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Digital Image Processing

Part 2

Image Processing

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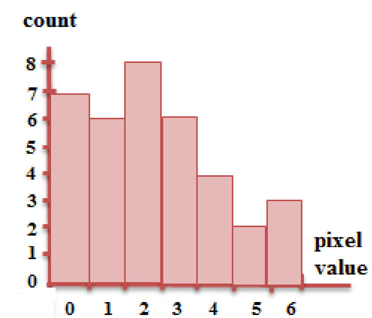
0	5	6	4	4	3
1	0	3	3	2	2
0	2	2	3	2	0
2	1	1	2	1	4
3	4	0	2	0	5
6	3	1	1	0	6

Image 6*6

Pixel value	count
0	7
1	6
2	8
3	6
4	4
5	2
6	3
Total	36

Histogram



Plot of the histogram

Type of Image

Photographic Negative

This is perhaps the simplest intensity transform. Supposing that we have a gray level image in the range [0, 1]. It is expected to transform the:

- Black points (0s) into the white ones (1s).
- White pixels (1s) into the black ones (0s).

this simple transform can be denoted by (assume that f(x, y) is normalized into the range [0, 1]).

$$\tilde{f}(x, y) = 1 - f(x, y)$$

For a 256 gray level image, the transformation can be accomplished

$$\tilde{f}(x, y) = 1 - f(x, y) / 256$$

An example of the photographic negative transform is shown in figure below

1-1=0

1	0	0	1
0	1	1	0
1	0	1	1
0	1	0	1

0	1	1	0
1	0	0	1
0	1	0	0
1	0	1	0

(a) (b)

Figure (a) A panda image, (b) negative transformed image

Gamma transform

Gamma transform is also called power-law transform. It is mathematically denoted as follows:

$$\tilde{f}\,(x, y) = C * f\,(x, y)^{\gamma}$$

Where: C and γ are two constants.

- **The gamma transform can make pixels look brighter or darker depending on the value of γ.**

- **When $f\,(x, y)$ is within the range [0, 1] and**
  - **γ is larger than one, it makes the image darker.**
  - **γ is smaller than one, it makes the image look brighter.**

- **Figure below shows the output of the gamma transform against different inputs with the parameters set as (γ = 0.5, 1 and 2), (C = 1).**

- **From this plot, we can see that the curve with γ = 2 is below the curve with γ = 1.**

- **This indicates that the output is smaller than the input, which explains why an image in the Gamma transform, when γ = 2, will become darker.**

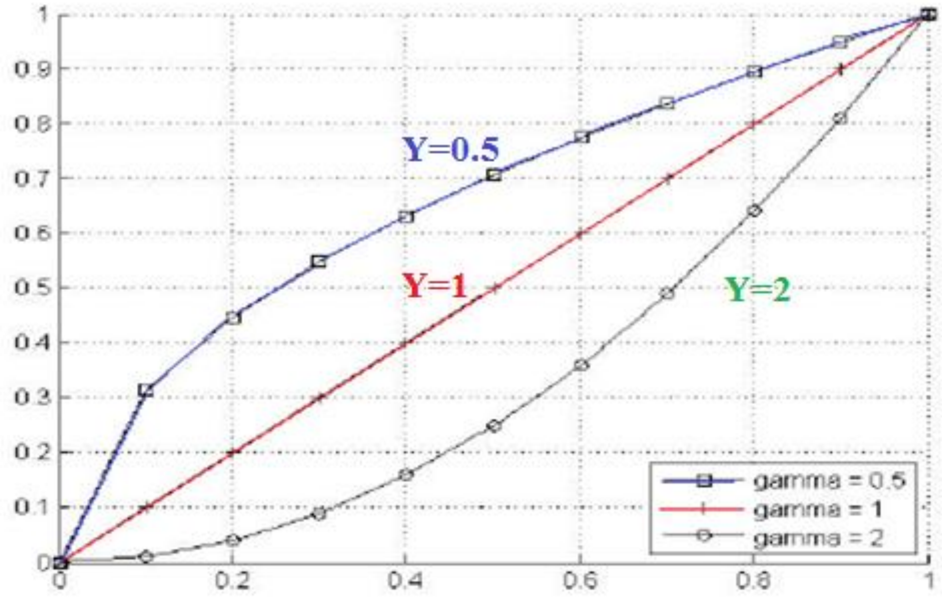


Figure (a) shown gamma transformed images different parameters Gamma=2, (b) Gamma=0.5

Image Processing

Image processing is computer imaging where application involves a human being in the visual loop. In other words the image are to be examined and an acted upon by people. The major topics within the field of image processing include:

1- Image Restoration

- **Is the process of taking an image with some known, or estimated degradation, and restoring it to its original appearance.**
- **Image restoration is often used in the field of photography or publishing where an image was somehow degraded but needs to be improved before it can be printed.**

2- Image Enhancement

Involves taking an image and improving it visually, typically by taking advantages of human Visual Systems responses, One of the simplest enhancement techniques is to simply stretch the contrast of an image.

