
Marwadi
University

Marwadi University

IMAGE PROCESSING
01CE0507

Unit - 3
Image Enhancement

Prof. Urvi Y. Bhatt
Department of Computer Engineering

Outline

- Image Enhancement Techniques
  - Spatial Domain Methods
    - Intensity (Gray-level) transformations functions
    - **Histogram Processing**
    - Spatial Filtering
  - Frequency Domain Methods

Histogram

- A histogram is a graph.
- A graph that shows frequency of anything.
- Usually histogram have bars that represent frequency of occurring of data in the whole data set

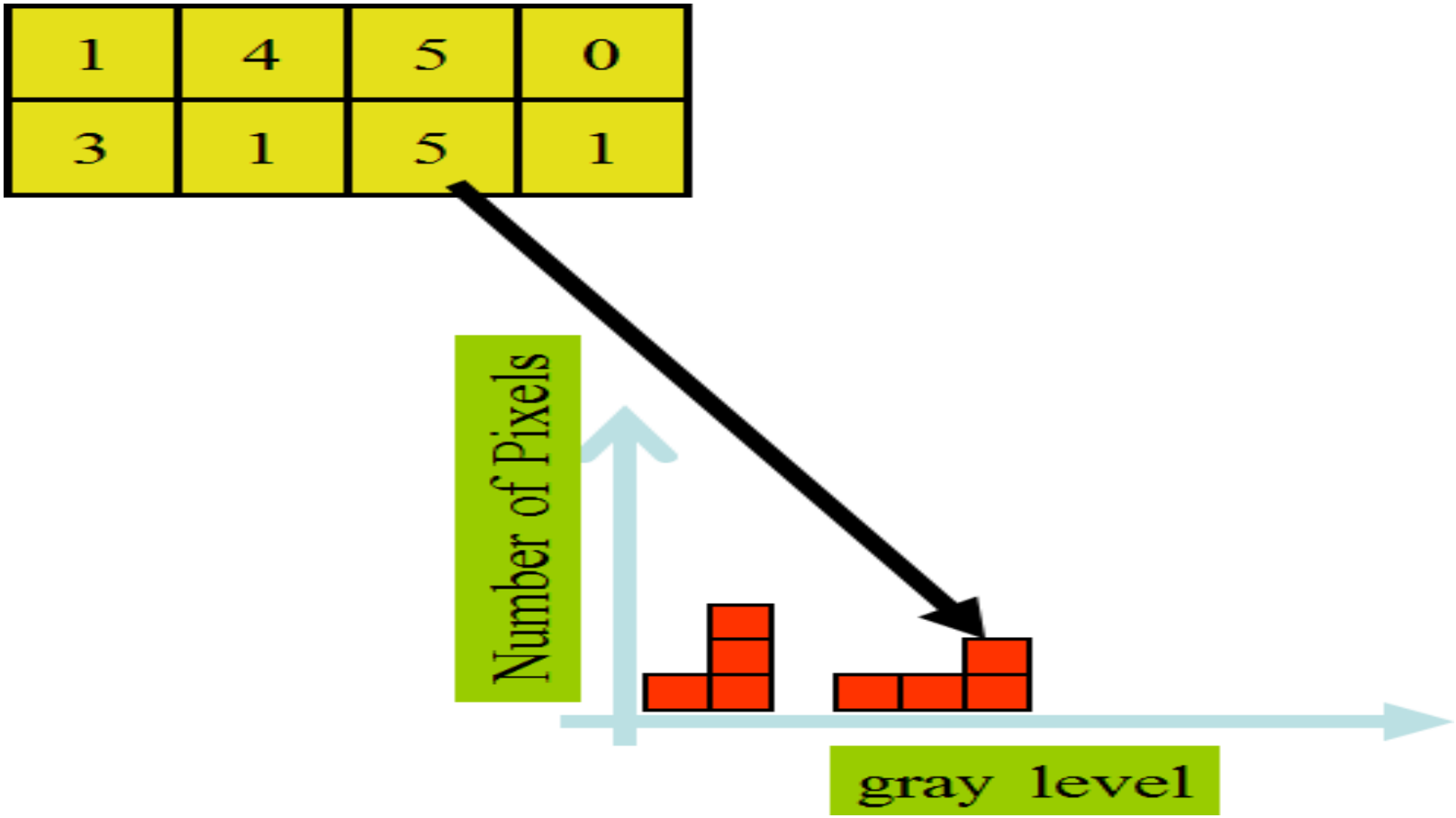
Histogram (Cont.)

- In Statistics, Histogram is a graphical representation showing a visual impression of the distribution of data.
- An Image Histogram is a type of histogram that acts as a graphical representation of the lightness/color distribution in a digital image.
- It plots the number of pixels for each value.

Histogram (Cont.)

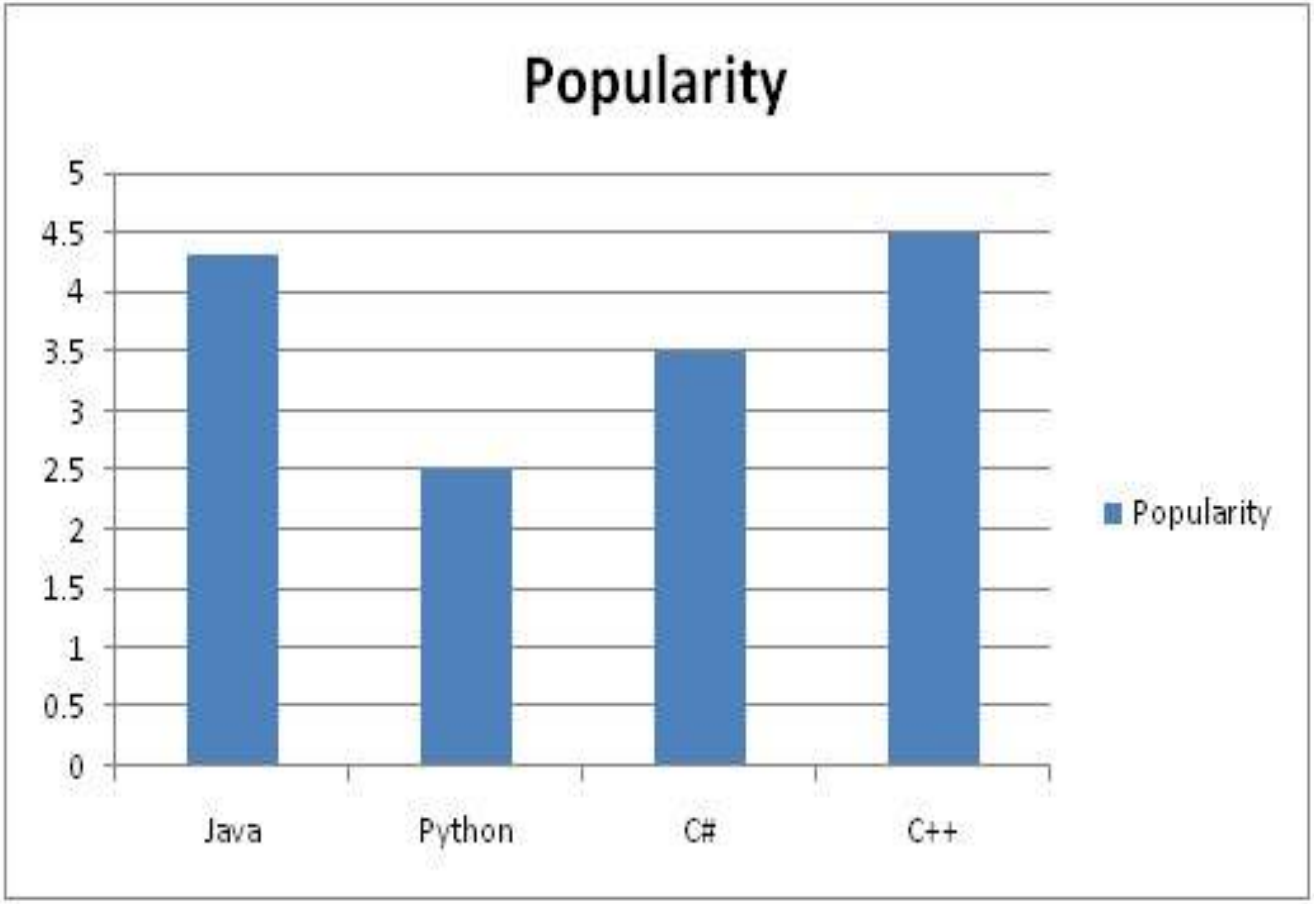
- A Histogram has two axis the x axis and the y axis.
- The x axis contains event whose frequency you have to count.
- The y axis contains frequency.
- The different heights of bar shows different frequency of occurrence of data.

Histogram (Cont.)

