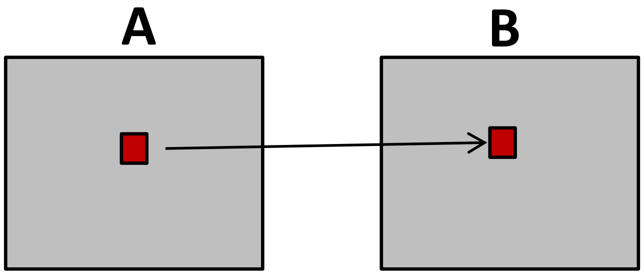
Chapter 4: Arithmetic and logical operations

Type of operations

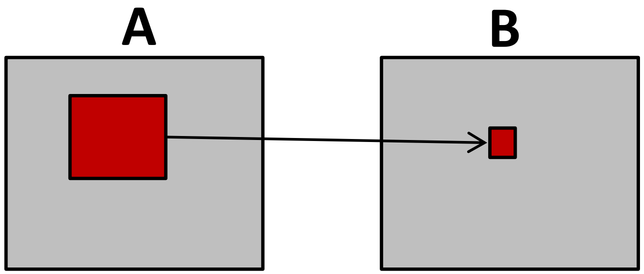
1. Point to point transformation

- The pixel **B(i,j)** of the output image, depends only on **A(i,j)** of the input image.



2. Local to point transformation

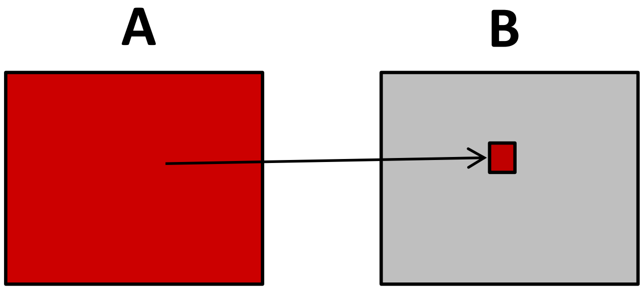
- The pixel **B(i,j)** of the output image, depends only on the values of all pixels of the mask (neighbourhood)



Type of operations

3. Global to point transformation

- The pixel **B(i,j)** of the output image, depends on the values of all pixels of image **A**.



Arithmetic operations

1. Constant addition

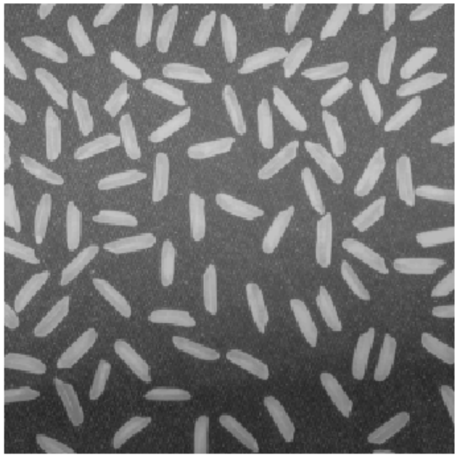
- Adding a constant value to an image → increase in its overall brightness

A

A+50

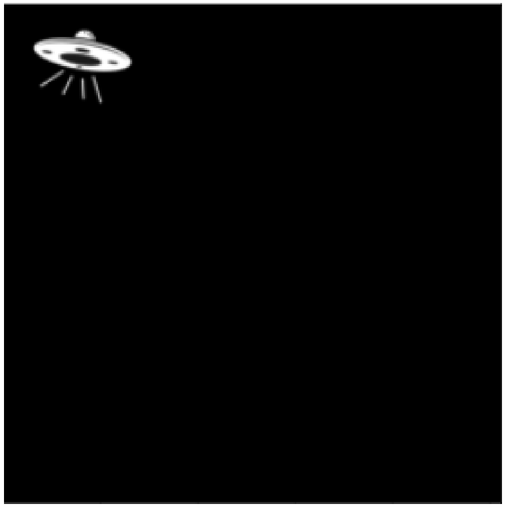
2. Addition of two images (same size)

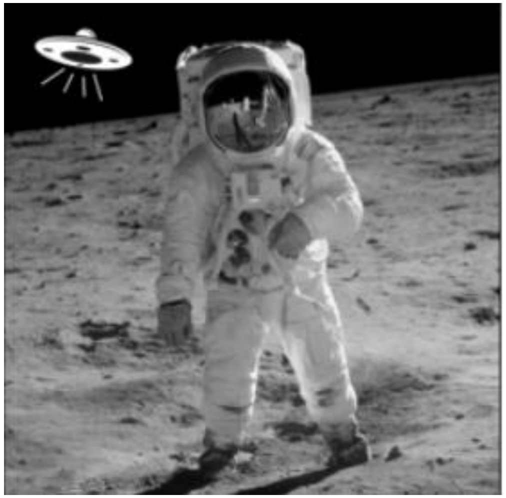
- Addition is used to mix the pixel content of two images.



