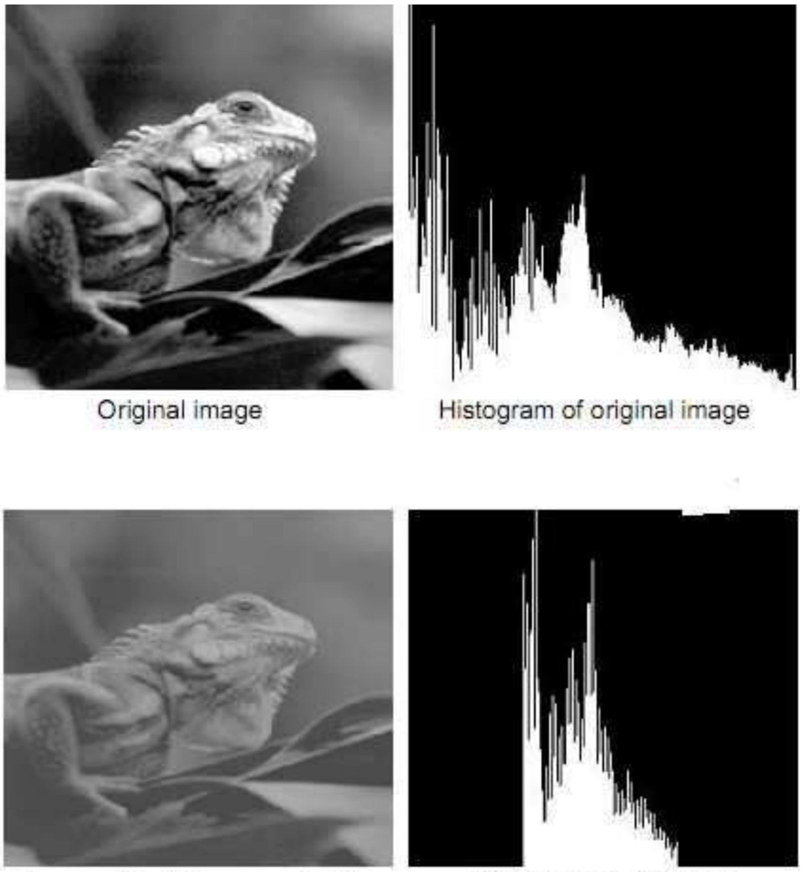
$$\text{Shrink}(I(r,c)) = \left[\frac{shrink_{max} - shrink_{min}}{I(r,c)_{max} - I(r,c)_{min}}\right]\left[I(r,c) - I(r,c)_{min}\right] + shrink_{min}$$

Where

$I(r,c)_{max}$ is the largest gray-level value in the image $I(r,c)$

$I(r,c)_{max}$ is the smallest gray- level value in $I(r,c)$

$shrink_{max}$ and $shrink_{min}$ correspond to the maximum and minimum desired in the compressed histogram. In general, this process produces an image of reduced contrast and may not seem to be useful an image enhancement (see figure (6) of shrink histogram).



Original image — Histogram of original image

Image after histogram shrink to the range [75, 175] — Histogram of the image

Histogram Sliding

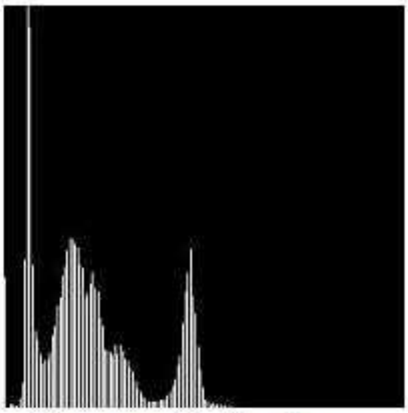
The histogram slide techniques can be used to make an image either darker or lighter but retain the relationship between gray-level values. This can be a accomplished by simply adding or subtracting a fixed number for all the gray-level values, as follows:

$$Slide(I(r,c)) = I(r,c) + OFFSET.$$

Where OFFSET values is the amount to slide the histogram.