Enhancement methods tend to be problem-specific.

For example: a method that is used to enhance satellite images may not suitable for enhancing medical images.

Although enhancement and restoration are similar in aim, to make an image look better, they differ in how they approach the problem.

Image with poor contrast

Image enhancement by contrast stretching

- **Restoration method attempt to model the distortion to the image and reverse the degradation,**
- **Enhancement methods use knowledge of the human visual systems responses to improve an image visually.**

3- <u>Image Compression</u>

Involves reducing the typically massive amount of data needed to represent an image, This done by eliminating data that are visually unnecessary and by taking advantage of the redundancy that is inherent in most images. Image processing systems are used in many and various types of environments, such as:

1. **Medical community**
2. **Computer – Aided Design**
3. **Virtual Reality**
4. **Image Processing.**

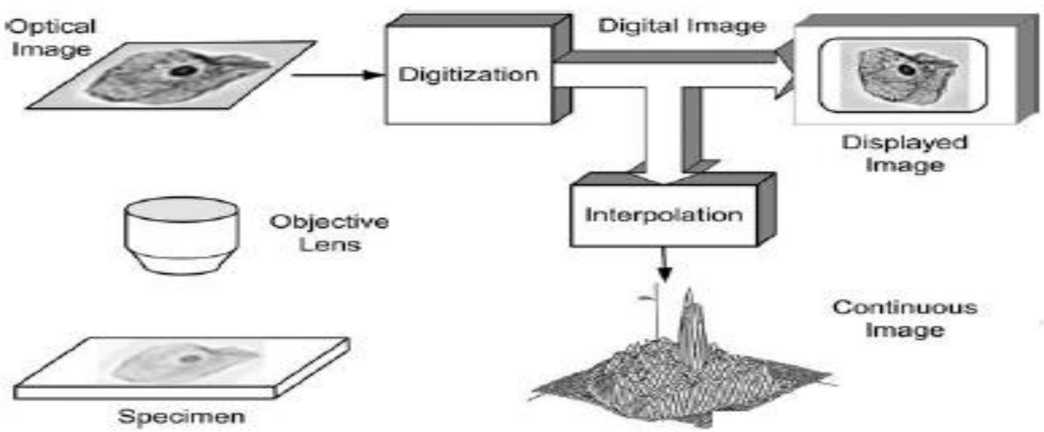
Image before compression
92 KB

Image after compression
6.59 KB

Computer Imaging Systems

Computer imaging systems are comprised of two primary components types, hardware and software.

- **The hardware components can be divided into image acquiring sub system (computer, scanner, and camera) and display devices (monitor, printer).**
- **The software allows us to manipulate the image and perform any desired processing on the image data.**



Computer image system

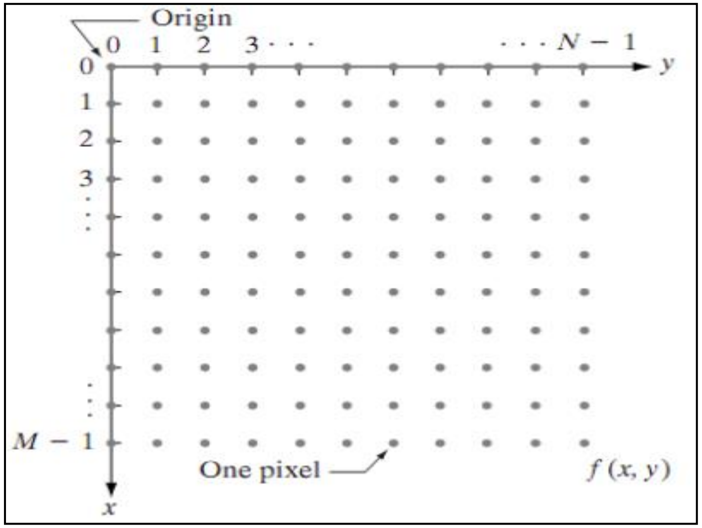
Representing Digital Images

The result of sampling and quantization is matrix of integer numbers. We will use two principal ways to represent digital images.