Arithmetic operations

2. Addition of two images (same size)





Arithmetic operations

3. Constant subtraction

- Subtract a constant value to an image → decrease in its overall brightness

A

A-80

4. Subtraction of two images (same size)

- Used to detect changes

example: motion detection for static camera

Arithmetic operations

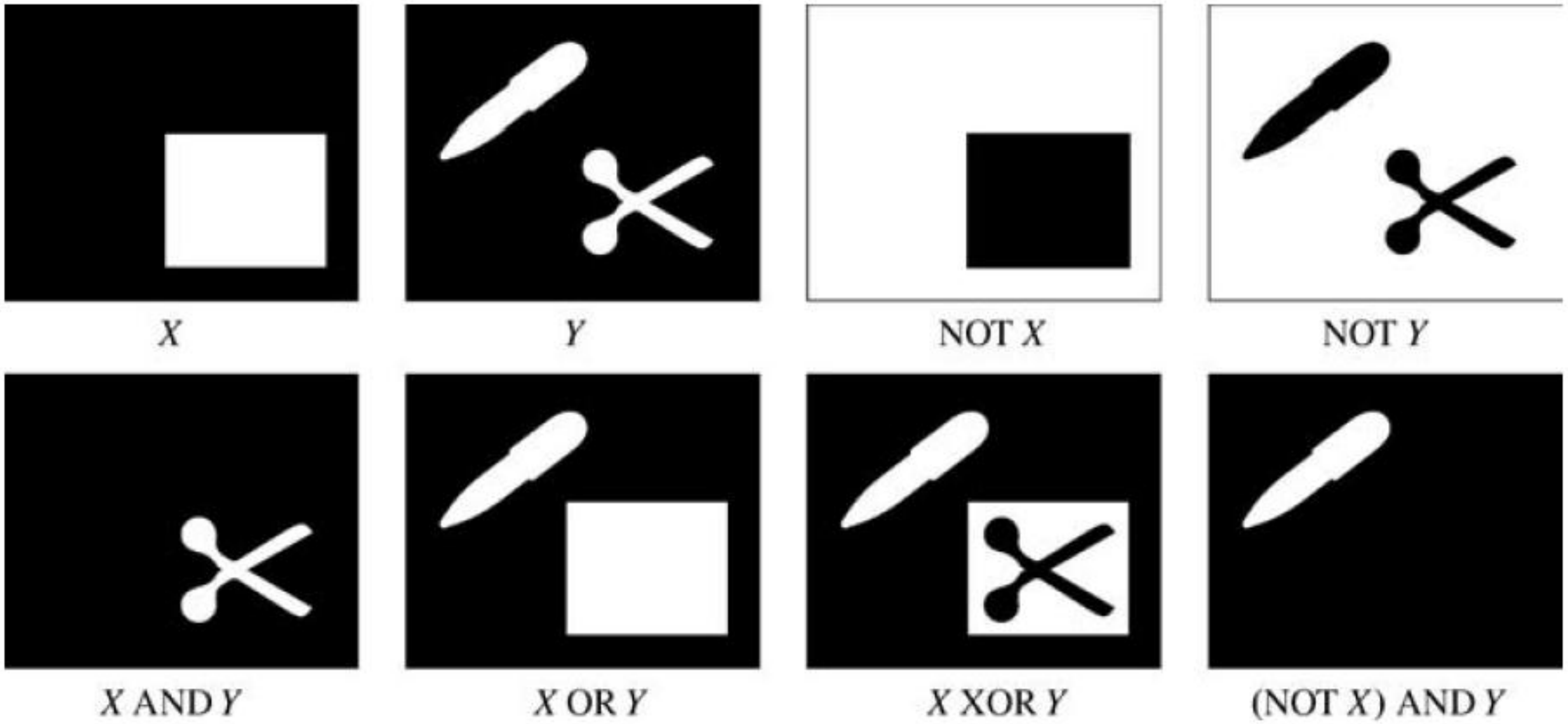
5. Negative image

- A negative image is a total inversion→ light areas appear dark and vice versa

Logical operations

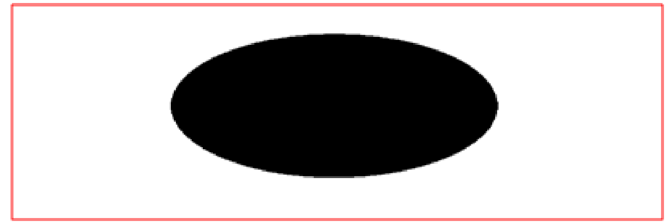
AND, OR, XOR, NOT…

- Between binary images
- **AND, OR :** Extract a region of interest, masking, similarity …
- **NOT** : Reverse an image



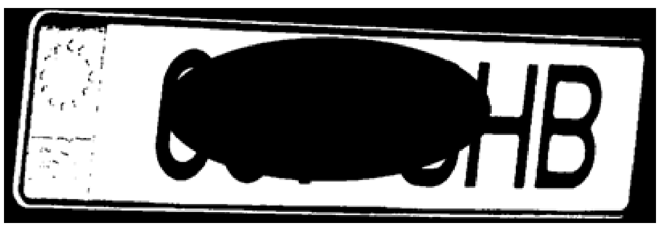
Logical operations

a

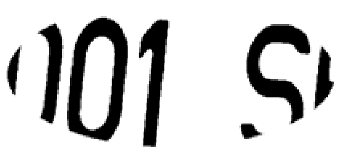


b

NOT(a)



a AND b



a OR b

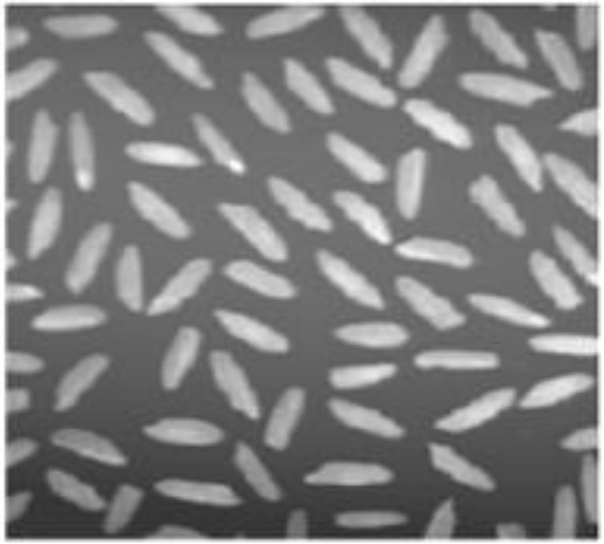
Chapter 5: Study of histograms

Histogram

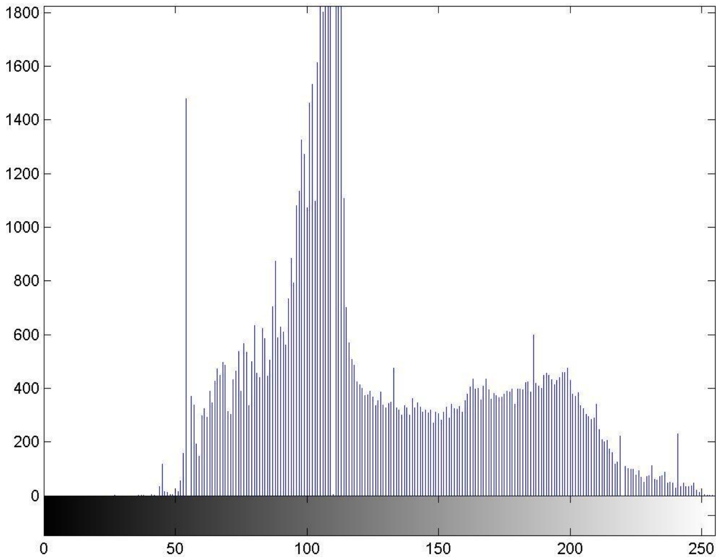
Definition

- The histogram of an image in 256 gray levels is a graph having 256 values (gray level) on the abscissa, and the number of times each grey level occurs in the image

- By convention, the intensity levels go from the darkest (on the left) to the lightest (on the right).