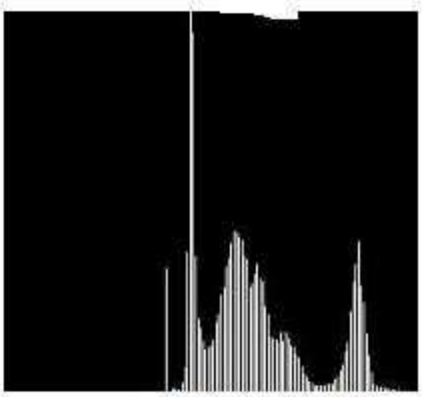
In this equation, a positive OFFSET value will increase the overall brightness; where as a negative OFFSET will create a darker image, figure below shows histogram sliding.

Original image



Histogram of original image

Image after positive-value histogram sliding



Histogram of image after sliding

Histogram features

The histogram features that we are considered are statically based features where the histogram is used as a model of the probability distribution of the gray levels. These statistical features provide us with information a bout the characteristic of the gray – level distribution for the image or sub image. We define the first – order histogram probability

$$P(g) = \frac{N(g)}{M}$$

P(a) as :

M is the number of pixels in the image or sub image (if the entire image is under consideration, then M= N^2 for N×N), and N (g) is the number of pixels at gray level g. as with any probability distribution, all values for P (g) are less than or equal to 1, histogram probability are mean, standard deviation, skew, energy and entropy.

1. Mean: the mean is the average value, so it tells us something about the general brightness of the image. A bright image will have a high mean, and a dark image will have a low mean. We will use L as the total number of gray levels available, so the gray levels range from 0 to L−1. For example, for typical 8−bit image data, L is 256 and ranges from 0 to 255. We can define the mean as follows:

$$\bar{g} = \sum_{g=0}^{L-1} gP(g) = \sum_{r}\sum_{c}\frac{I(r,c)}{M}$$

If we use the second form of the equation, we sum over the rows and columns corresponding to the pixels in the image or sub image under consideration.

2. **Standard deviation:** Which is also known as the square root of the variance, tell us something about the contrast. It describe the spread in the data, so a high contrast image will have a high variance, and a low – contrast image will have a low variance. It is defined as follows:

$$\sigma = \sqrt{\sum_{g=0}^{L-1}(g-\bar{g})^2 P(g)}$$

3. Skew :the skew measure the asymmetry a bout the mean in the gray−level distribution .it is defined as:

$$Skew = \frac{\bar{g} - \text{mod}\, e}{\sigma_g}$$

4. Energy :The energy measure tell us something a bout how the gray level are distributed

$$\text{Energy} = \sum_{g=0}^{L-1} [P(g)]^2$$

The energy measure has a maximum value of 1 for an image with a constant value and gets increasingly smaller as the pixel values are distributed a cross more gray level values(remember that al the P(g) values are less than or equal to 1).the lager this value is, the easier it is to compress the image data. If the energy is high, it tells us that the number of gray levels in the image is few, that is, the distribution is concentrated in only a small number of different gray levels.

2. Entropy: the entropy is a measure that tells us how many bits we need to code the image data and given by :

$$Entropy = -\sum_{g=0}^{L-1} P(g) \log_2 [P(g)]$$

As the pixel values in the image are distributed among more gray levels, the entropy increases. This measure tends to vary inversely with the energy.

1- Histogram Equalization:

Sometimes a better approach is provided by histogram equalization. To transform the grey levels to obtain a better contrast image, we change gray level I to

1/n (n0+ n1+ n2+ n3+……………….+ ni)(L-1)

And this number is rounded to the nearest integer.

Example

Suppose our images

Gray level	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
n_i	15	0	0	0	0	0	0	0	0	70	110	45	80	40	0	0

n_i=15+0+0++0+0+0+0 +80+40+0+0=360

L−1=15

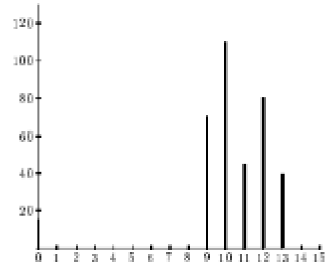
To equalize this histogram, we form running totals of the n_i ,

