In addition to masking, logical operation can be used in feature detection. Logical operation can be used to compare between two images, as shown below:

AND^

This operation can be used to find the ***similarity*** white regions of two different images (it required two images).

$$g(x,y) = a(x,y) \wedge b(x,y)$$

Exclusive OR ⊗

This operator can be used to find the differences between white regions of two different images (it requires two images).

$$g(x,y) = a(x,y) \bullet b(x,y)$$

NOT

NOT operation can be performed on gray-level images, it's applied on only one image, and the result of this operation is the ***negative*** of the original image.

$$g(x,y) = 255 - f(x,y)$$

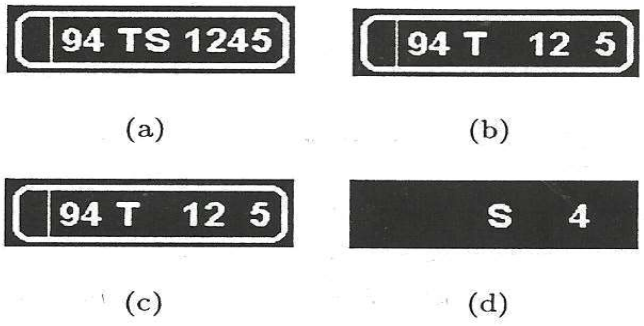


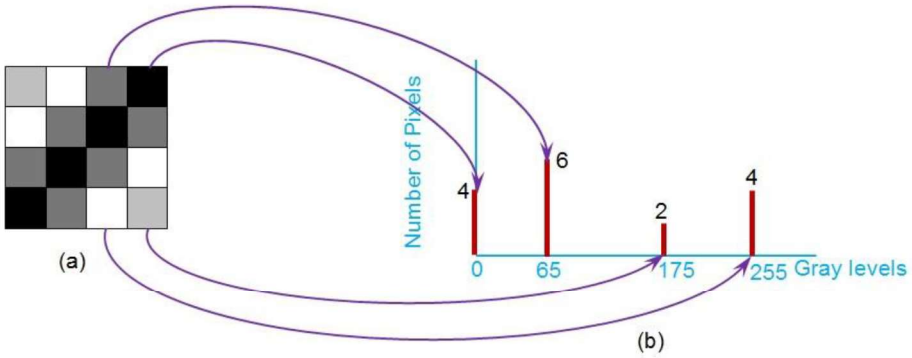
Figure a) input image a(x,y); b) input image b(x,y) ; c) a(x,y) ^ b(x,y) ; d) a(x,y) ^ ~ b(x,y)

16. Image Histogram

A histogram is a graph that shows the frequency of anything.

A histogram is an accurate representation of the distribution of numerical data. It is an estimate of the probability distribution of a continuous variable (quantitative variable). A histogram is a graph showing the number of pixels in an image at each different intensity value found in that image. It's a bar chart of the count of pixels of every tone of gray that occurs in the image.

For an 8-bit grayscale image there are 256 different possible intensities, and so the histogram will graphically display 256 numbers showing the distribution of pixels amongst those grayscale values.



The gray level ***histogram*** is showing, the gray level, for each pixel in the image.

The histogram of an image records the frequency distribution of gray levels

The histogram of an 8-bit image, can be though 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.

An algorithm below shows how we can accumulate in a histogram from an image.

ALGORITHM: for Calculating image Histogram

```
create an array histogram.
For all gray levels ,I,do
Histogram [I] =0
Endfor
For all pixels coordinates, x and y , do
```

- The histogram of a digital image with *L* total possible intensity levels in the range [*0, G*] is defined as the discrete function

$$h(r_k) = n_k$$

- Where r_k is the *k*th intensity level in the interval [*0,G*] and n_k is the number of pixels in the image whose intensity level is r_k.

Example: Figure shows an image and its histogram.

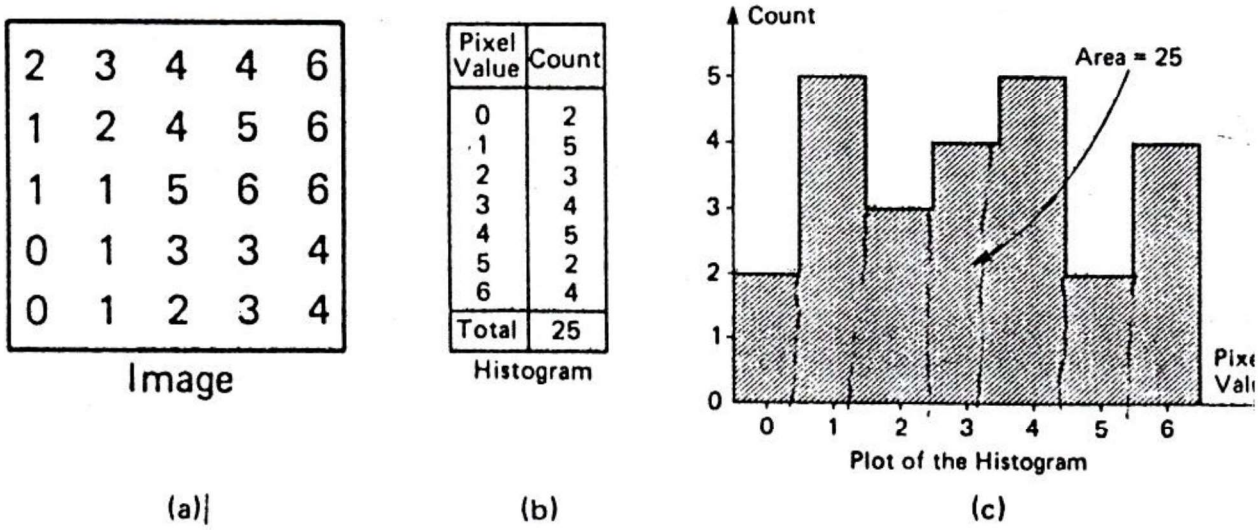


Figure: sub image and its histogram

The shape of the histogram provides us with information about the nature of the image, or sub image if we are considering an object in the image. For example, a ***very narrow*** histogram implies a low contrast, a histogram ***skewed toward the right*** implies a bright image, a histogram ***skewed toward the left*** implies a dark image, and a histogram with ***two major peaks***, implies an object that in contrast with the background.