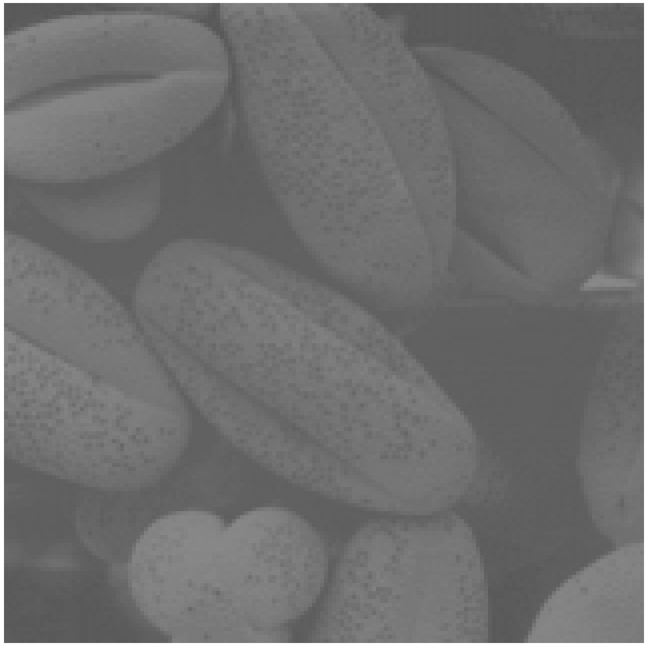
Image

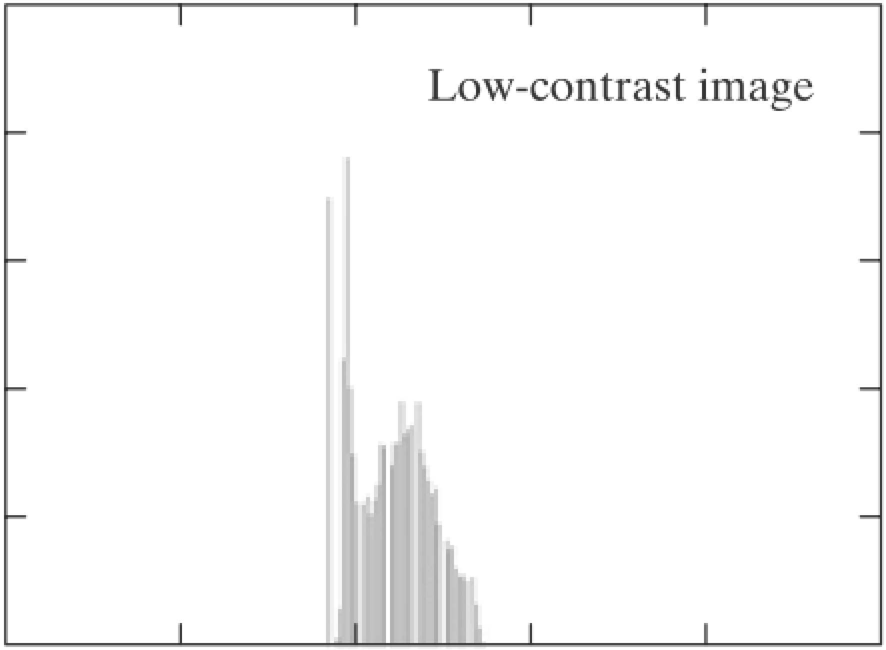


Histogram

Histogram analysis

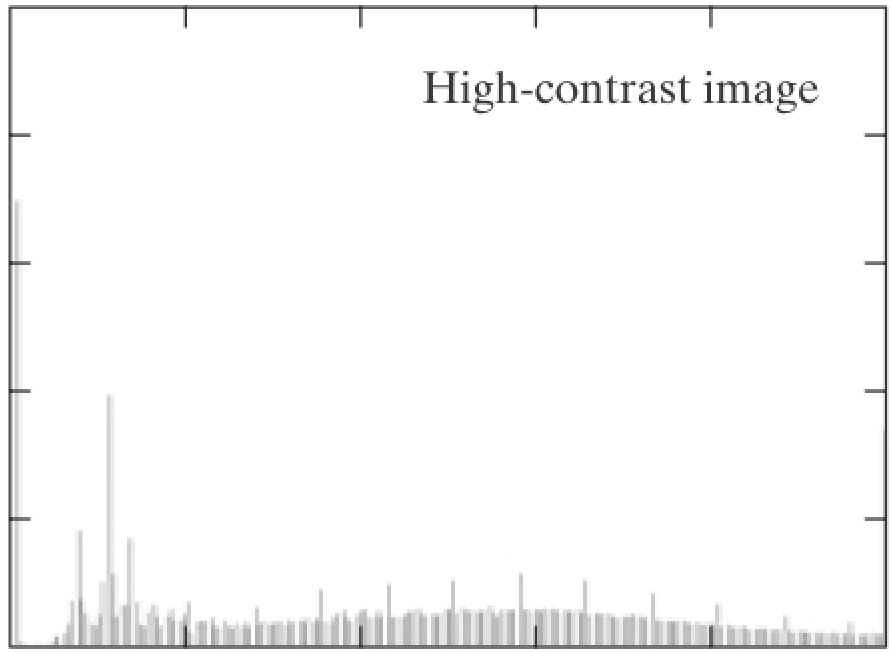
- The histogram is used to analyze contrast and luminance
- Low contrast image → curve occupies the central part: the majority of intensities are found around gray.





Histogram analysis

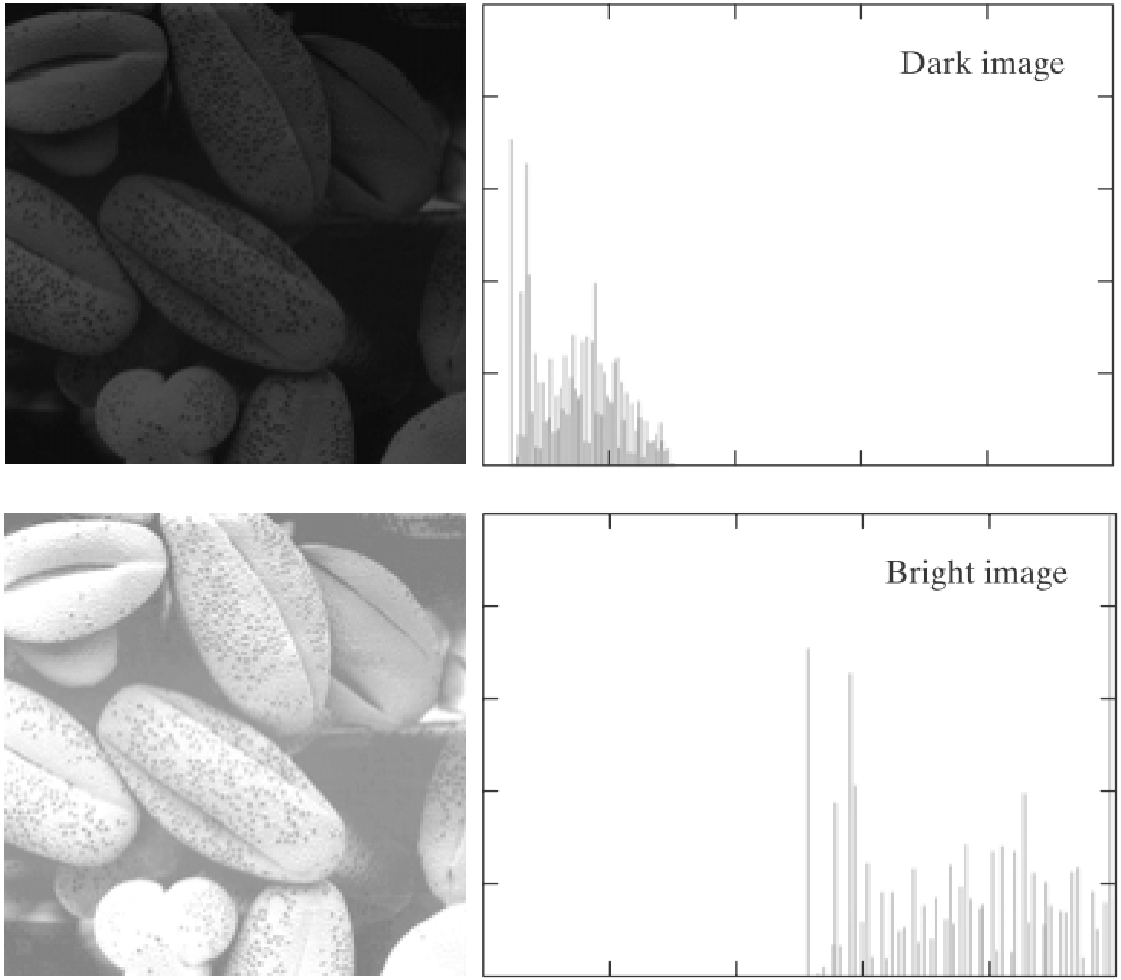
- A contrasted image will be represented by a curve going from left to right.



- A very high contrast image → a curve occupying only the extremities

Histogram analysis

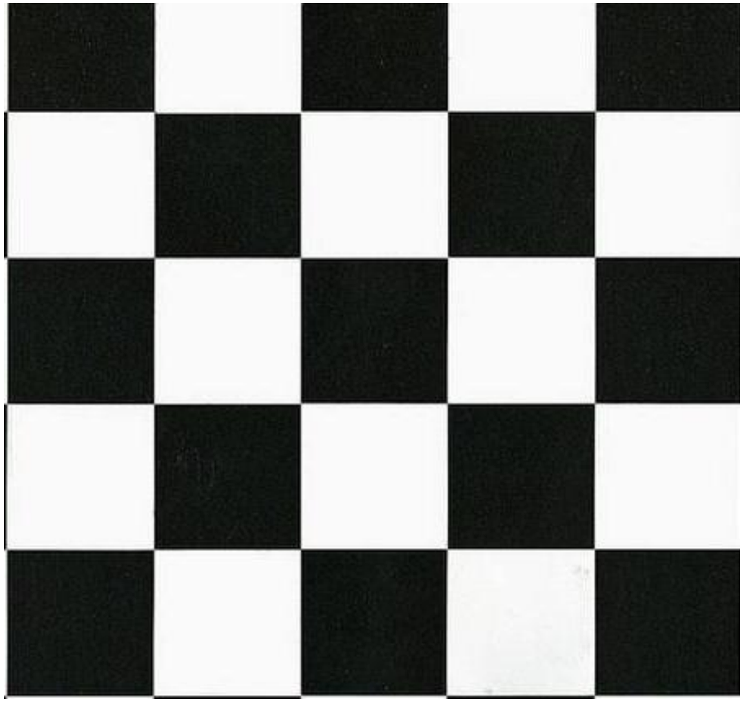
- Underexposed image → left side of the histogram
- Overexposed image → right side of the histogram



Histogram analysis

- The histogram provides information on the occurrences (frequencies of appearance) of gray levels in an image, but without indicating the distribution of these levels within the image.