- Assume that an image f(x, y) is sampled so that the resulting digital image has rows and columns. The values of the coordinates (x, y) now become discrete quantities.
- For notational clarity and convenience, we shall use integer values for these discrete coordinates. Thus, the values of the coordinates at the origin are (x, y) = (0, 0).

The next coordinate values along the first row of the image are represented as (x, y)= (0, 1). It is important to keep in mind that the notation (0, 1) is used to signify the second sample along the first row.

It does not mean that these are the actual values of physical coordinates when the image was sampled.



Coordinate convention used in this book to represent digital images

The notation introduced in the preceding paragraph allows us to write the complete M*N digital image in the following compact matrix form:

$$f(x, y) = \begin{bmatrix} f(0,0) & f(0,1) & \cdots & f(0, N-1) \\ f(1,0) & f(1,1) & \cdots & f(1, N-1) \\ \vdots & \vdots & & \vdots \\ f(M-1,0) & f(M-1,1) & \cdots & f(M-1, N-1) \end{bmatrix}.$$

- **The right side of this equation is by definition a digital image.**
- **Each element of this matrix array is called an *image element, picture element*, and *pixel*.**

In some discussions, it is advantageous to use a more traditional matrix notation to denote a digital image and its elements:

$$\mathbf{A} = \begin{bmatrix} a_{0,0} & a_{0,1} & \cdots & a_{0,N-1} \\ a_{1,0} & a_{1,1} & \cdots & a_{1,N-1} \\ \vdots & \vdots & & \vdots \\ a_{M-1,0} & a_{M-1,1} & \cdots & a_{M-1,N-1} \end{bmatrix}.$$

The Quality of the Digital Image

The quality of digital image is directly related to the Number of pixel and lines along with the range of brightness values, in the image. These aspects are known as image Resolution

Image resolution: is the capability of the digital image to resolve the elements of the original scene.

For digital image, the resolution characteristic can be broken in to two primary parts

1- Spatial resolution.

2- Brightness resolution or (color resolution) in the image color.

Image Histogram

The histogram of an image records the frequency distribution of gray levels in the image. The histogram of an 8-bit image, can be thought of as a table with 256 entries, or “bins”, indexed from 0 to 255. in bin 0 we record the number of times a gray level of 0 occurs; in bin 1 we record the number of times a gray level of 1 occurs, and so on , up to bin 255.

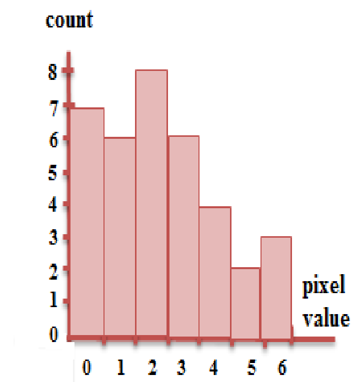
One of the principle uses of the histogram is in the selection of threshold parameter. Closely related to the histogram of an image is it’s cumulative histogram, which record the cumulative frequency distribution of gray levels in an image

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

Image 6*6

Pixel value	count
0	7
1	6
2	8
3	6
4	4
5	2
6	3
Total	36

Histogram



Plot of the histogram

The cumulative frequency of a gray levels, *I*, is the number of times that gray level less than or equal to *I* occurs in an image. Cumulative frequencies, *Ci* , *ar* computed from histogram counts, *hi* , using

$$C_j = \sum_{i=0}^{j} hi$$

Properties of histogram

We can normalize a histogram by dividing the counts in each bin by the total number of pixels in the image associated with that histogram. This gave us a table of estimated probabilities. i.e. probability density function (pdf) of the image .

A normalized histogram can be mathematically defined as

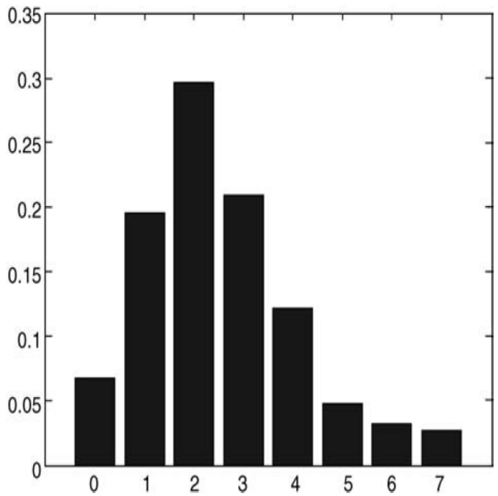
$$p(rk) = nk/n$$

where n is the total number of pixels in the image and $p(rk)$ is the probability (percentage) of the kth gray level (rk).