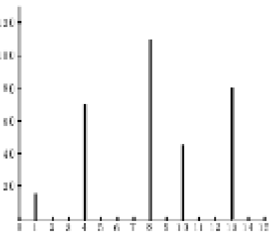
15/360=1/24

Grey level i	n_i	Σn_i	$(1/24)\Sigma n_i$	Rounded value
0	15	15	0.63	1
1	0	15	0.63	1
2	0	15	0.63	1
3	0	15	0.63	1
4	0	15	0.63	1
5	0	15	0.63	1
6	0	15	0.63	1
7	0	15	0.63	1
8	0	15	0.63	1
9	70	85	3.65	4
10	110	195	8.13	8
11	45	240	10	10
12	80	320	13.33	13
13	40	360	15	15
14	0	360	15	15
15	0	360	15	15

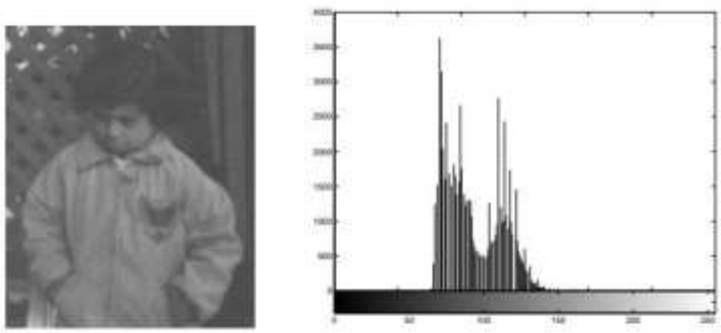
We now have the following transformation of grey values, obtained by reading off the first and last columns in the above table:

Original grey level i	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Final grey level j	1	1	1	1	1	1	1	1	1	4	8	10	13	15	15	15

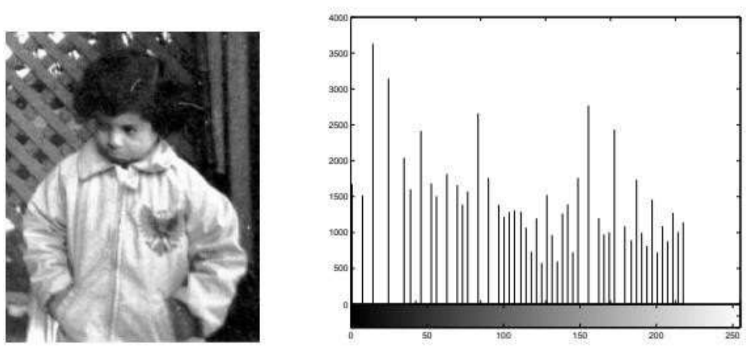




Before Histogram Equalization **After Histogram Equalization**



Before Histogram Equalization



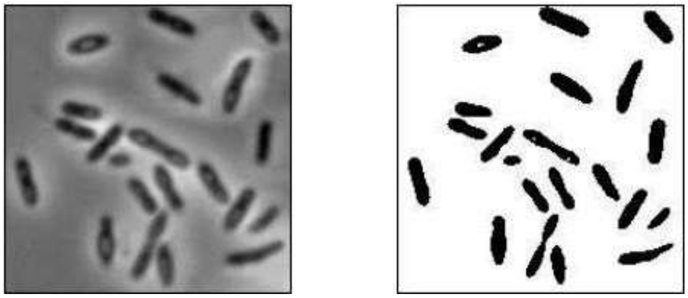
After Histogram Equalization

<u>Thresholding</u> :

1 −**Single thresholding:** A greyscale image is turned into a binary (black and white) image by first choosing a grey level in the original image, and then turning every pixel black or white according to whether its grey value is greater than or less than T:A pixels become becomes white if its gray level > T. A pixels become

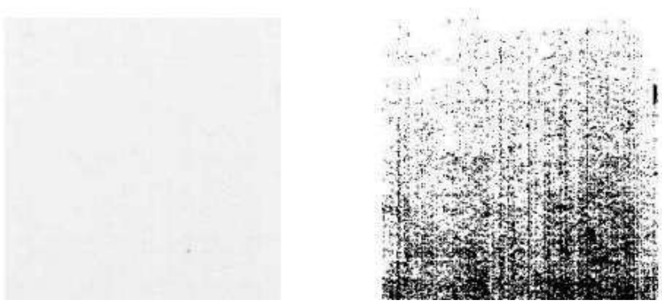
becomes black if its gray level <=T

Thresholding is a vital part of image segmentation, where we wish to isolate objects from the background. It is also an important component of robot vision.