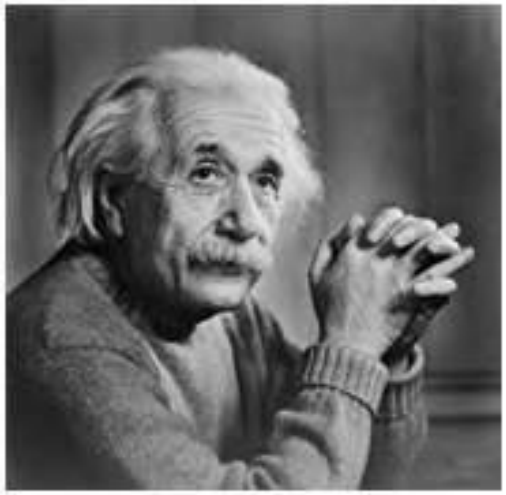


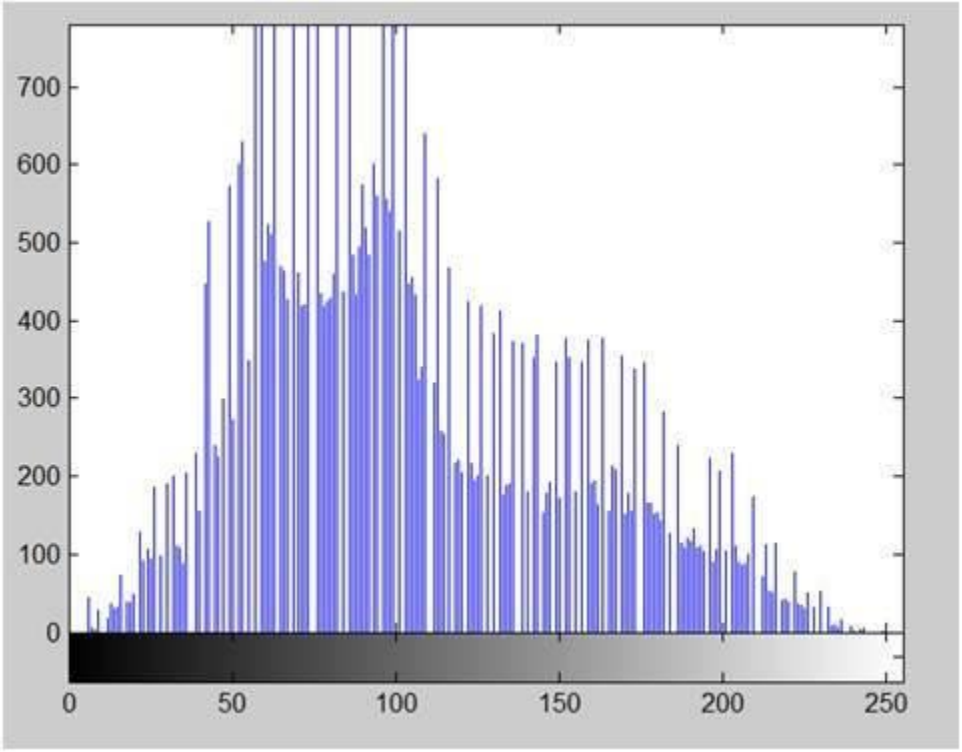
Histogram (Cont.)

- Usually a histogram looks like this.



Histogram (Cont.)





Histogram (Cont.)

- The range of x axis starts from 0 and end at 255 with a gap of 50. Whereas on the y axis, is the count of these intensities.
- Most of the bars that have high frequency lies in the first half portion which is the darker portion.
- That means that the image we have got is darker. And this can be proved from the image too.

Histogram (Cont.)

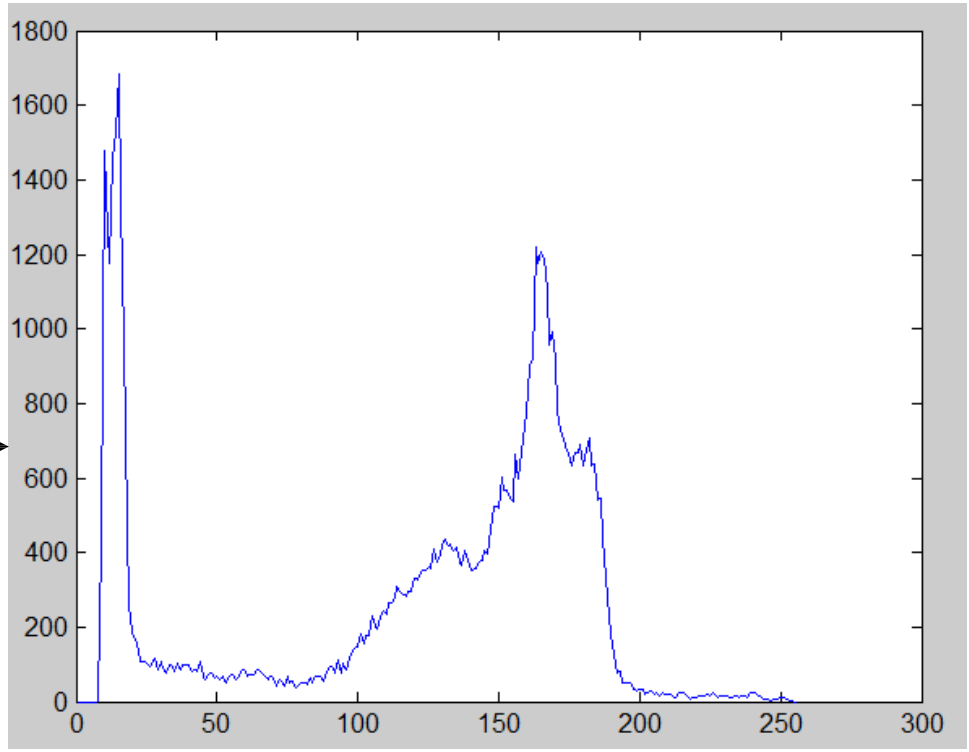
- The histogram of a digital image with gray levels in the range [0, L-1] is a discrete function:

$$h(r_k) = n_k$$

Where:

- r_k : kth gray level
- n_k : No of pixels with having gray level r_k

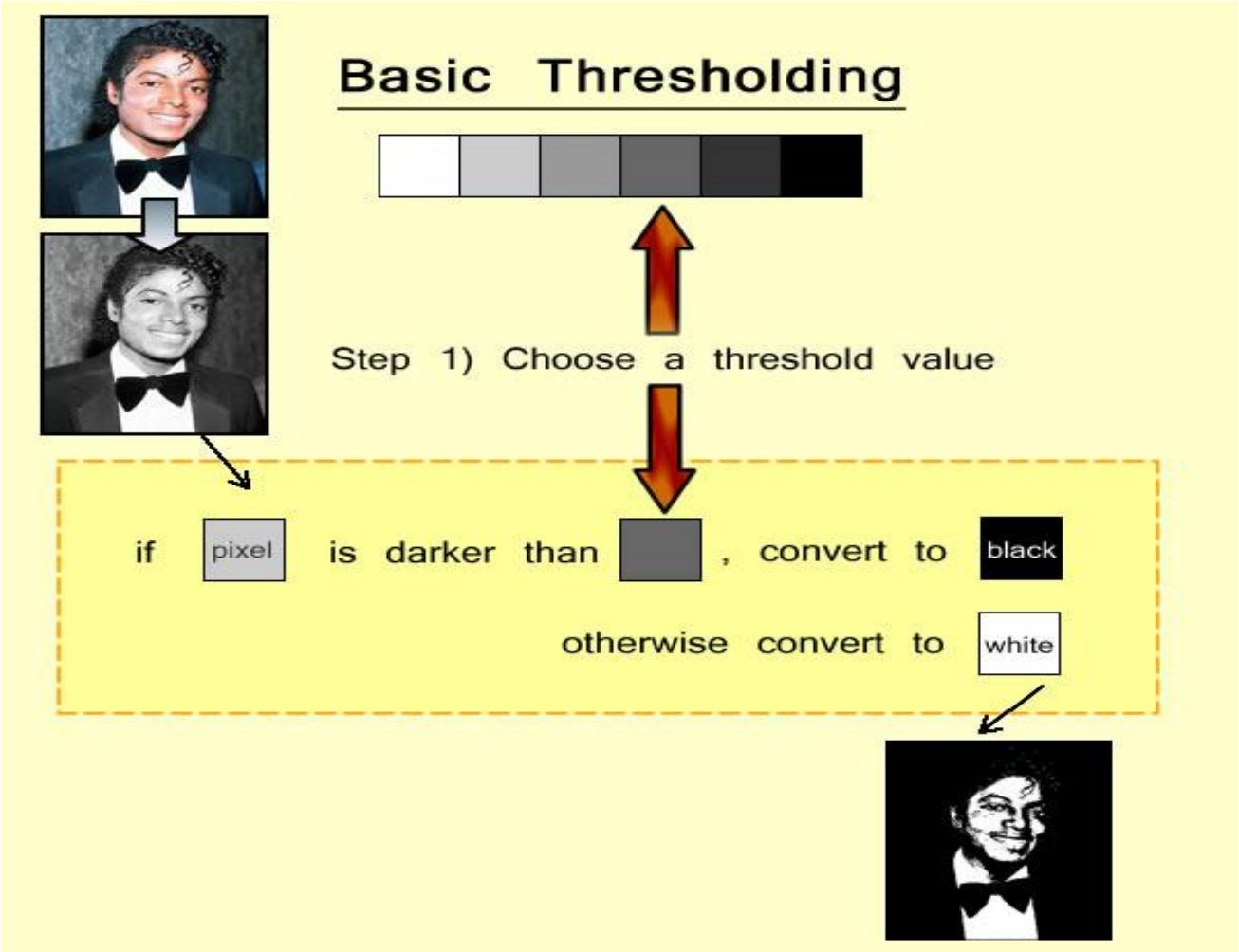
Histogram (Cont.)



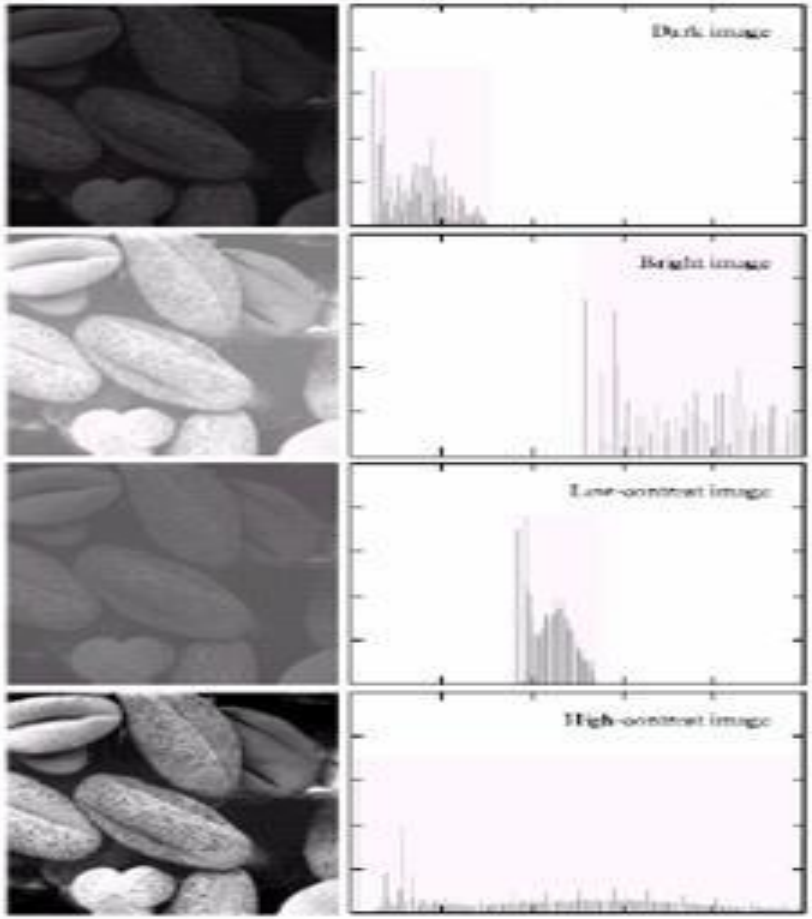
Importance of Histogram

- Histograms are the basis for numerous spatial domain processing techniques
- Histogram manipulation can be used effectively for image enhancement
- Histograms can be used to provide useful image statistics
- Information derived from histograms are quite useful in other image processing applications, such as image compression

Importance of Histogram (Cont.)