Table below shows the pixel counts for a hypothetical image containing 128×128 pixels, with eight gray levels.

Gray Level (rk)	nk	$p(rk)$
0	1120	0.068
1	3214	0.196
2	4850	0.296
3	3425	0.209
4	1995	0.122
5	784	0.048
6	541	0.033
7	455	0.028
total	16.384	1.000

- **Histograms are normally represented using a bar chart, with one bar per gray level, in which the height of the bar is proportional to the number (or percentage) of pixels that correspond to that particular gray level.**
- **A normalized cumulative histogram is a table of Cumulative probabilities, i.e , the cumulative distribution function (CDF) of the image .**

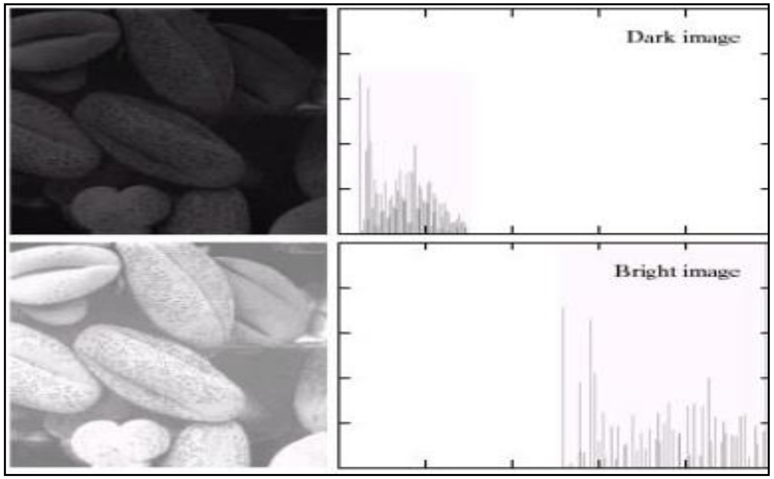


- **When an image is condensed into a histogram, all spatial information is discarded.**
- **The histogram specifies the number of pixels having each gray level but gives no hint as to where those pixels are located within the image.**
- **Thus the histogram is unique for any particular image, but the reverse is not true.**
- **Vastly different images could have identical histograms.**
- **Such operations as moving objects around within an image typically have no effect on the histogram.**

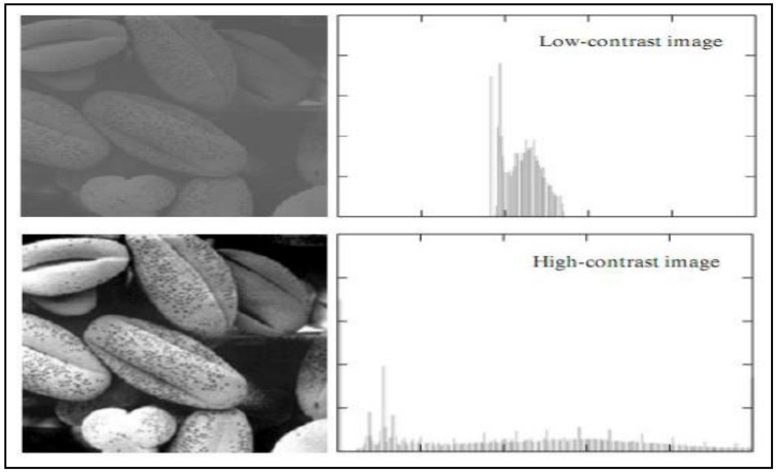
Type of histogram

You can get a general idea of the brightness of an image by looking at the histogram and observing the spatial distribution of the values

1. If the histogram values are concentrated toward the left, the image is darker .
2. If the histogram values are concentrated toward the right, the image is lighter .



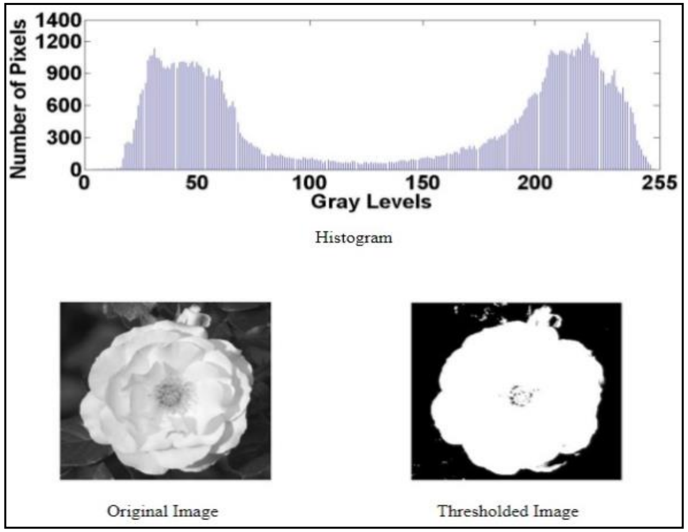
3. A histogram in which the pixel counts that are restricted to a smaller range indicate low contrast.
4. A histogram in which the pixel counts evenly cover a broad range of grayscale levels indicates an image with good contrast .