Thresholded image of bacteria at T>100

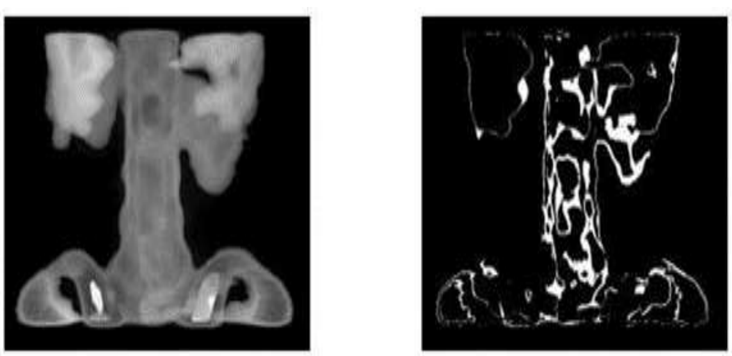
Thresholding provides a very simple way of showing hidden aspects of an image. For example, the image paper as shown in figure below:



Double thresholding:

Here we choose two values and T_1 and T_2 apply a thresholding operation.

A pixels become becomes white its gray level between T_1 and $T_{2.}$ A pixels become becomes black if its gray level is otherwise.as shown in figure below:



Exercises :

1- Consider the following 8x8 image.

3	148	117	148	145	178	132	174
2	176	174	110	185	155	118	165
0	100	124	113	193	136	146	108
0	155	170	106	158	130	178	170
9	196	138	113	108	127	144	139
6	188	143	183	137	162	105	169
9	122	156	119	188	179	100	151
8	176	137	114	135	123	134	183

Threshold it at

(a) level 100

(b) level 150

2,3

The following table gives the number of pixels at each of the grey levels 0 7 in an image with those grey values only:

0	1	2	3	4	5	6	7
3244	3899	4559	2573	1428	530	101	50

Draw the histogram corresponding to these grey levels, and then perform a histogram equalization and draw the resulting histogram.

The following tables give the number of pixels at each of the grey levels 0–15 in an image with those grey values only. In each case draw the histogram corresponding to these grey levels, and then perform a histogram equalization and draw the resulting histogram.

(a)

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
20	40	60	75	80	75	65	55	50	45	40	35	30	25	20	30

(b)

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
0	0	40	80	45	110	70	0	0	0	0	0	0	0	0	15

9. The following small image has grey values in the range 0 to 19. Compute the grey level histogram and the mapping that will equalize this histogram. Produce an 8×8 grid containing the grey values for the new histogram-equalized image.

12	6	5	13	14	14	16	15
11	10	8	5	8	11	14	14
9	8	3	4	7	12	18	19
10	7	4	2	10	12	13	17
16	9	13	13	16	19	19	17
12	10	14	15	18	18	16	14
11	8	10	12	14	13	14	15
8	6	3	7	9	11	12	12

Bubble Sheet Questions

Q1. What does the horizontal axis of an image histogram represent?

a. Number of pixels
b. Brightness levels
c. Contrast values
d. Image dimensions

Answer: b. Brightness levels

Q2. What can you determine from the shape of an image histogram?

a. The image dimensions
b. The number of pixels in the image
c. Whether the image is dark or light and its contrast
d. The image's color distribution

Answer: c. Whether the image is dark or light and its contrast

Q3. What does a narrow histogram imply about an image?

a. High contrast
b. Low contrast
c. Brightness
d. Colorful content

Answer: b. Low contrast

Q4. What is the purpose of histogram stretching?

a. To decrease image contrast
b. To compress the gray levels
c. To increase image contrast
d. To change the image dimensions

Answer: c. To increase image contrast

Q5. How does histogram sliding affect an image?

a. It changes the image dimensions.
b. It alters the color distribution.
c. It makes the image either darker or lighter while retaining gray-level relationships.
d. It removes certain gray levels from the image.

Answer: c. It makes the image either darker or lighter while retaining gray-level relationships.