Importance of Histogram (Cont.)



→ low contrast image

→ low contrast image

→ low contrast image

→ high-contrast image

An image whose pixels tend to occupy the entire range of possible gray levels and, in addition, tend to be distributed uniformly, will have an appearance of high contrast and will exhibit a large variety of gray tones.

Histogram in MATLAB

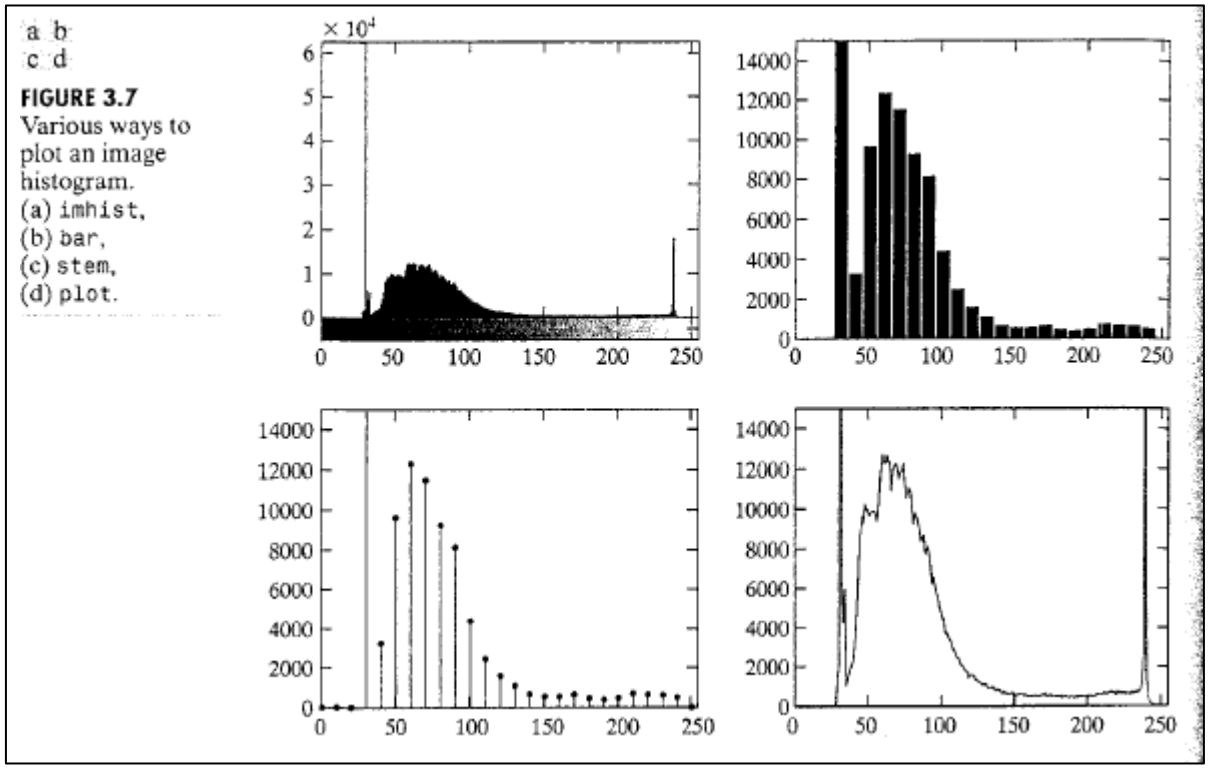
h = imhist (f)

Where

- f is the input image
- h is the histogram

Other ways to display Histograms

- A stem graph
- A bar graph
- A Plot graph



Types of Histogram in MATLAB

- Regular Histogram:

```
h = imhist(f);
```

- A stem graph

```
bar (h);
```

- A bar graph

```
plot (h);
```

- A Plot graph

```
stem (h);
```

Histogram Processing

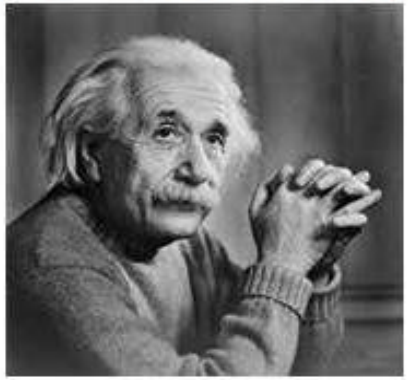
- Histogram Sliding / Histogram Stretching
- Histogram Normalization (PMF)
- Histogram Equalization (CDF)
- Histogram Matching / Histogram Specification

Histogram Sliding / Histogram Stretching

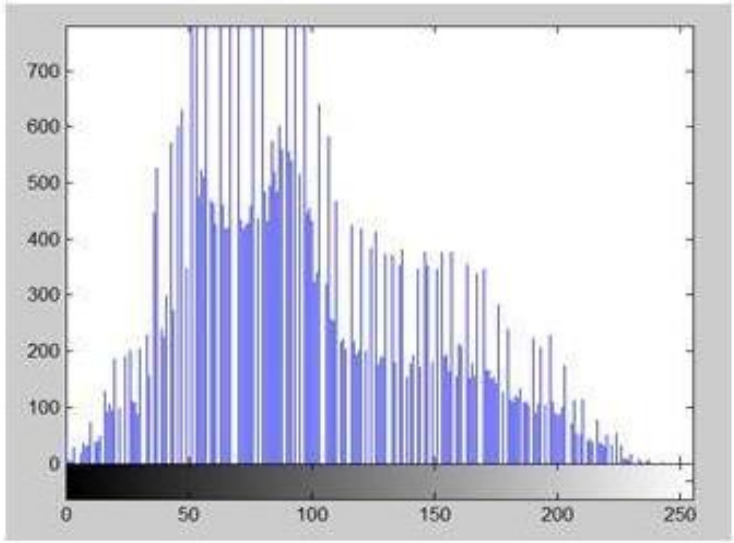
- In histogram sliding, we just simply shift a complete histogram rightwards or leftwards.
- Due to shifting or sliding of histogram towards right or left, a clear change can be seen in the image

Histogram Sliding / Histogram Stretching (Cont.)

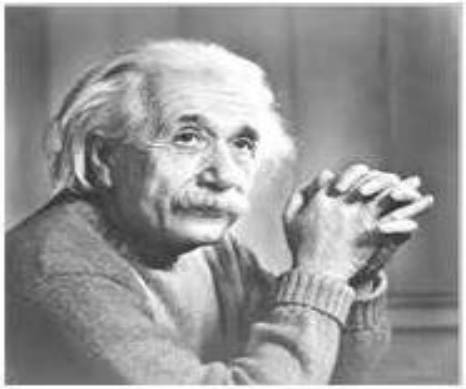
Increasing brightness using histogram sliding



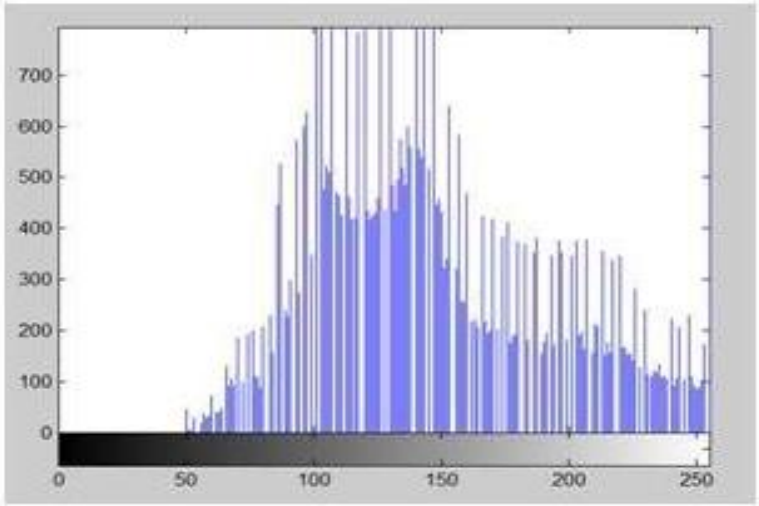
Histogram of this image has been shown below.



The image has been shown below.



And its histogram has been shown below.



Histogram Sliding / Histogram Stretching (Cont.)

- The formula for stretching the histogram of the image to increase the contrast is

$$g(x,y) = \frac{f(x,y)-fmin}{fmax-fmin} * 2^{bpp}$$

Histogram Sliding / Histogram Stretching (Cont.)

- In our case the image is 8bpp, so levels of gray are 256.
- The minimum value is 0 and the maximum value is 225. So the formula in our case is

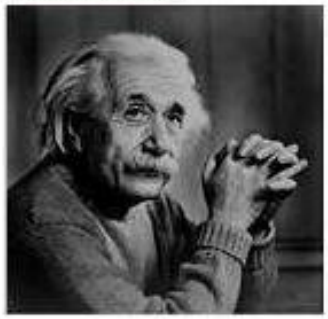
$$g(x,y) = \frac{f(x,y) - 0}{225 - 0} * 255$$

- where f(x,y) denotes the value of each pixel intensity. For each f(x,y) in an image , we will calculate this formula.
- After doing this, we will be able to enhance our contrast.