Example : checkerboard

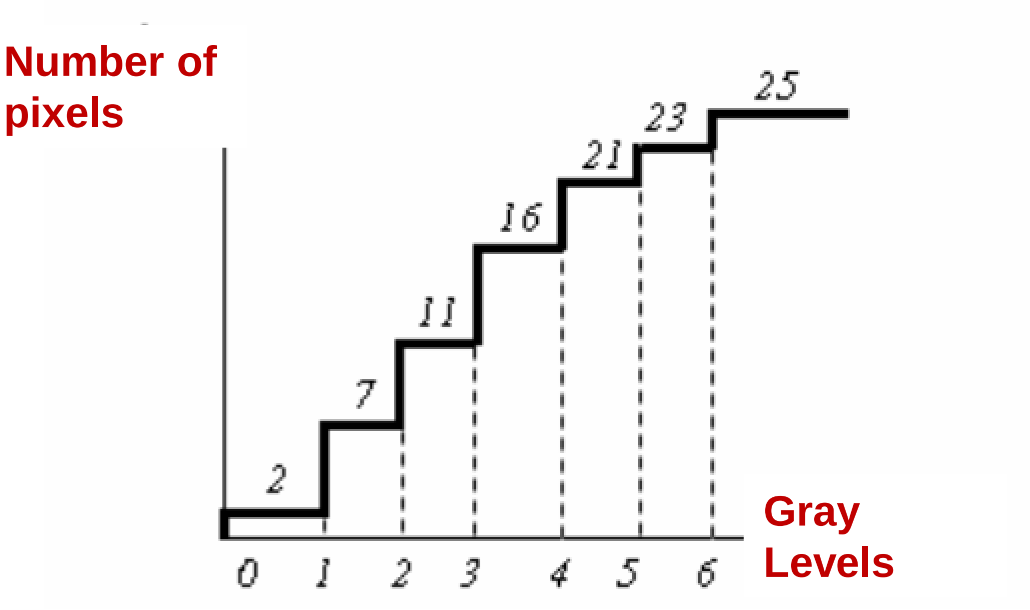


Cumulative histogram

- The cumulative histogram represents the cumulative distribution of intensities

Example:

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



Operations on histogram

- Histograms can be used to enhance or modify the characteristics of an image, particularly its contrast.
- Modifying the histogram does not alter the information contained in the image but makes it more or less visible.

Two main operations for contrast enhancement :

1. Stretching

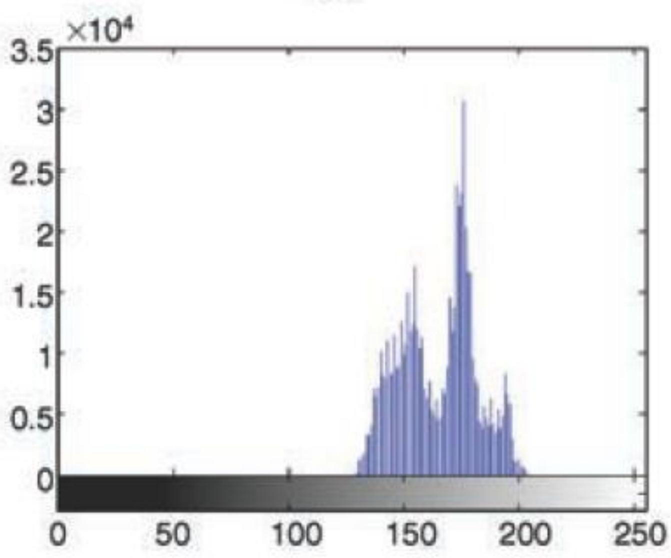
2. Equalization

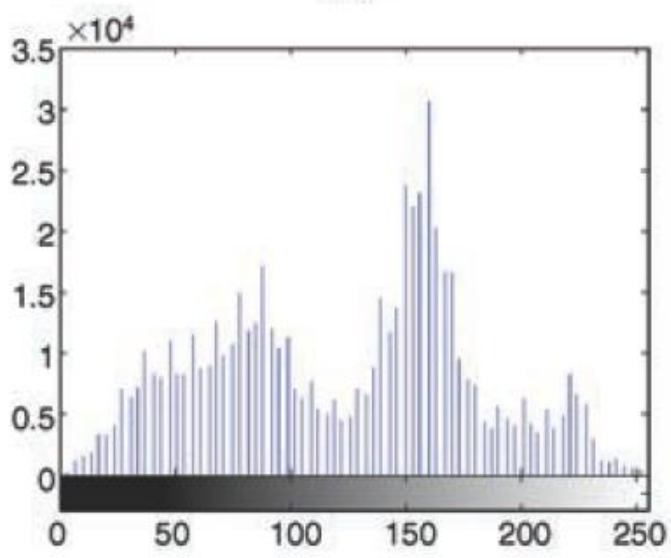
Operations on histogram

1. Stretching

- Increase the contrast of an image

- Consists of distributing the frequencies of appearance as best as possible on the scale of available values





Operations on histogram

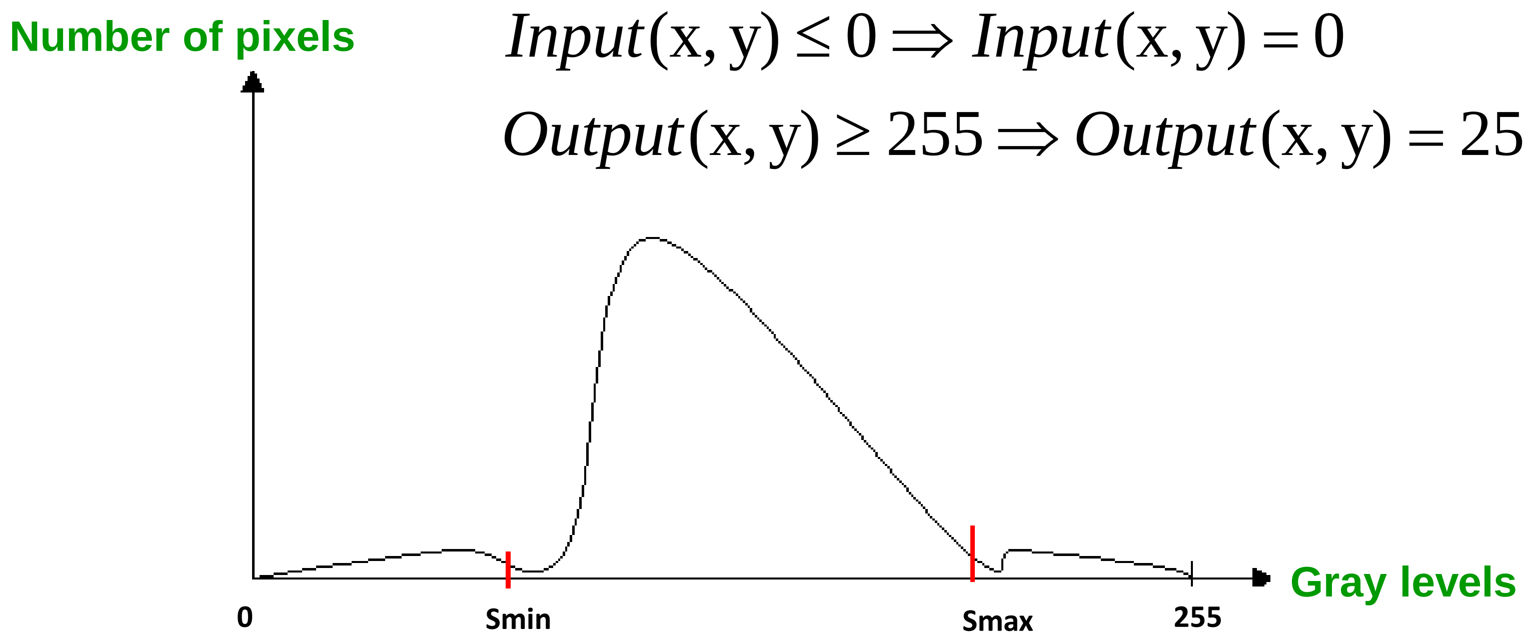
1. Stretching

- The range [Smin, Smax] (Input image: **Input**) will be stretched to the range [0, 255] for the output image: **Output**