Applications of Histogram

1. Thresholding

A grayscale image can be converted into a black-and-white image by choosing a threshold and converting all values above the threshold to the maximum intensity and all values below the threshold to the minimum intensity. A histogram is a convenient means of identifying an appropriate threshold.



2. Image Enhancement

Image enhancement refers to the process of transforming an image so as to make it more visually appealing or to facilitate further analysis. An image histogram can help us to quickly identify processing operations that are appropriate for a particular image.

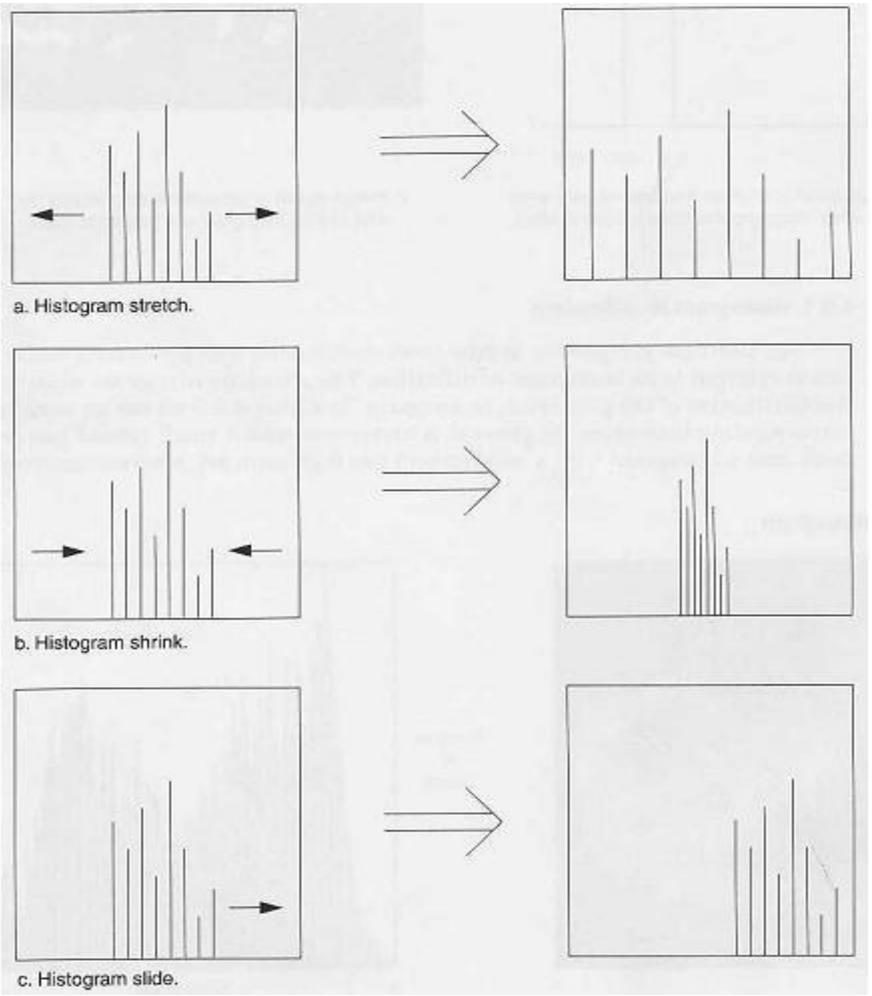
Histogram Modifications

The gray level histogram of an image is the distribution of the gray level in an image.

The histogram can be modified by mapping functions, which will

1. Stretch,
2. Shrink (compress),
3. Slide the histogram

Figure below illustrates a graphical representation of histogram stretch, shrink and slide.