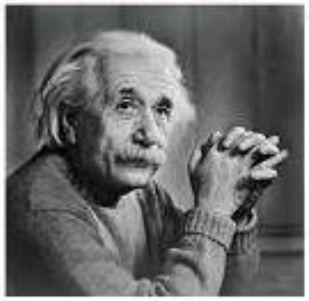
Histogram Sliding / Histogram Stretching (Cont.)

- Decreasing brightness using histogram sliding

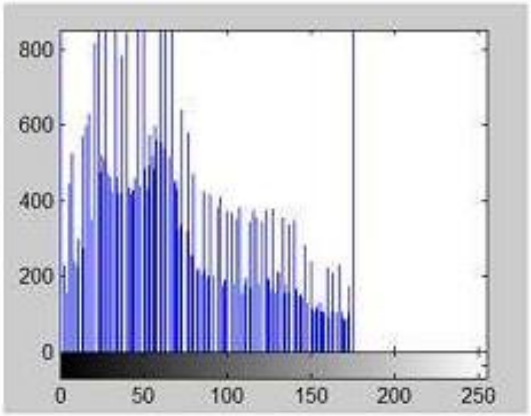
New image.



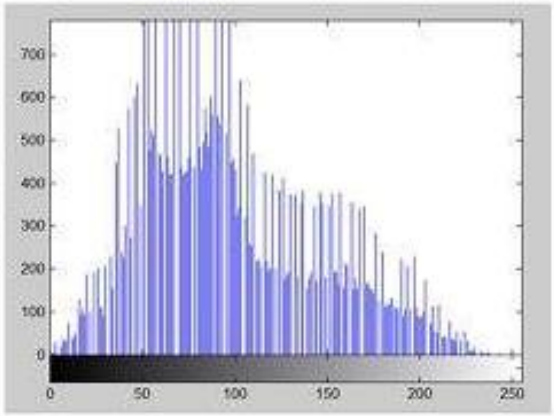
Original image.



New Histogram.



Original Histogram.



Failing of histogram stretching

- Those cases include images with when there is pixel intensity 0 and 255 are present in the image.

- Because when pixel intensities 0 and 255 are present in an image, then in that case they become the minimum and maximum pixel intensity which ruins the formula like this.

Failing of Histogram Stretching (Cont.)

Original Formula

$$g(x,y) = \frac{f(x,y)-fmin}{fmax-fmin} * 2^{bpp}$$

Putting fail case values in the formula:

$$g(x,y) = \frac{f(x,y)-0}{255-0} * 255$$

Simplify that expression gives

$$g(x,y) = \frac{f(x,y)}{255} * 255$$

$$g(x,y) = f(x,y)$$

That means the output image is equal to the processed image. That means there is no effect of histogram stretching has been done at this image.

Histogram Normalization

- It is common practice to normalize a histogram by dividing each of its values by the total number of pixels in the image, denoted by n. Thus, a normalized histogram is given by

$$p(r_k) = n_k / n,$$

for k = 0, 1, …, L -1.

- Thus, $p(r_k)$ gives an estimate of the probability of occurrence of gray level r_k.
- Note that the sum of all components of a normalized histogram is equal to 1.

Histogram Normalization in MATLAB

- We obtain the normalized histogram simply by using the expression.

$$p = \text{imhist}(f, b) / \text{numel}(f)$$

- numel (f): a MATLAB function that gives the number of elements in array f (i.e. the number of pixels in an image).

PMF - Probability Mass Function

- PMF stands for probability mass function.
- As it name suggest, it gives the probability of each number in the data set or you can say that it basically gives the count or frequency of each element.

How PMF is calculated

Marwadi University

Example: Calculate PMF for Below Image.

1	2	7	5	6
7	2	3	4	5
0	1	5	7	3
1	2	5	6	7
6	1	0	3	4

How PMF is calculated (Cont.)

1	2	7	5	6
7	2	3	4	5
0	1	5	7	3
1	2	5	6	7
6	1	0	3	4

Total No of Pixel K = 25

Gray level / Intensity Level	No of pixels / Frequency n_K	PMF / $P_K = n_K/K$
0	2	2/25=0.08
1	4	4/25=0.16
2	3	3/25=0.12
3	3	3/25=0.12
4	2	2/25=0.08
5	4	4/25=0.16
6	3	3/25=0.12
7	4	4/25=0.16

How PMF is calculated (Cont.)

- Calculate PMF for the Following image

Gray level / Intensity Level	0	1	2	3	4	5	6	7
No of pixels / Frequency n_K	9	8	11	4	10	15	4	3

How PMF is calculated (Cont.)

Gray level / Intensity Level	No of pixels / Frequency n_K	PMF / $P_K = n_K/K$
0	9	9/64 = 0.141
1	8	8/64 = 0.125
2	11	11/64 = 0.172
3	4	4/64 = 0.0625
4	10	10/64 = 0.156
5	15	15/64 = 0.234
6	4	4/64 = 0.0625
7	3	3/64 = 0.047

Total No of Pixel K = 64

How PMF is calculated (Cont.)

- The above histogram shows frequency of gray level values for an 8 bits per pixel image.

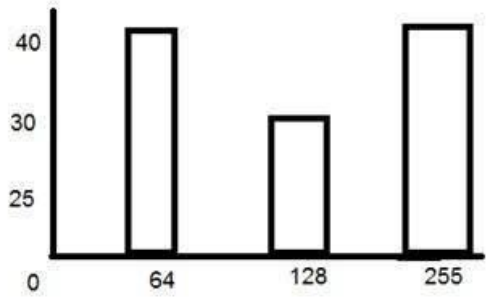
- Now if we have to calculate its PMF, we will simple look at the count of each bar from vertical axis and then divide it by total count.

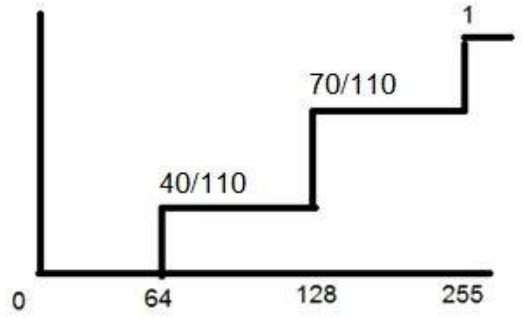
CDF (Cumulative Distributive Function)

- Another important thing to note in the above histogram is that it is not monotonically increasing. So in order to increase it monotonically, we will calculate its CDF
- CDF stands for cumulative distributive function. It is a function that calculates the cumulative sum of all the values that are calculated by PMF. It basically sums the previous one.

CDF (Cont.)

- Consider the histogram which shows PMF. Since this histogram is not increasing monotonically, so will make it grow monotonically.
- For CDP, We will simply keep the first value as it is, and then in the 2nd value , we will add the first one and so on.





How CDF is calculated

- Example: Calculate CDF for the Following image

1	2	7	5	6
7	2	3	4	5
0	1	5	7	3
1	2	5	6	7
6	1	0	3	4

How CDF is calculated (Cont.)

1	2	7	5	6
7	2	3	4	5
0	1	5	7	3
1	2	5	6	7
6	1	0	3	4

Total No of Pixel
K = 25

Gray level / Intensity Level	No of pixels / Frequency n_K	PMF / $P_K = n_K/K$	CDF / S_K
0	2	2/25=0.08	0.08
1	4	4/25=0.16	0.24
2	3	3/25=0.12	0.36
3	3	3/25=0.12	0.48
4	2	2/25=0.08	0.56
5	4	4/25=0.16	0.72
6	3	3/25=0.12	0.84
7	4	4/25=0.16	1

How CDF is calculated (Cont.)

Marwadi University

Example: Calculate CDF for the Following image

Gray level / Intensity Level	0	1	2	3	4	5	6	7
No of pixels / Frequency n_K	9	8	11	4	10	15	4	3

How CDF is calculated (Cont.)

Gray level / Intensity Level	No of pixels / Frequency n_K	PMF / $P_K = n_K/K$	CDF / S_K
0	9	9/64 = 0.141	0.141
1	8	8/64 = 0.125	0.266
2	11	11/64 = 0.172	0.438
3	4	4/64 = 0.0625	0.5005
4	10	10/64 = 0.156	0.6565
5	15	15/64 = 0.234	0.8905
6	4	4/64 = 0.0625	0.953
7	3	3/64 = 0.047	1

Total No of Pixel K = 64

How CDF is calculated (Cont.)

- Example: Calculate CDF for the Following image

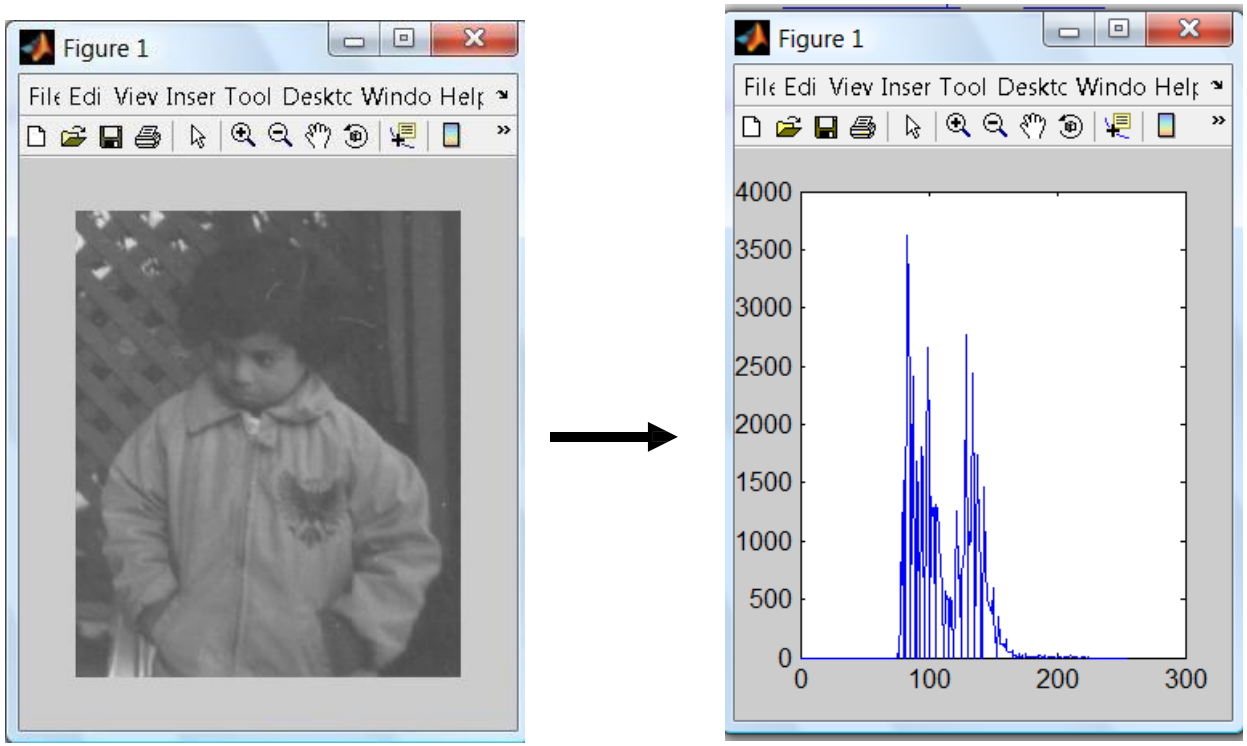
100	110	90	95
98	140	145	135
89	90	88	85
102	105	99	115