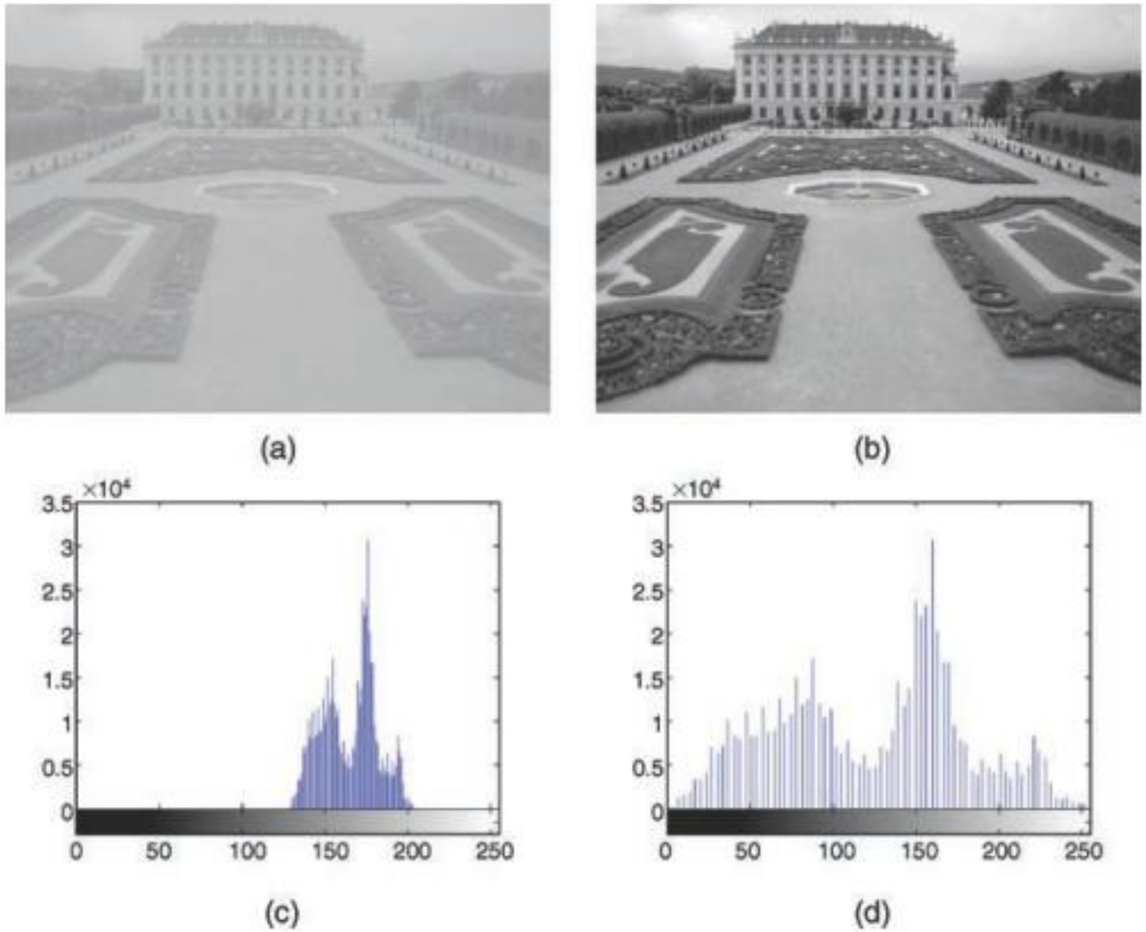
$$Output(x, y) = \frac{255}{S\max - S\min}(Input(x, y) - S\min)$$

$$Input(x, y) \le 0 \Rightarrow Input(x, y) = 0$$

$$Output(x, y) \ge 255 \Rightarrow Output(x, y) = 255$$



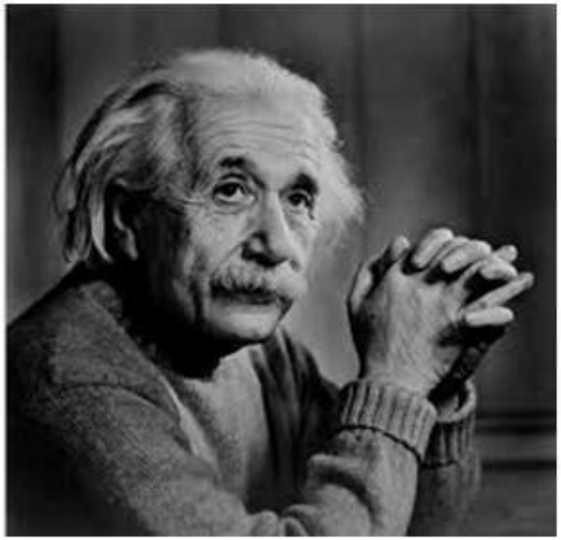
1. Stretching

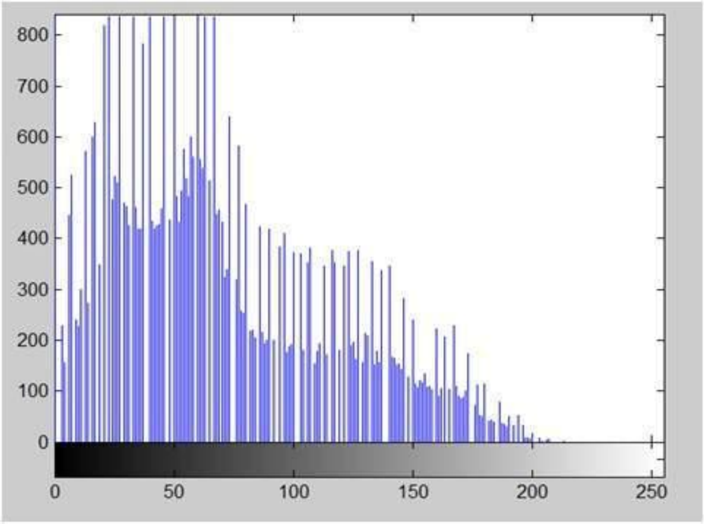


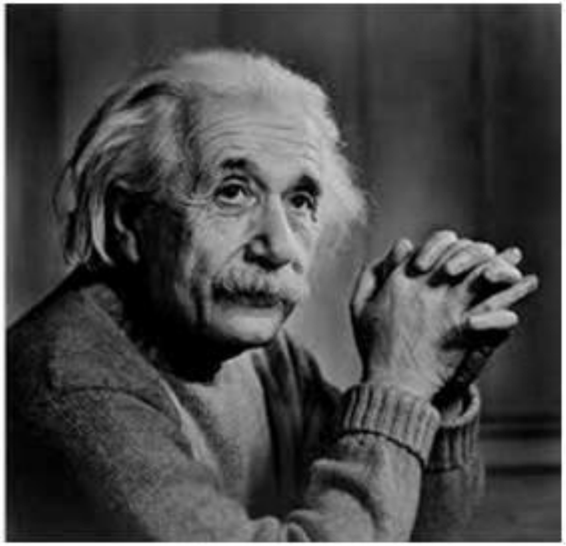
Example of using histogram stretching to improve contrast: (a) original image ($r_{min} = 129$, $r_{max} = 204$); (b) result of stretching using equation (9.12); (c and d) histograms corresponding to images in (a) and (b).

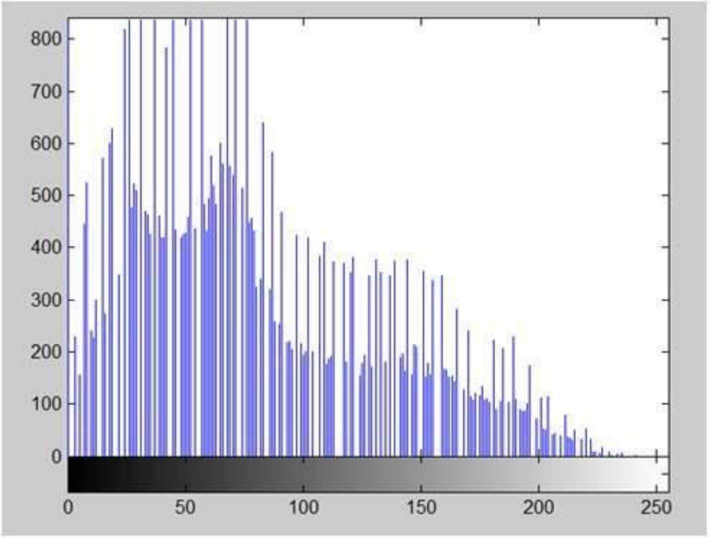
Operations on histogram

1. Stretching









Operations on histogram

1. Stretching

$$Output(x,y) = \frac{255}{S\max - S\min}(Input(x,y) - S\min)$$

The algorithm fails on some cases

If there are pixels (intensities 0 and 255) present in the image !!!