1. Stretch histogram

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

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

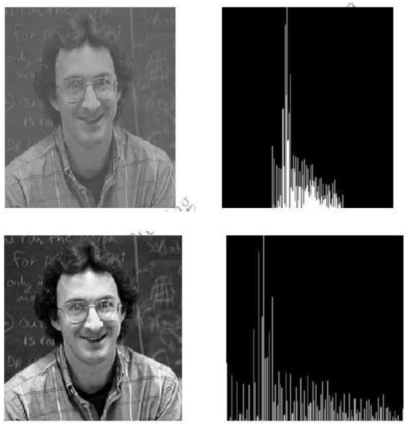
Where:

I(r, c) max is the largest gray- level in the image ***I(r, c)***.

I(r, c) min is the smallest gray- level in the image ***I(r, c)***.

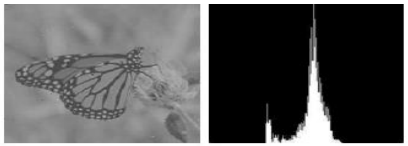
max **and** ***min*** **the maximum and minimum gray – level values possible (for an 8-bit image these are 255 and 0).**

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 of histogram stretching.



Low-contrast image Histogram of low-contrast image

- **In most of the pixel values in an image fall within small range, but a few outlines force the histogram to span the entire range, a pure histogram stretch will not improve the image.**
- **In this case it is useful to allow a small proceeding of the pixel values to be aliped at the low and high end of the range (for an 8-bit image this means truncating at 0 and 255).**



Original Image Histogram of the original image

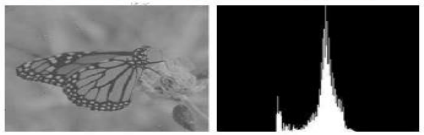


Image after histogram stretching without clipping Histogram of the image

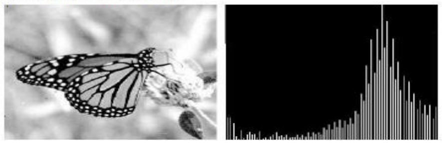


Image after histogram stretching Histogram of the image

2. Shrink (compress)

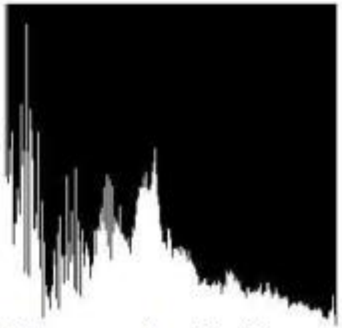
The opposite of a histogram stretch is a histogram shrink, used to decrease image contrast by compressing the gray levels. The mapping function for a histogram shrinking can be found by the following equation:

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

Where : Shrink $_{max}$ and shrink $_{min}$ correspond to the maximum and minimum desired in the compressed histogram.

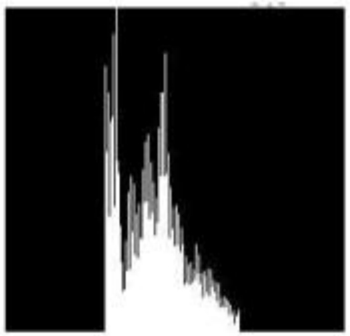
In general, this process produces an image of reduced contrast and may not seem to be useful an image enhancement.

Original image



Histogram of original image

Image after histogram shrink



Histogram of the image

3. Slide the histogram

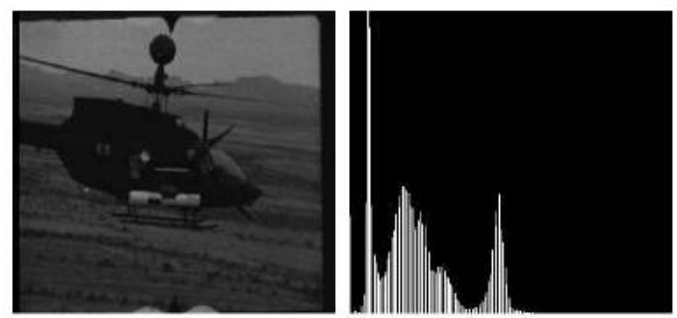
The histogram slide techniques can be used to make an image either darker or lighter but retain the relationship between gray-level values.

