Introduction

An image is a way of recording and presenting information visually. imaging machines can capture and operate on images generated by sources that cannot be seen by humans. These include X-ray, ultrasound, electron microscopy, and computergenerated images. Thus, image processing has become an essential field that encompasses a wide and varied range of applications

الصورة هي طريقة لتسجيل وتمثيل العلومات بطريقة مرئية و هناك الات
للتصوير تجمع وتعمل على المعلومات التي لايستطيع رؤيتها الانسان
مثل include X-ray, ultrasound, electron microscopy,
and computer generated images
وموضوع المعالجة الصورية اصبح اساسي في العديد من التطبيقات

Basic definitions

- **<u>Image processing</u>** is a general term for the wide range of techniques that exist for manipulating and modifying images in various ways .

المعالجة الصورية
وهي مصطلح عام للعديد من التطبيقات لتنفيذ وتحسين الصور بعدة طرق

- **<u>Digital Image</u>** may be defined as a finite, discrete representation of the original continuous image.

A digital image is composed of a finite number of elements called pixels, each of which has a particular location and value .

The term digital image processing refers to processing digital images by means of a digital computer.

الصورة الرقمية
هي شكل محدد ومتقطع (discrete)
للصورة الاصلية بشكل ال(continuous(analoge))
والصورة الرقمية مكونة من عدد محدد من العناصر كل
واحد له قيمة رقمية وموقع يسمى (pixel)

Digital image processing applications Image processing is used in a wide range of applications for example :

- Security (e.g. face, fingerprint and iris recognition)
- Surveillance (e.g. car number plate recognition)
- Medical applications.

تطبيقات المعالجة الصورية

- الامنية مثل تميز الوجوه وبصمة الاصبع
- انظمة الملاحة مثل تميز ارقام السيارات
- التطبيقات الطبية

Fundamental tasks in digital image processing

Image applications require a variety of techniques that can be divided into two main categories: image processing techniques whose input and output are images, and image analysis techniques whose inputs are images, but whose outputs are attributes extracted from those images.

A. Image processing techniques include:

1. Image Enhancement
2. Image Restoration:
3. Image Segmentation

B. Image Analysis tasks include:

1. Image Segmentation
2. Image Representation and Description
3. Image Recognition

التطبيقات الصورية تتطلب العديد من التقنيات وتكون على نوعين

A. تقنيات المعالجة الصوريةالتي يكون المدخل والمخرج صورة

B. النوع الاخر هو تحليل الصور ويكون المدخال صورة والناتج خصائص الصورة

Types of Digital Images

The images types we will consider are:

1) binary, 2) gray-scale, 3) color, and 4) multispectral.

1. **Binary images :**the simplest type of images and can take on two values, typically black and white, or 0 and 1.

A binary image is referred to as a 1-bit image because it takes only 1 binary digit to represent each pixel.

هناك عدة انواع للصورة الرقمية

١. الثنائية
٢. الرمادية
٣. الملونة
٤. متعددة الاطياف

(a)

Figure 2.1 Binary images. (a) Object outline.

الصورة الثنائية وهي ابسط نوع من انواع الصور الرقمية وتتكون من لونين فقط ابيض واسود وكل موقع Pixel داخل الصورة يمتلك bit واحد فقط اما ابيض (١) او اسود (٠)

بالتالي عدد الالوان التي ممكن ان تكون لهذا لنوع هي

$2^{\text{عدد البتات}}$

$2=2^1$

2. Gray-scale images Gray-scale images are referred to as monochrome (one-color) imagesThey contain gray-level information, no color information.
The typical gray-scale image contains 8bits/pixel data, which allows us to have 256 different gray levels. The figure below shows examples of gray-scale images.

Figure 2.2 Examples of gray-scale images

In applications like medical imaging 12 or 16 bits/pixel images are used. These extra gray levels become useful when a small section of the image is made much larger to discern details .