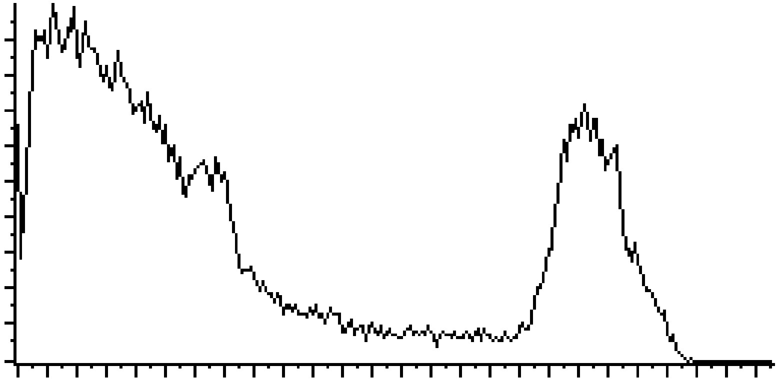
$$Output(x,y) = Input(x,y)$$

No effect of histogram stretching has been done at this image

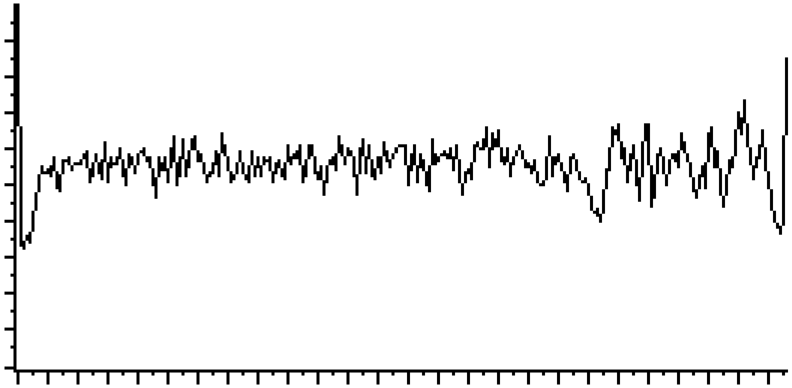
Operations on histogram

2. Equalization

- Histogram equalization is used to enhance contrast.
- Obtain an uniforme histogram → each grey level in the image occurs with the saem frequency (as best as possible).
- The ideal is to obtain a flat histogram



Histogram before



Histogram after equalization

Operations on histogram

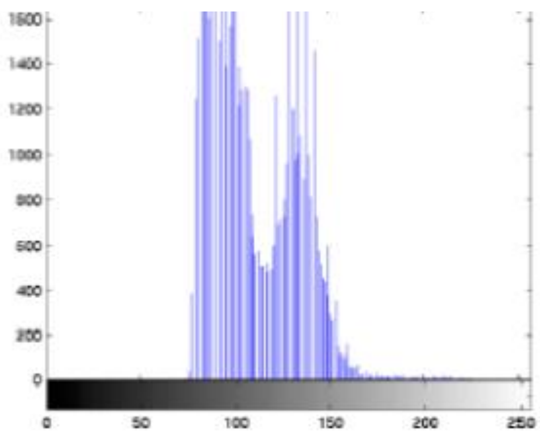
2. Equalization

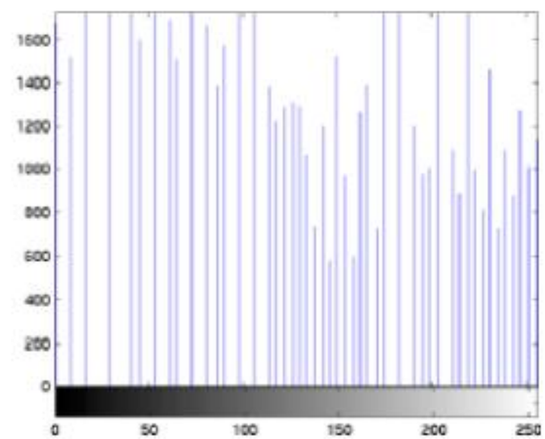
- **N**: total number of pixels
- **Max**: max gray level
- **CH**: Cumulative histogram

$$Output(\mathrm{x},\mathrm{y}) = Round\left[\frac{CH(Input(\mathrm{x},\mathrm{y})).Max}{N}\right]$$