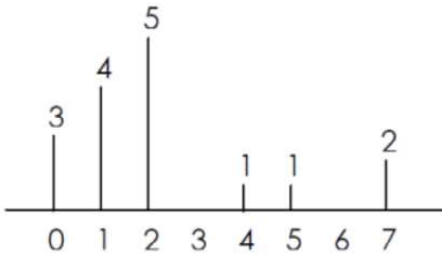
A color histogram counts pixels with a given pixel value in red, green, and blue (RGB). For example, in pseudocode, for images with 8-bit values in each of R, G, B, we can fill a histogram that has 256^3 bins:

```
inthist[256][256][256]; // reset to 0

//image is an appropriate struct

//with byte fields red,green,blue

fori=0..(MAX_Y-1)

for j=0..(MAX_X-1)

{

R = image[i][j].red;

G = image[i][j].green;
```

Example : Plot the Histogram of the following example with 4x4 matrix of a 3-bit image.

0	0	0	4
1	1	1	5
1	2	2	7
2	2	2	7

Answer



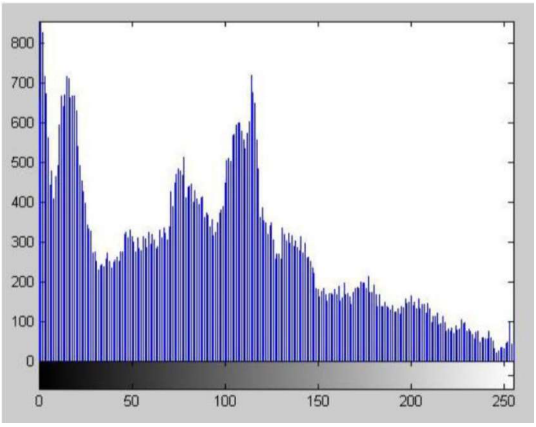
Properties and usage of histogram

One of the ***principle use*** of the histogram is in the selection of ***threshold*** parameter.

The histogram of an image provides a useful indication of the relative importance of different gray levels in an image, indeed, it is sometimes possible to ***determine*** whether ***brightness*** or ***contrast*** ***adjustment*** is necessary merely by ***examining*** the ***histogram*** and ***not the image*** itself.

When an image is condensed into a histogram, ***all spatialinformation is discarded.*** The histogram specifies the number of pixelshaving each gray level but ***gives no hint*** as to ***where those pixels arelocated*** within the image. Thus the histogram is ***unique*** for any particularimage, 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.

Histograms are used in numerous image processing techniques, such as image enhancement, compression and segmentation.



Note that the horizontal axis of the histogram plot (Figure (b) above) represents gray level values, k, from 0 to 255. The vertical axis represents the values of $h(k)$ i.e. the number of pixels which have the gray level k.

It is customary to **"normalize"** a histogram by dividing each of its values by the total number of pixels in the image, i.e. uses the probability distribution (previously stated) as:

$$p(k) = \frac{h(k)}{M \times N}$$

Thus, $p(k)$ represents the probability of occurrence of gray level k.

As with any probability distribution:

- ***All the values of a normalized histogram*** $p(k)$ ***are less than or equal to 1.***
- ***The sum of all*** $p(k)$ ***values is equal to 1***

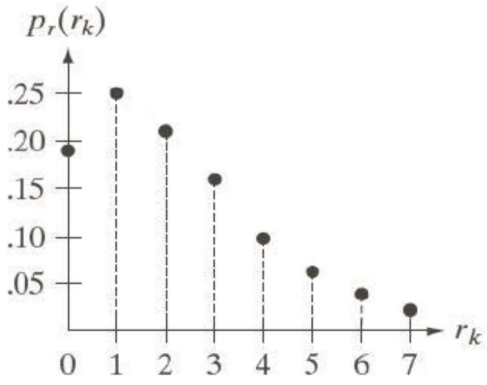
Another way of getting histogram is to plot pixel intensities vs. pixel probabilities. However, probability histogram should be used when comparing the histograms of images with different sizes.

Example: Suppose that a 3-bit image (L = 8) of size 64×64 pixels has the gray level (intensity) distribution shown in the table below.***Perform normalized histogram.***

r_k	n_k
$r_0 = 0$	790
$r_1 = 1$	1023
$r_2 = 2$	850
$r_3 = 3$	656
$r_4 = 4$	329
$r_5 = 5$	245
$r_6 = 6$	122
$r_7 = 7$	81

Solution:*M × N = 4096 .* We compute the normalized histogram:

r_k	n_k	$p(r_k) = n_k/MN$
$r_0 = 0$	790	0.19
$r_1 = 1$	1023	0.25
$r_2 = 2$	850	0.21
$r_3 = 3$	656	0.16
$r_4 = 4$	329	0.08
$r_5 = 5$	245	0.06
$r_6 = 6$	122	0.03
$r_7 = 7$	81	0.02



Normalized histogram