Histogram Equalization

- Histogram Equalization is the process of adjusting intensity values of pixels.
- The process which increases the dynamic range of the gray level in a law contrast image to cover full range of gray levels.

Histogram Equalization (Cont.)

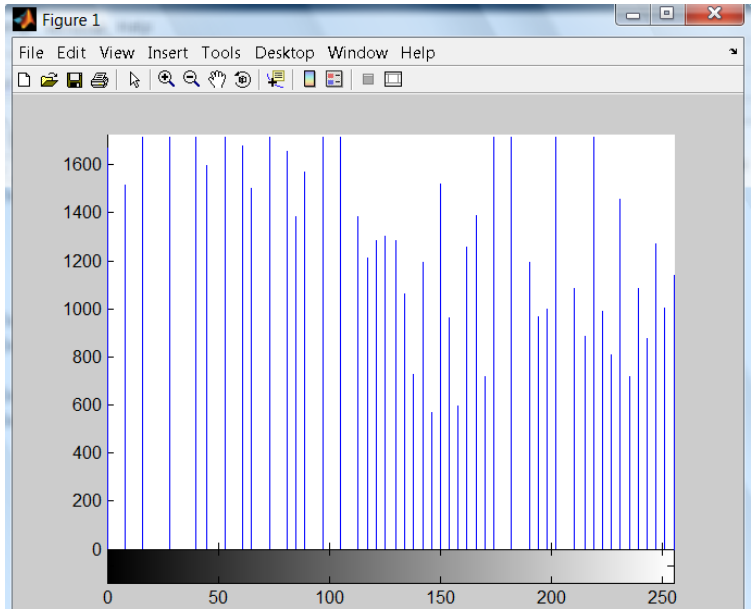
- We have this image in matlab called pout.tif, when we plot its histogram it is showed like this:



Notice that the pixels intensity values are concentrated on the middle

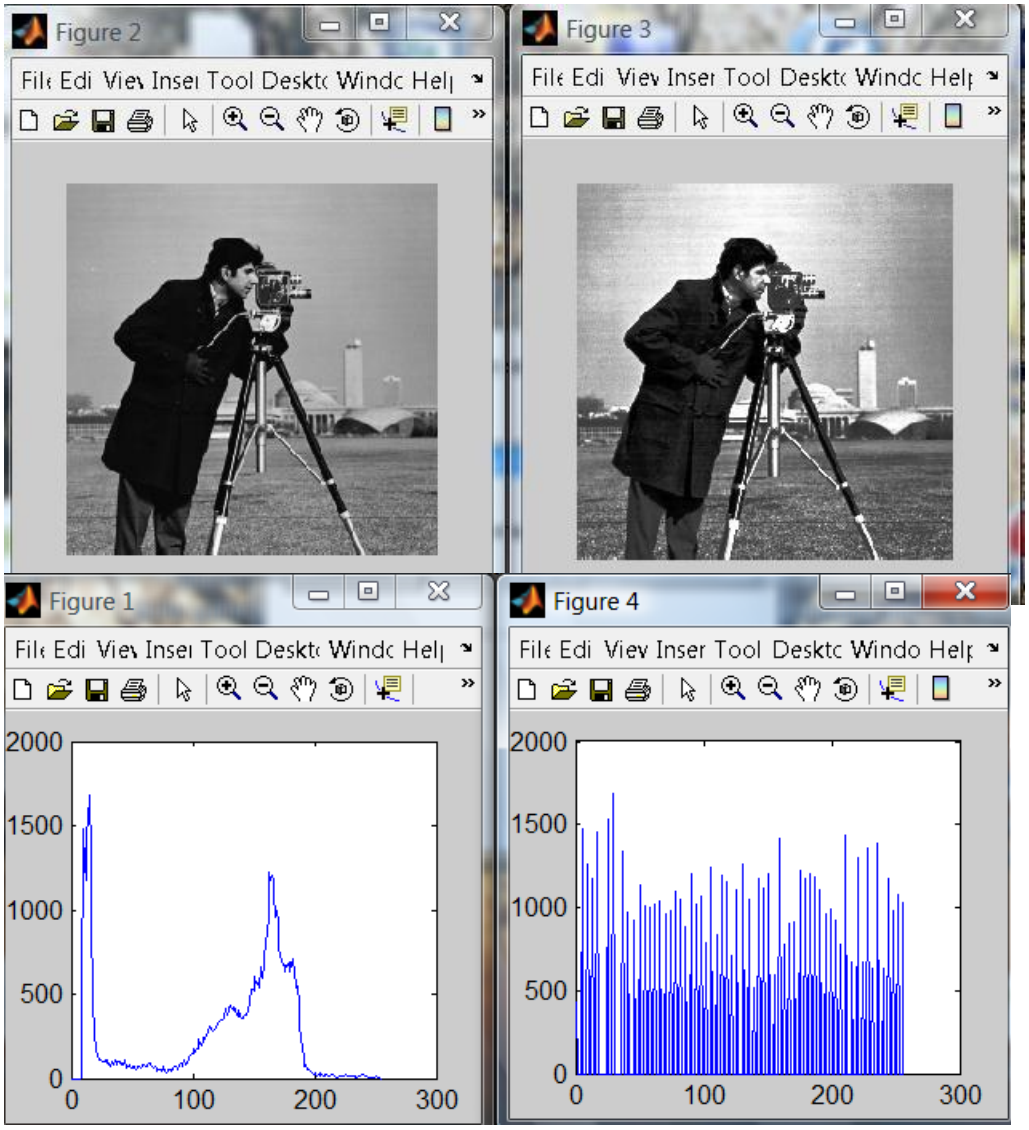
(low contrast)

Histogram Equalization (Cont.)



Histogram produces pixels having values that are distributed throughout the range

Histogram Equalization (Cont.)



Notice that histogram equalization does not always produce a good result

Histogram Equalization (Cont.)

- Steps to Perform Histogram Equalization
  - **Calculate PMF** (PMF helps us calculating the probability of each pixel value in an image)
  - **Calculate CDF** (S_k) (CDF gives us the cumulative sum of PMF values)
  - **Calculate S_k*(L-1)** (CDF is multiplied by levels- 1)
  - **Find out Histogram Equalization Level** (find the new pixel intensities)
  - **Mapping** (mapping of Histogram Equalization Level to Frequency)

Histogram Equalization (Cont.)

- Example: Perform Histogram Equalization for the following Image.

Gray level / Intensity Level	0	1	2	3	4	5	6	7
No of pixels / Frequency n_K	9	8	11	4	10	15	4	3

Histogram Equalization (Cont.)

Gray level / Intensity Level	No of pixels / Frequency n_K	PMF / $P_K = n_K/K$	CDF / S_K	$S_K * (L-1) = S_K * (8-1) = S_K * 7$	Histogram Equalization Level
0	9	9/64 = 0.141	0.141	0.987	1
1	8	8/64 = 0.125	0.266	1.862	2
2	11	11/64 = 0.172	0.438	3.066	3
3	4	4/64 = 0.0625	0.5005	3.5035	4
4	10	10/64 = 0.156	0.6565	4.5955	5
5	15	15/64 = 0.234	0.8905	6.2336	6
6	4	4/64 = 0.0625	0.953	6.671	7
7	3	3/64 = 0.047	1	7	7

Total No of Pixel K = 64 , L=8

Histogram Equalization (Cont.)

Histogram Equalization Level	No of pixels / Frequency n_K
1	9
2	8
3	11
4	4
5	10
6	15
7	4
7	3

New Gray level / Intensity Level	No of pixels / Frequency n_K
1	9
2	8
3	11
4	4
5	10
6	15
7	7

Histogram Equalization (Cont.)

- Example: Perform Histogram Equalization for the following Image.

1	2	7	5	6
7	2	3	4	5
0	1	5	7	3
1	2	5	6	7
6	1	0	3	4

Histogram Equalization (Cont.)

Gray level / Intensity Level	No of pixels / Frequency n_K	PMF / $P_K = n_K/K$	CDF / S_K	S_K* (L-1)	Histogram Equalization Level
0	2	2/25=0.08	0.08	0.56	1
1	4	4/25=0.16	0.24	1.68	2
2	3	3/25=0.12	0.36	2.52	3
3	3	3/25=0.12	0.48	3.36	3
4	2	2/25=0.08	0.56	3.92	4
5	4	4/25=0.16	0.72	5.04	5
6	3	3/25=0.12	0.84	5.88	6
7	4	4/25=0.16	1	7	7

Total No of Pixel K = 25 , L=8

Histogram Equalization (Cont.)