2. Equalization

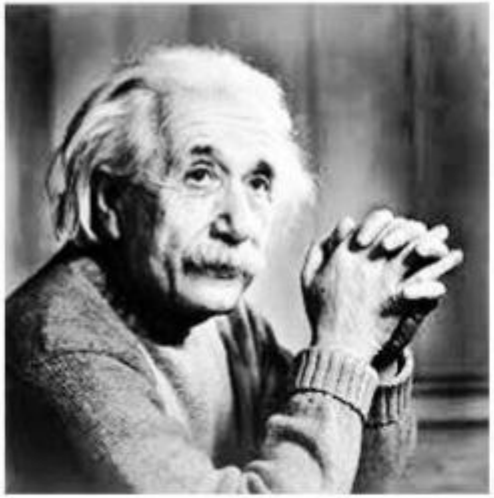
Before **After**

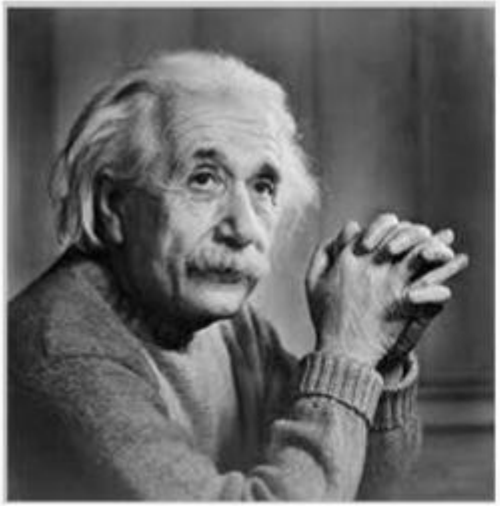




Operations on histogram

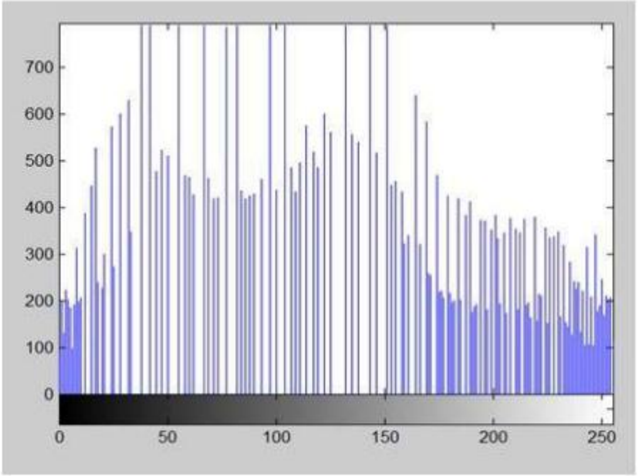
2. Equalization

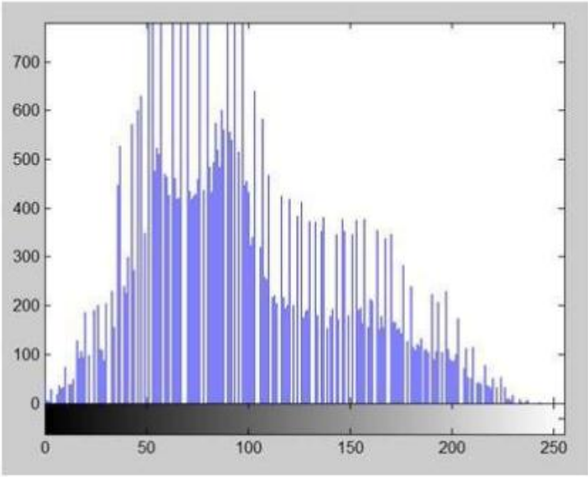




After

Before

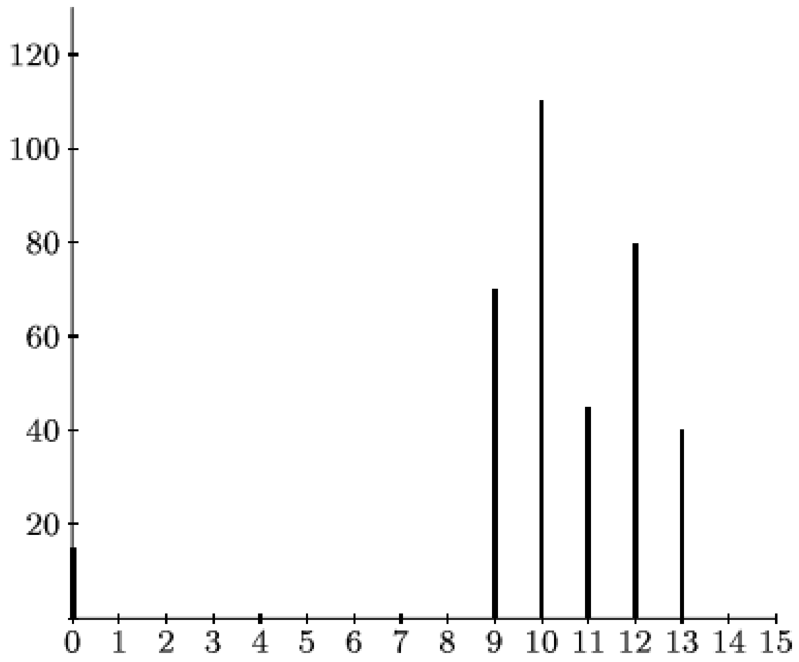




2. Equalization

Example

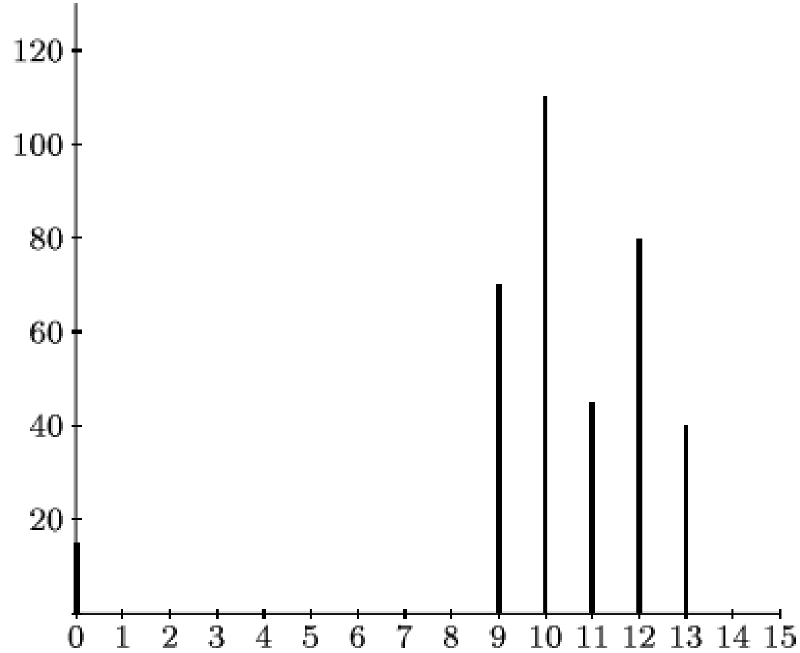
Suppose a 4-bit greyscale image has the histogram shown below.



2. Equalization

Example

Grey level i	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



2. Equalization

Example

Grey level i	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

$15/360 = 1/24$:

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

Operations on histogram

Measures

- Global contrast measur $C^M = \frac{L_{max} - L_{min}}{L_{max} + L_{min}}$

maximum luminance, L_{max}, to minimum luminance, L_{min},

- Standard deviation **std2**

"An image with a ***high global contrast*** *causes a global feeling of a detailed and variation-rich image. As opposed to it, an image with a* ***lower global contrast*** *contains less information, less details, and appears more uniform"*

Operations on histogram

Measures

"Global measures have some disadvantages……………. Two single points of extreme brightness or darkness can determine the measure of contrast of the whole image, while the perceived contrast is clearly affected as illustrated in figure"

"Image contrasts measuring globally is not efficient tool to estimate image visibility and separate image targets" → ***Local contrast measures***

Chapter 6: Thresholding

Thresholding

Simple thresholding

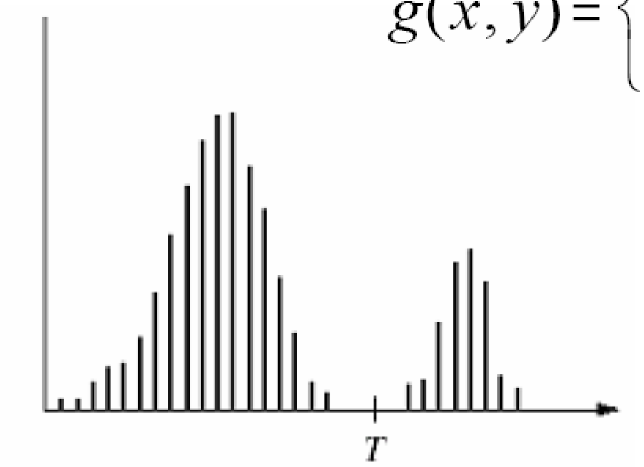
- Simple thresholding is an operation that reduces a color or gray-scale image at two intensity levels (black and white).
- Simple thresholding → setting pixel values to 1 or 0 depending on whether they are above or below the **threshold** value **T**

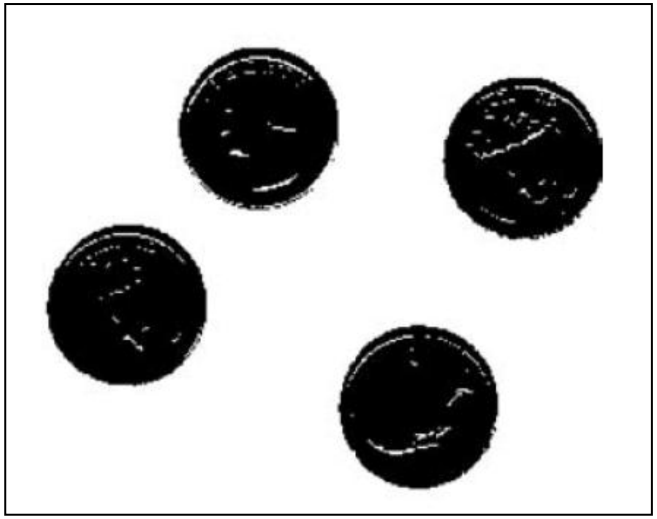
$$\text{A pixel becomes} \begin{cases} \text{white if its grey level is} > T, \\ \text{black if its grey level is} \leq T. \end{cases}$$

Thresholding

Simple thresholding

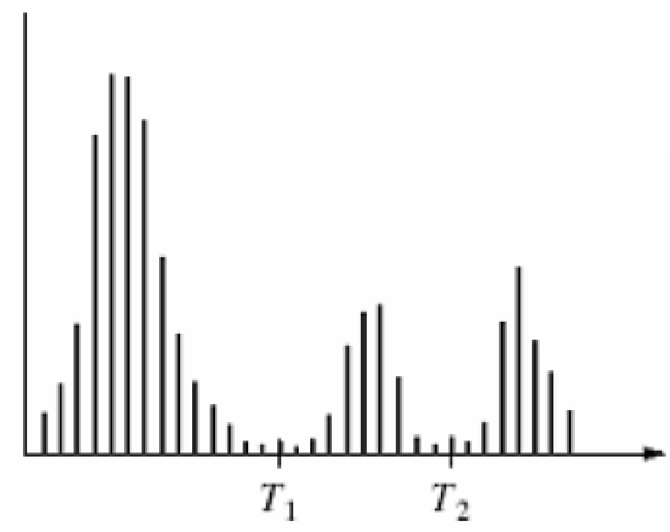
$$g(x,y)=\begin{cases}1 & si\ f(x,y)>T\\ 0 & si\ f(x,y)\leq T\end{cases}$$