This can be a accomplished by simply adding or subtracting a fixed number for all the gray-level values, as follows:

$$Slide\left(I(r,c)\right) = [I(r,c)] + OFFSET$$

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 of image after sliding

Histogram Modifications

Example :

Suppose you have the following sub of image. Perform the following operation

1. **Stretch histogram.**
2. **Shrink (compress) histogram**
3. **Slide the histogram**

7	12	8	7
11	9	6	4
10	5	1	5

Where: **Image with 6 bit for each pixel**

$Shrink_{max} = 30$, $Shrink_{min} = 10$

OFFSET values = 50

Answer :

1. Stretch histogram

$I(r,c)_{max} = 12$, $I(r,c)_{min} = 1$, Max = 63 , Min = 0

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

I(r, c) = ((7-1)/(12-1)) * (63-0)+0

= (6/11)*63 = 34.36

34.36			

2. Shrink histogram

$I(r,c)_{max} = 12$, $I(r,c)_{min} = 1$,
$Shrink_{max} = 30$, $Shrink_{min} = 10$

7	12	8	7
11	9	6	4
10	5	1	5

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

I(r, c) = ((30 - 10) / (12-1)) * (7 - 1) + 10
= (20/11)*6 + 10 = 20.86

20.86			

3. Slide the histogram

OFFSET values = 50

$$Slide\left(I(r,c)\right) = [I(r,c)] + OFFSET$$

I(r, c)= 7 + 50
= 57

57	62	58	

Histogram Equalization

- **Is a popular technique for improving the appearance of a poor image.**

It's a function is similar to that of a histogram stretch but often provides more visually pleasing results a cross a wide rang of images.

- **Histogram equalization is a technique where the histogram of the resultant image is as flat as possible (with histogram stretching the overall shape of the histogram remains the same)**

The results in a histogram with a mountain grouped closely together to "spreading or flatting histogram makes the dark pixels appear darker and the light pixels appear lighter

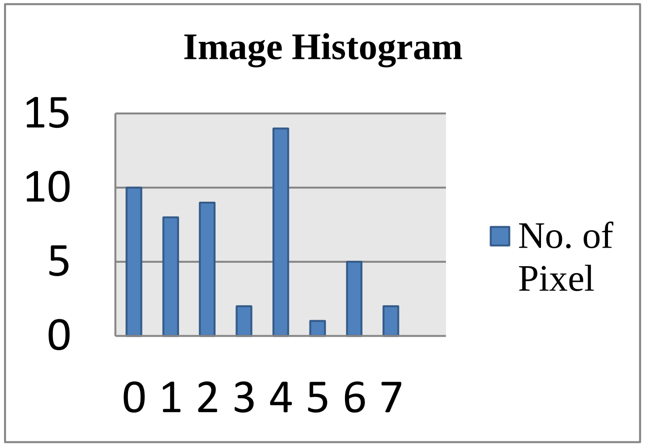
The histogram equalization process for digital images consists of four steps:

1. **Find the running sum of the histogram values**
2. **Normalize the values from step1 by dividing by total number of pixels.**
3. **Multiply the values from step2 by the maximum gray level value and round.**
4. **Map the gray-level values to the results from step 3, using a one-to-one correspondence.**

Example : -

We have an image with 3 bit /pixel, so the possible range of values is 0 to 7 .
We have an image with the following histogram

Gray level value	0	1	2	3	4	5	6	7
No. of Pixel histogram value	10	8	9	2	14	1	5	2



Answer :

Step 1:

Great a running sum of histogram values. This means that the first values is 10, The second is 10+8=18, next is 10+8+9=27, and soon. Here we get 10,18,29,43,44,49,51.

Gray level value	0	1	2	3	4	5	6	7
No. of Pixel	10	8	9	2	14	1	5	2
Run sum	10	18	27	29	43	44	49	51

Step 2:

Normalize by dividing by total number of pixels. The total number of pixels is 10+8+9+2+14+1+5+2=51.

Gray level value	0	1	2	3	4	5	6	7
No. of Pixel	10	8	9	2	14	1	5	2
Run sum	10	18	27	29	43	44	49	51
Normalize	10/51	18/51	27/51	29/51	43/51	44/51	49/51	51/51

Step 3:

Multiply these values by the maximum gray level values in this case 7 , and then round the result to the closet integer. After this is done we obtain 1,2,4,4,6,6,7,7.

Gray level value	0	1	2	3	4	5	6	7
No. of Pixel	10	8	9	2	14	1	5	2
Run sum	10	18	27	29	43	44	49	51
Normalize	10/51	18/51	27/51	29/51	43/51	44/51	49/51	51/51
Multiply by 7	1	2	4	4	6	6	7	7

Step 4:

Map the original values to the results from step 3 by a one–to-one correspondence.

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

All pixel in the original image with gray level 0 are set to 1, values of 1 are set to 2, and values 2 set to 4, and values 3 set to 4, and so on.
Histogram equalization, you can see the original histogram and the resulting histogram equalized histogram. Although the result is not flat, it is closer to being flat than the original.