Histogram Equalization Level	No of pixels / Frequency n_K
0	0
2	8
4	8
5	2
5	0
7	7
7	0
7	0

New Gray level / Intensity Level / Histogram Equalization Level	No of pixels / Frequency n_K
0	0
2	8
4	8
5	2
7	7

Total No of Pixel K = 25 , L=8

Histogram Equalization in MATLAB

- Im matlab : we use **histeq** function

```
X=imread('rice.png');

equalized_Image=histeq(X);

imshow(equalized_Image);
imhist(equalized_Image);
```

Histogram Equalization VS Histogram Matching

The goal of histogram equalization is to produce an output image that has a flattened histogram

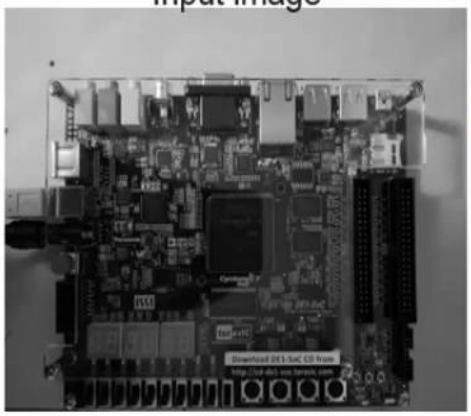
The goal of histogram matching is to take an input image and generate an output image that is based upon the shape of a specific (or reference) histogram.

Histogram Matching / Histogram Specification

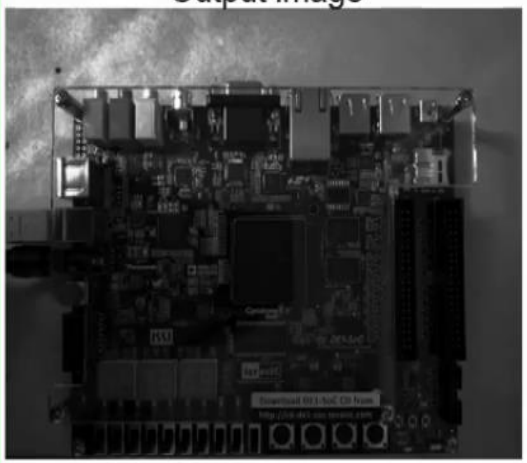
- Histogram matching is useful when we want to unify the contrast level of a group of images.

Histogram Matching / Histogram Specification (Cont.)

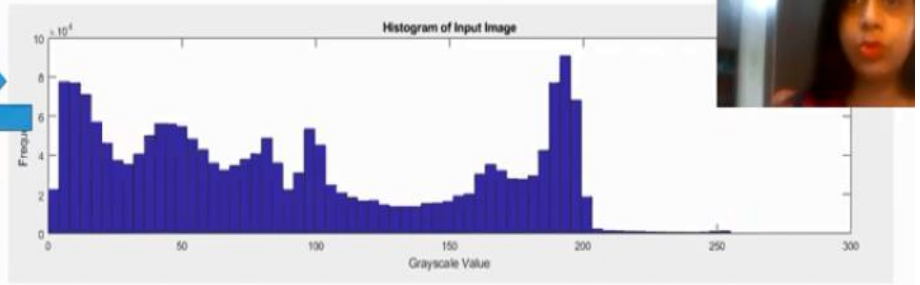
Input image



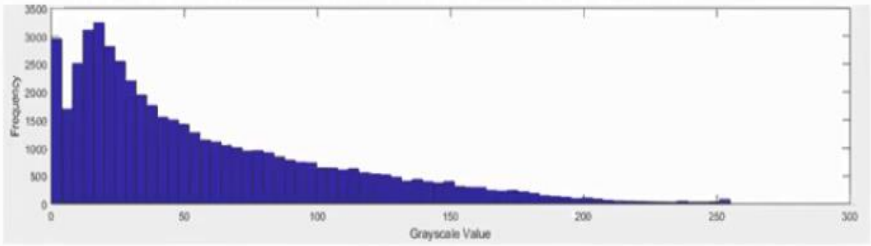
Output image



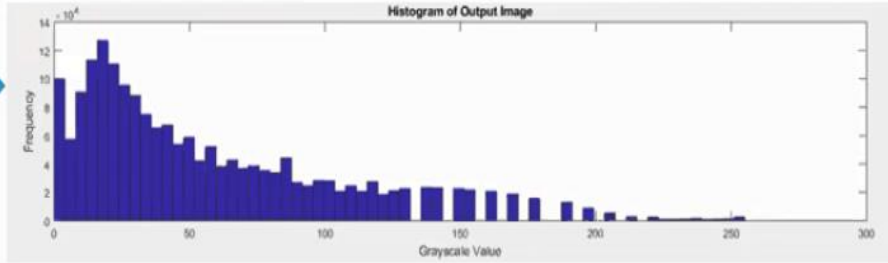
Histogram of input image



Reference histogram that emphasize the lower gray levels.



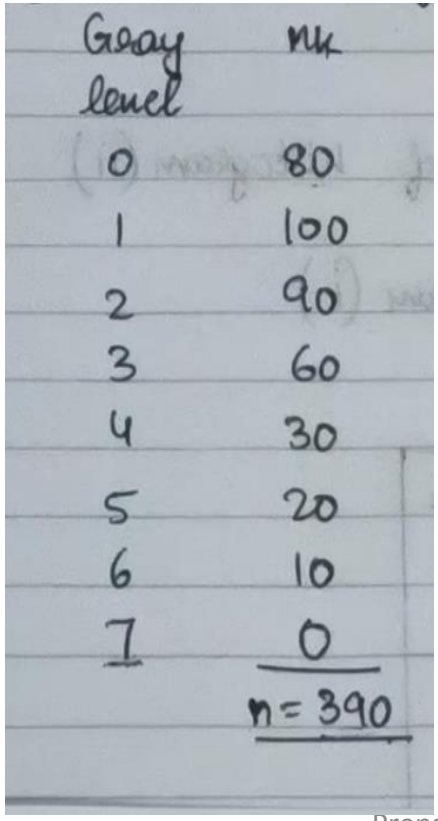
Histogram of output image



Histogram Matching / Histogram Specification (Cont.)

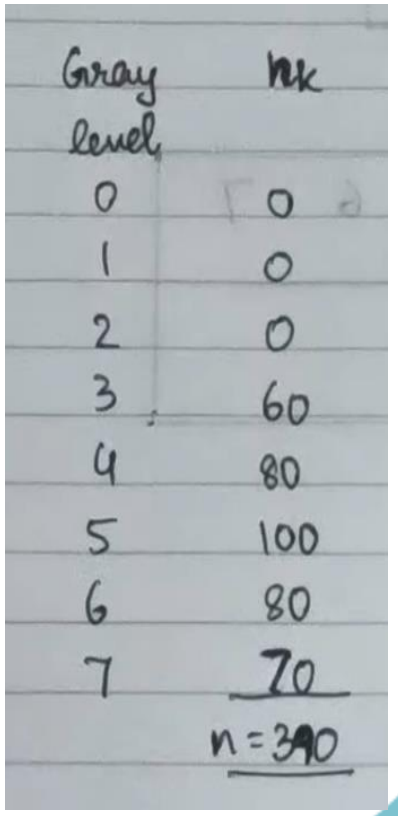
- Example: Perform Histogram Matching. (Consider Image 1 as input Image and Image 2 as reference Image)

Image 1



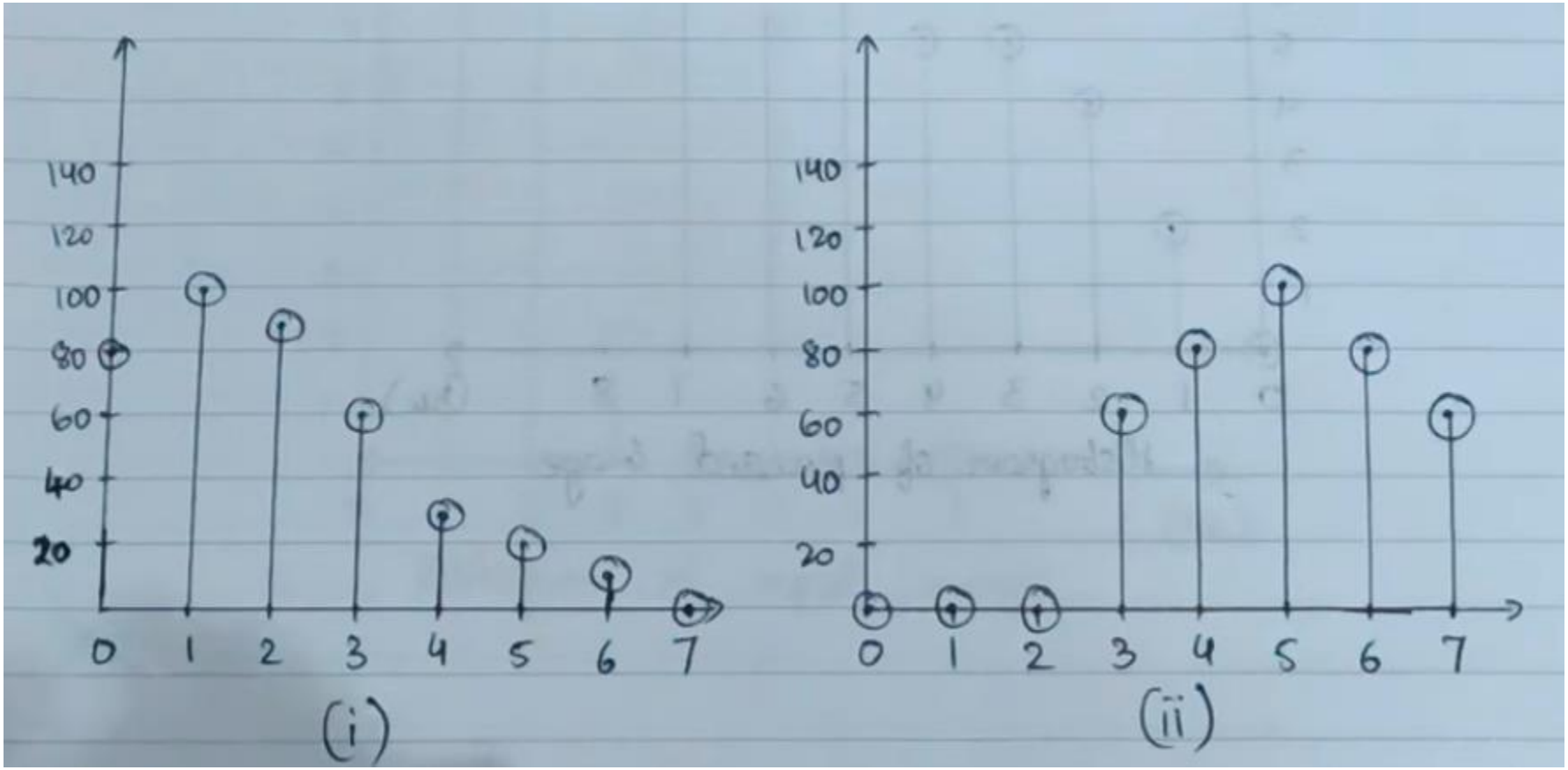
Gray level	n_k
0	80
1	100
2	90
3	60
4	30
5	20
6	10
7	0
	$n = 390$