Thresholding

Double thresholding

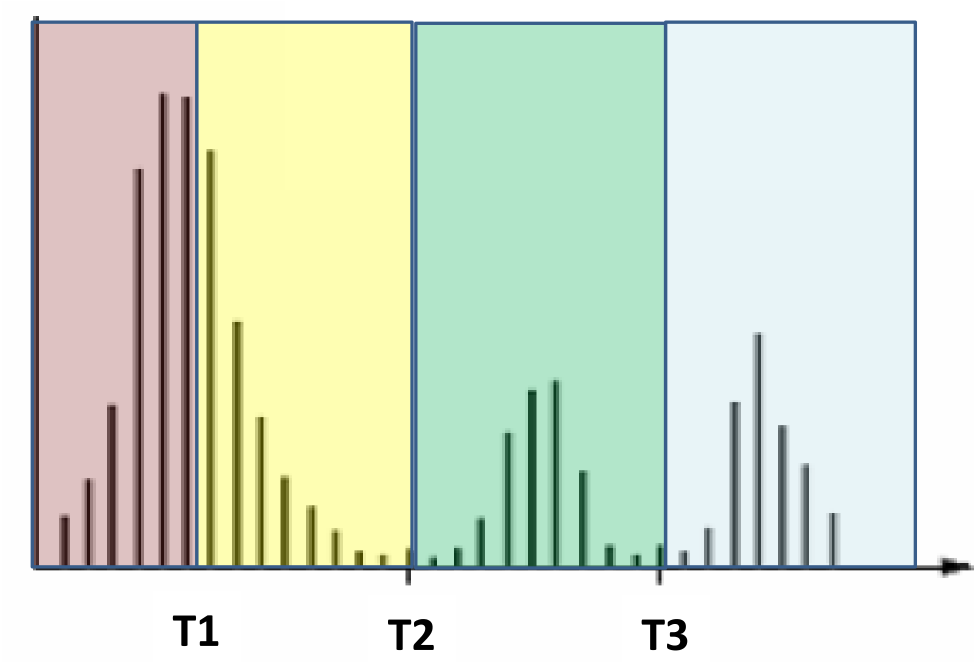


$$\text{A pixel becomes} \begin{cases} \text{white if its grey level is between } T_1 \text{ and } T_2, \\ \text{black if its grey level is otherwise.} \end{cases}$$

Thresholding

Multithresholding

- The multi-thresholding operation allows to define several thresholds in order to group pixels into different classes, where each class is delimited by two thresholds.



Multithresholding

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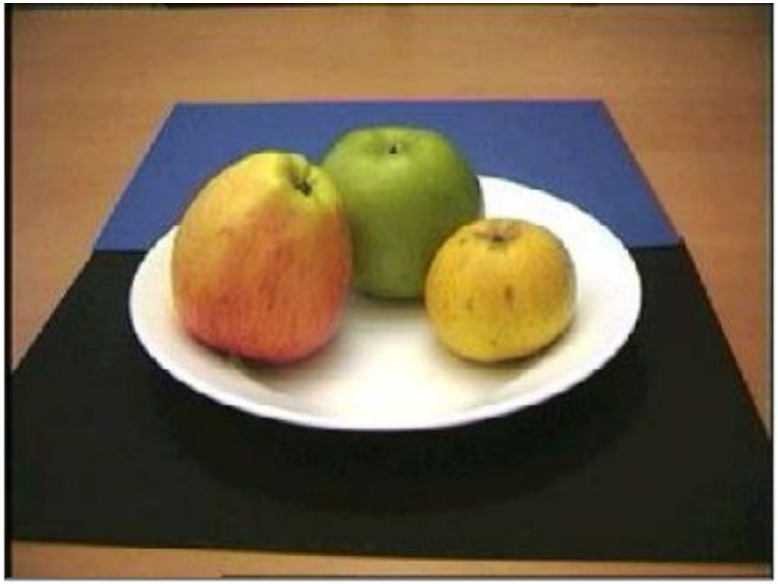
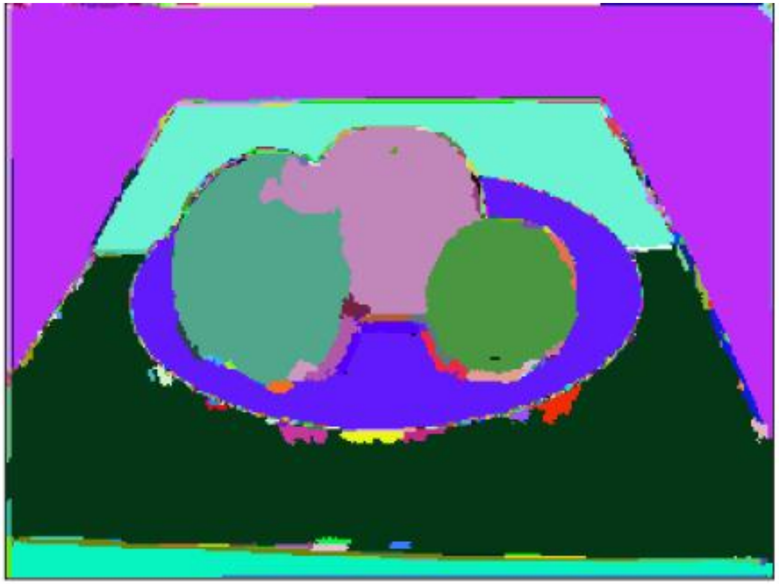



Thresholding

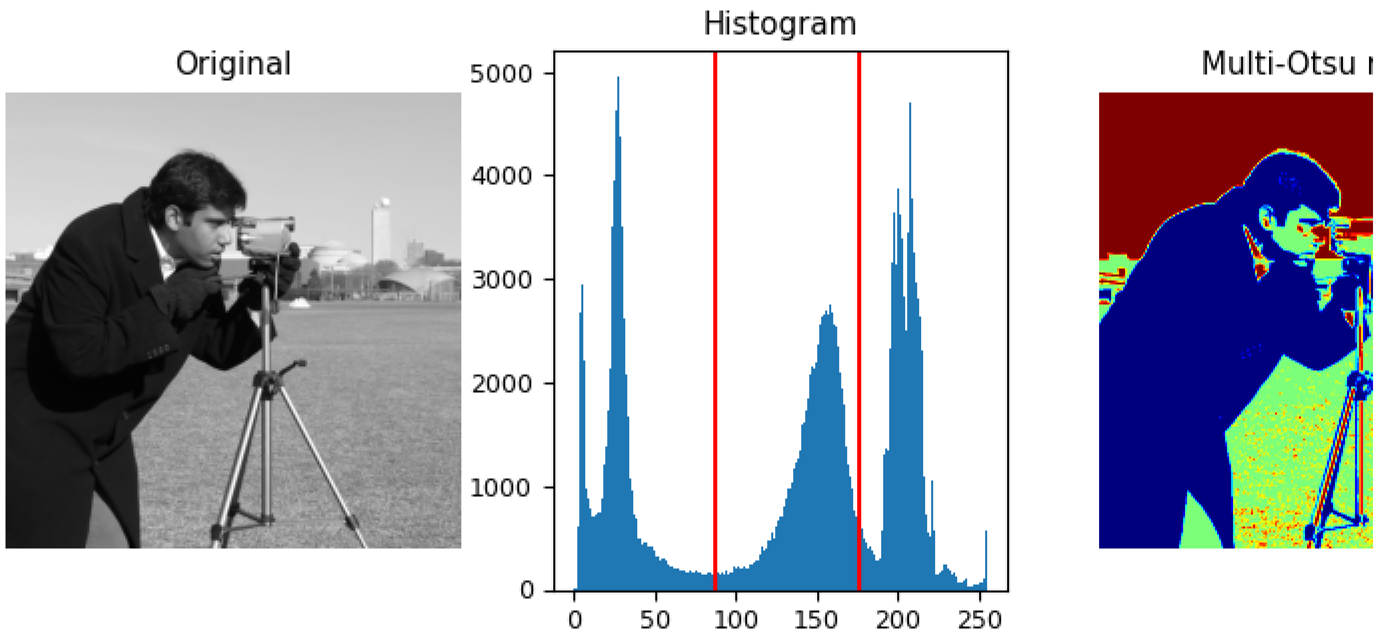
Applications of thresholding

- Object detection, image segmentation and character recognition ...
- Remove unnecessary detail from an image.
- Extraction of important information from an image

Thresholding

Choice of threshold?

- From histogram



Thresholding

Choice of threshold?

- Value obtained by tests.
- Mean value of gray-levels
- Automatic method OTSU (*Nobuyuki Otsu*)
- ……………..

Thresholding

Advantages

- Simple to implement
- Identify separate objects easily
- Less information to process (faster calculations)

Disadvantages

- Threshold selection is crucial
- Loss of useful information (256 levels →2 levels)
- High sensitivity to the noise