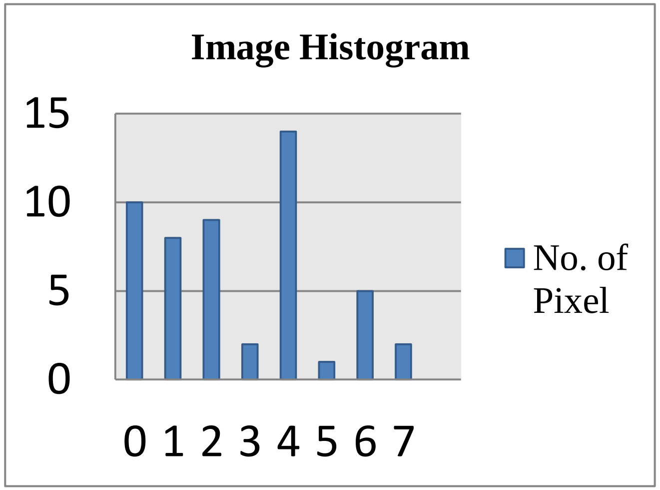
Before Histogram Equalization

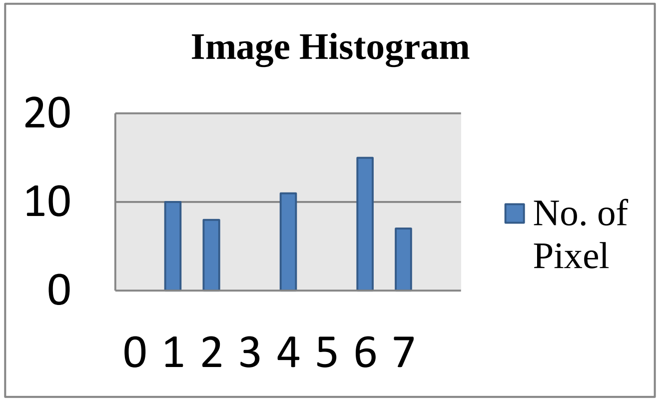
Gray level value	0	1	2	3	4	5	6	7
No. of Pixel histogram value	10	8	9	2	14	1	5	2

After Histogram Equalization

Gray level value	0	1	2	3	4	5	6	7
No. of Pixel histogram value	0	10	8	0	11	0	15	7

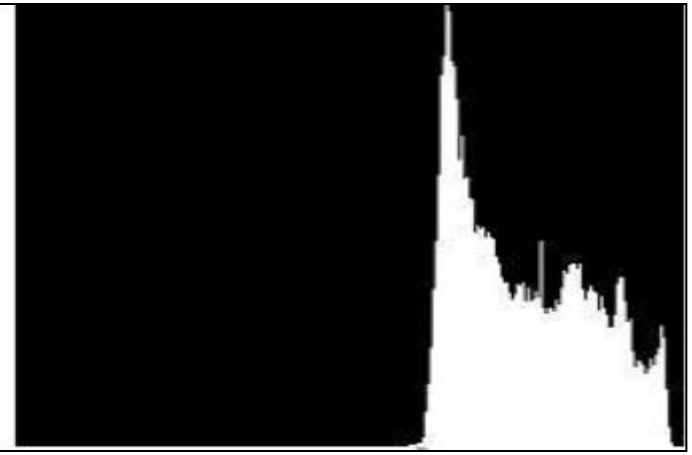
Before Histogram Equalization





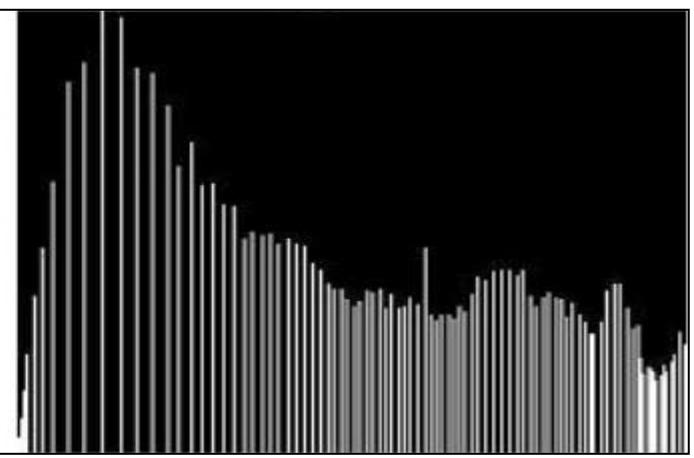
After Histogram Equalization

Original image



Histogram of original image

Image after histogram equalization



Histogram after equalization

Histogram Equalization

The End