Image 2

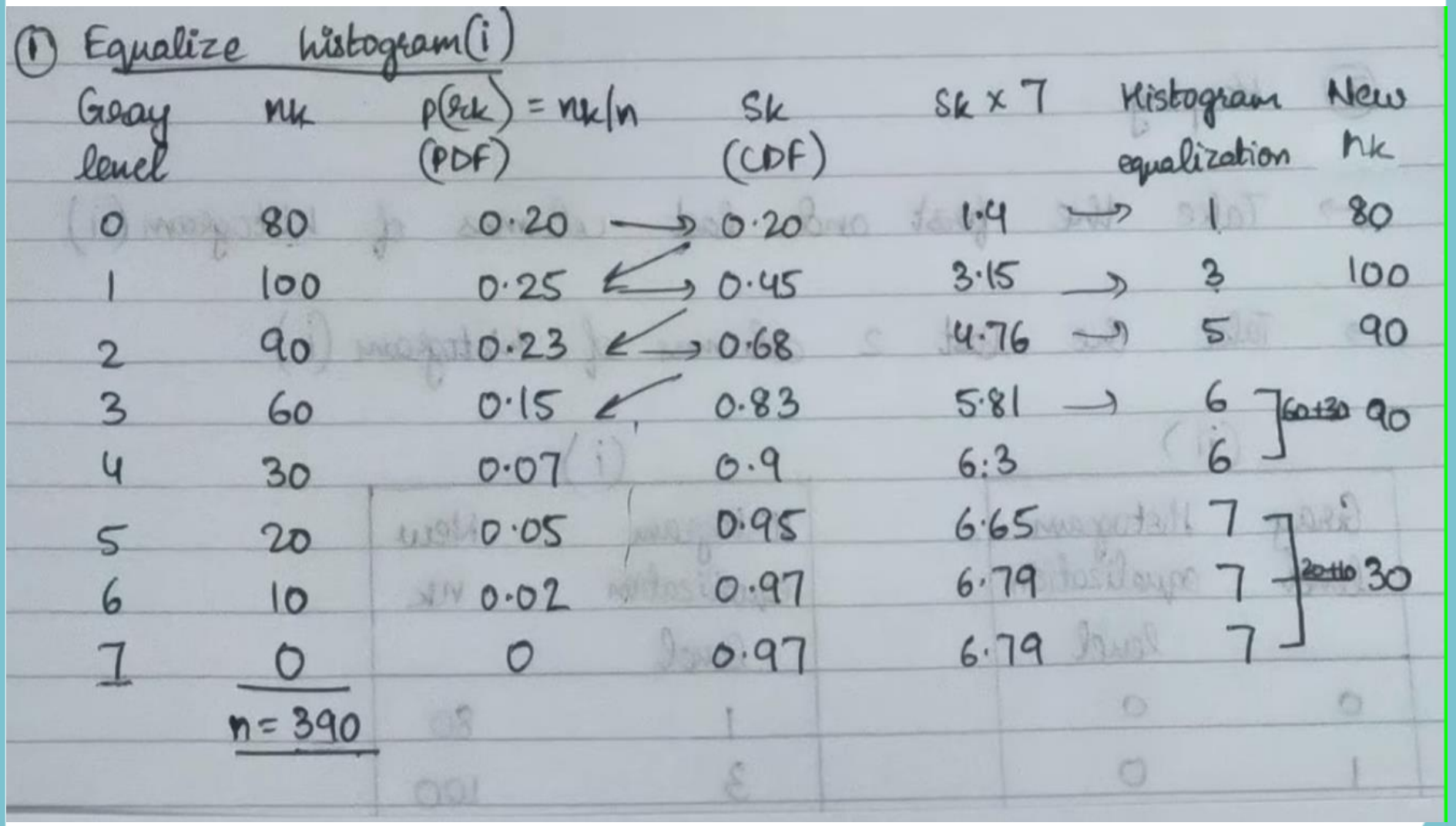


Gray level	n_k
0	0
1	0
2	0
3	60
4	80
5	100
6	80
7	70
	$n = 390$

Histogram Matching / Histogram Specification (Cont.)



Histogram Matching / Histogram Specification (Cont.)



(1) Equalize histogram(i)

Gray level	n_k	$p(r_k) = n_k/n$ (PDF)	s_k (CDF)	$s_k \times 7$	Histogram equalization	New n_k
0	80	0.20	0.20	1.4	1	80
1	100	0.25	0.45	3.15	3	100
2	90	0.23	0.68	4.76	5	90
3	60	0.15	0.83	5.81	6	90 (60+30)
4	30	0.07	0.9	6.3	6	
5	20	0.05	0.95	6.65	7	30 (20+10)
6	10	0.02	0.97	6.79	7	
7	0	0	0.97	6.79	7	

$n = 390$

Histogram Matching / Histogram Specification (Cont.)

Marwadi University

② Equalize histogram (ii)

Gray level	n_k	$p(r_k) = n_k/n$ (PDF)	S_k (CDF)	$S_k \times 7$	Histogram equalization level
0	0	0	0	0	0
1	0	0	0	0	0
2	0	0	0	0	0
3	60	0.15	0.15	1.05	1
4	80	0.20	0.35	2.45	2
5	100	0.25	0.6	4.2	4
6	80	0.20	0.8	5.6	6
7	70	0.17	0.97	6.79	7

$n = 390$

Histogram Matching / Histogram Specification (Cont.)

(3) Mapping

→ Take the first and last columns of histogram (ii).

→ Take the last 2 columns of histogram (i).

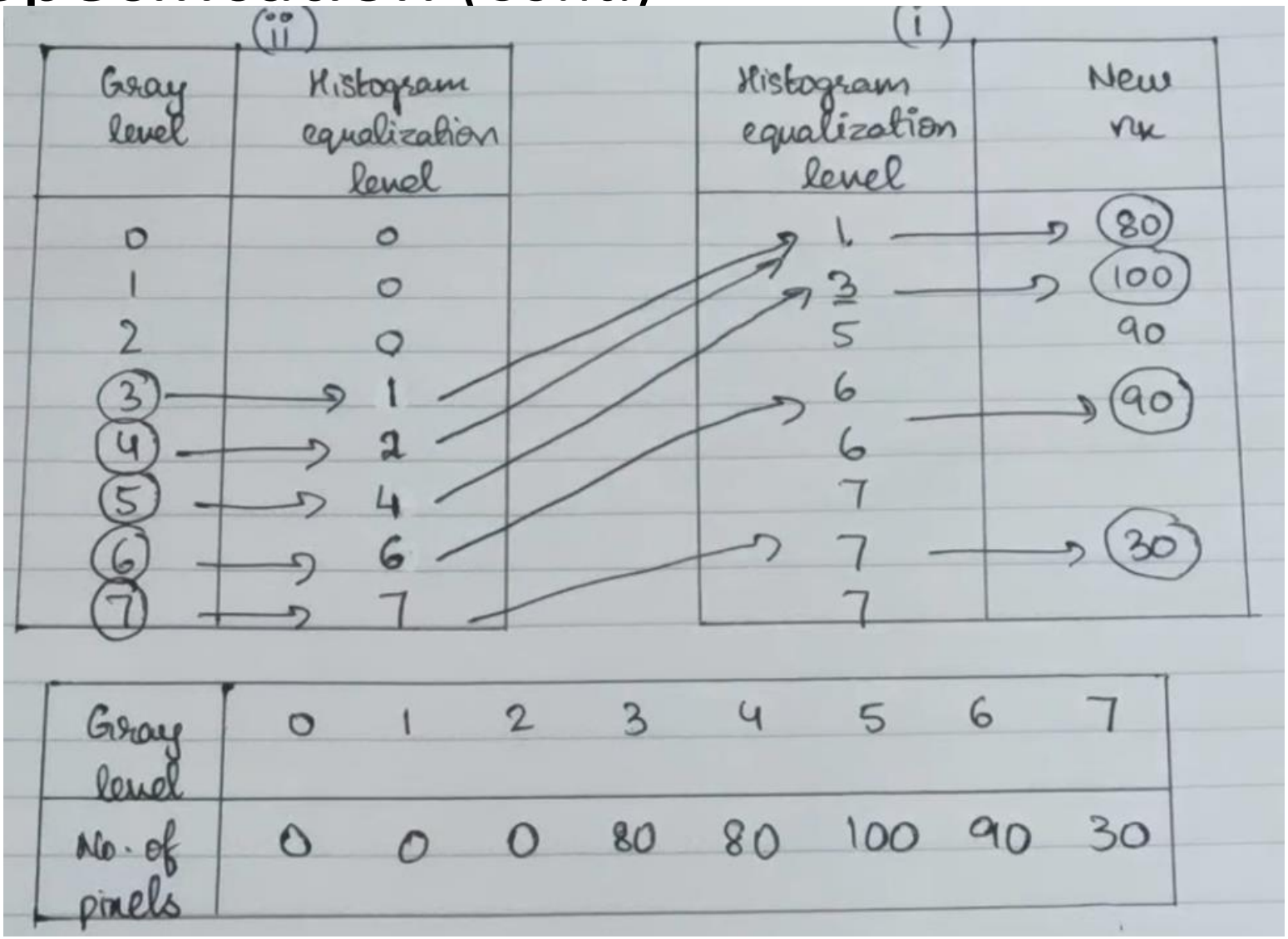
(ii)

Gray level	Histogram equalization level
0	0
1	0
2	0
3	1
4	2
5	4
6	6
7	7

(i)

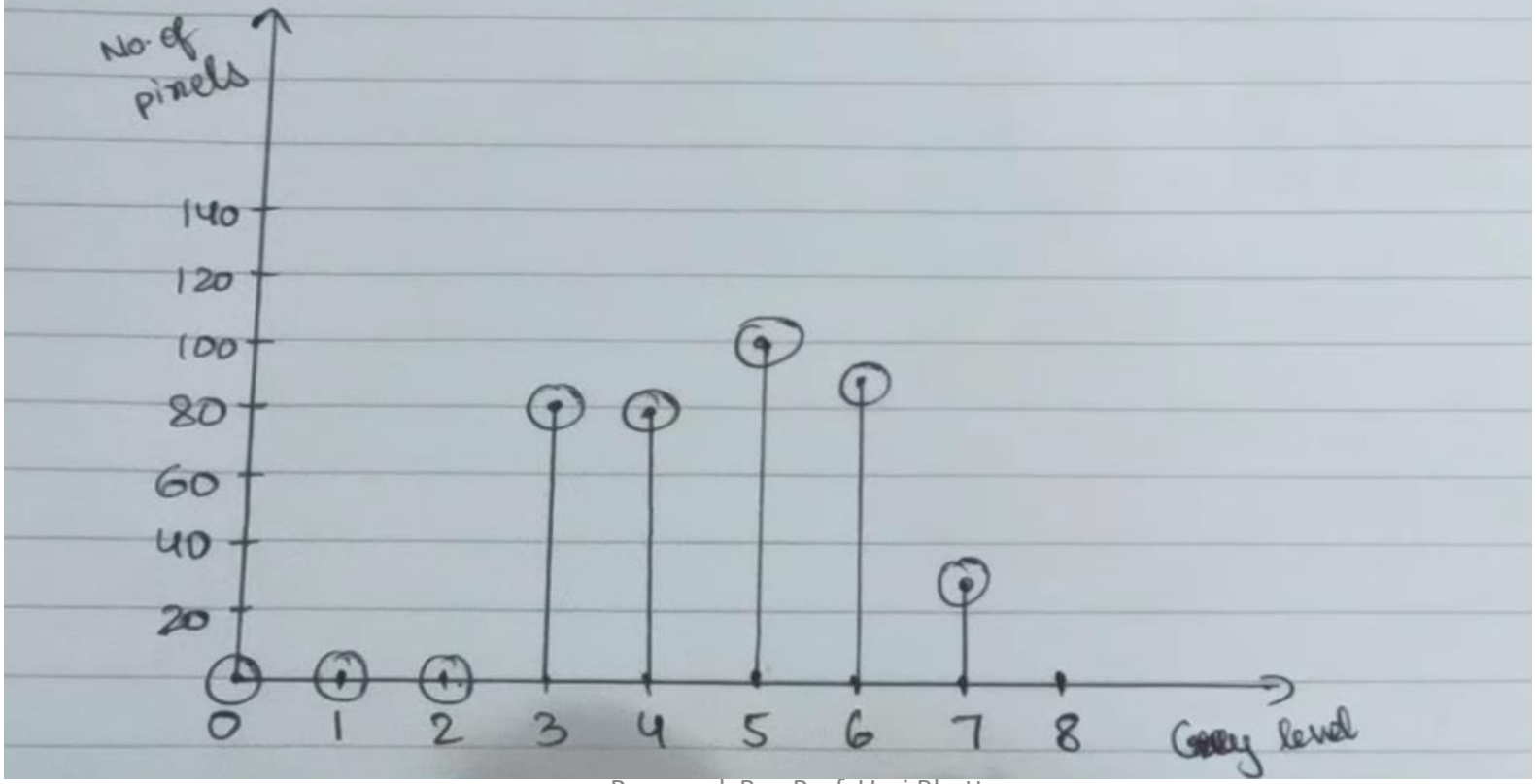
Histogram equalization level	New n_k
1	80
3	100
5	90
6	90
6	
7	
7	30
7	

Histogram Matching / Histogram Specification (Cont.)



Histogram Matching / Histogram Specification (Cont.)

Gray level	0	1	2	3	4	5	6	7
No. of pixels	0	0	0	80	80	100	90	30



Histogram Matching / Histogram Specification (Cont.)

Example : Given histogram (a) & (b), modify histogram (a) as given by histogram (b)

(a)

Gray level.	0	1	2	3	4	5	6	7
No. of pixels	790	1023	850	656	329	245	122	81

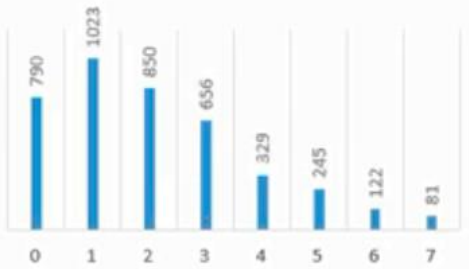
(b)

Gray level.	0	1	2	3	4	5	6	7
No. of pixels	0	0	0	614	819	1230	819	614

Histogram Matching / Histogram Specification (Cont.)

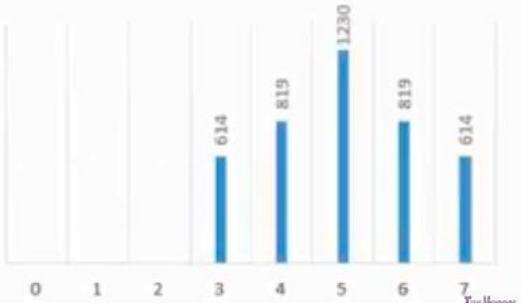
(a)

Gray level.	0	1	2	3	4	5	6	7
No. of pixels	790	1023	850	656	329	245	122	81



(b)

Gray level.	0	1	2	3	4	5	6	7
No. of pixels	0	0	0	614	819	1230	819	614



Histogram Matching / Histogram Specification (Cont.)

- Equalizing Histogram A

Gray level	nk	PDF	CDF	Sk x 7	Round off	New nk.
0	790	0.19	0.19	1.33	1	790
1	1023	0.25	0.44	3.08	3	1023
2	850	0.21	0.65	4.55	5	850
3	656	0.16	0.81	5.67	6	985
4	329	0.08	0.89	6.23	6 (656+329)	
5	245	0.06	0.95	6.65	7	
6	122	0.03	0.98	6.86	7 (245 +122+81)	448
7	81	0.02	1	7	7	
	N=4096					

Histogram Matching / Histogram Specification (Cont.)

Marwadi University

Now equalize histogram (b).

Gray level	nk	PDF	CDF	Sk x 7	Round off
0	0	0	0	0	0
1	0	0	0	0	0
2	0	0	0	0	0
3	614	0.149	0.149	1.05	1
4	819	0.20	0.35	2.50	3
5	1230	0.30	0.65	4.55	5
6	819	0.20	0.85	5.97	6
7	614	0.15	1	7	7
	N=4096				

Histogram Matching / Histogram Specification (Cont.)

Mapping

First and last columns of histogram (b)

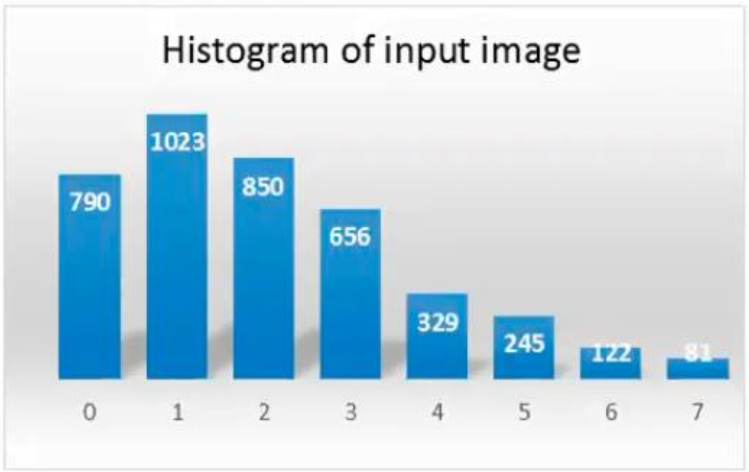
Gray level	Round off
0	0
1	0
2	0
3	1
4	3
5	5
6	6
7	7

Last two columns of histogram (a)

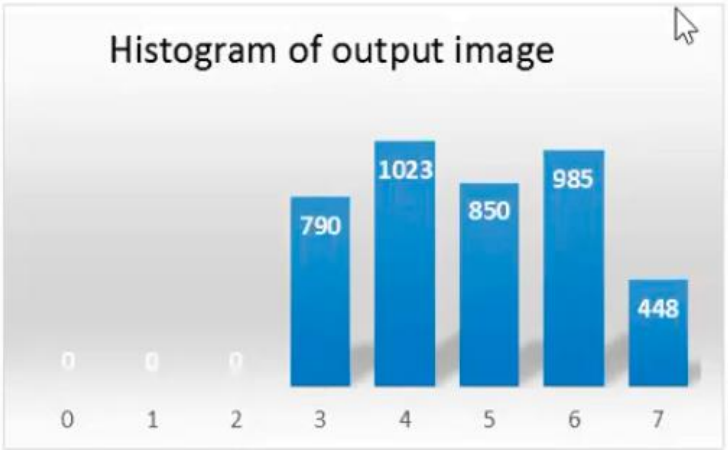
Round off	New nk.
1	790
3	1023
5	850
6	
6	985
7	
7	448
7	

Gray level.	0	1	2	3	4	5	6	7
No. of pixels	0	0	0	790	1023	850	985	448

Histogram Matching / Histogram Specification (Cont.)



Plot histogram for modified image.



Histogram Matching / Histogram Specification in MATLAB

- For Performing Histogram Matching / Histogram Specification in MATLAB we use, imhistmatch() function

MI= imhistmatch(input_image,reference_image)


Thank
you