بعض التطبيقات الطبية ممن ان تستخدم
بدل من ال8 bits/pixel
ممكن ان تستخدم ١٢ او ١٦ وتكون
مفيدة عندما يكون هناك مقطع صغير
يحتاج للتكبير ومعرفة التفاصيل

النوع الثاني الصورة الرمادية وتشير للصور الاحادية الالوان حيث ان كل
موقع pixel
داخل الصورة يتكون من 8bits/pixel
بالتالي عدد الالوان التي ممكن ان تكون لهذا لنوع هي
$2^{\text{عدد البتات}}$
$256=2^8$

3. Color images Color images can be modeled as three-band monochrome image data, where each band of data corresponds to a different color .

Typical color images are represented as red, green, and blue (RGB images). Using the 8-bit monochrome standard as a model, the corresponding color image would have 24-bits/pixel (8-bits for each of the three color bands red, green, and blue). The figure below illustrates a representation of a typical RGB color image.

النوع الثالث الصور الملونة وهنا
الصورة متكونة من ٣ حزم لوية
الاحمر والاشخضر والازرق
وكل حزمة تتكون من 8bitsLpixel
اي ان الصورة تتكون من ٢٤ بت
للموقع الواحدبالتالي عدد الالوان التي
ممكن ان تكون لهذا لنوع هي
$2^{\text{عدد البتات}}$
$2^8*2^8*2^8$
2^{24} =

4. Multispectral imagestypically contain information outside the normal human perceptual range. This may include infrared, ultraviolet, X-ray, acoustic, or radar data. These are not images in the usual sense because the information represented is not directly visible by the human system .

الصور متعددة الاطياف وتحتوي على معلومات خارج نطاق
الرؤيا للانسان مثل : infrared, ultraviolet, X-ray,
acoustic, or radar data
وهي لاتكون بالشكل المعتاد للصور لان المعلومات لاتمثل
بطريقة مباشرة

A simple image formation model

- In a mathematical view, a monochromatic image is a two-dimensional function, $f(x, y)$, where x and y are spatial (plane) coordinates, and the amplitude of f at any pair of coordinates (x, y) is called the *intensity* or *gray level* of the image at that point.
- The values of a monochromatic image (i.e. intensities) are said to span the *gray scale*.
- When x,y, and the amplitude value of f are all finite, discrete quantities, the image is called a *digital image*.

The function $f(x, y)$ must be nonzero and finite; that is,

$$0 < f(x, y) < \infty$$

نموذج تشكيل الصور البسيط
بصيغة رياضية فان الصورة الرقمية
عبارة عن دالة ثنائية الابعاد f(x,y)
X,yهي الاحداثيات لمواقع النقط
بالصورة وتسمى intensity or
gray level
ويجب ان تكون للدالة قيمة اكبر من
صفر ومحددة

كل موقع داخل الصورة يسمى
pixel
ولكل موقع قيمة رقمية وكذلك
احداثي

هذه الارقام تمثل رقم الصفوف
والاعمدة وتشكل الاحداثيات
لمواقع الصورة

0,0	0,1	0,2	0,3	0,4
1,0	1,1	1,2	1,3	1,4
2,0	2,1	2,2	2,3	2,4
3,0	3,1	3,2	3,3	3,4
4,0	4,1	4,2	4,3	4,4

عددالبتات لكل pixel
يعتمد على نوع الصورة
اذا كانت ثنائية او رمادية
او ملونة

وضوحية الصورة
image
resolution

وضوحية الصورة =حجم الصورة =عدد الصفوف *عدد الاعمدة
٥*٥=٢٥ موقع (pixel)

Digital Image Representation

The monochrome digital image *f(x,y)* resulted from sampling and quantization has finite discrete coordinates *(x,y)* and intensities (gray levels). We shall use integer values for these discrete coordinates and gray levels. Thus, a monochrome digital image can be represented as a 2-dimensional array (matrix) that has *M* rows and *N* columns:

تمثيل الصورة الرقمية التي تنتج عن عمليتي
sampling and quantization
وتكون الصورة مكونة من مواقعع محددة ومنفصلة,
لكل موقع احداثي وقيمة ودائما تستخدم الاعداد
الصحيحة لتمثيل القيم داخل الصور الرقمية

Image Sampling and Quantization

To convert the continuous function $f(x,y)$ to digital form, we need to sample the function in both coordinates and in amplitude.

- Digitizing the coordinate values is called *sampling*.
- Digitizing the amplitude values is called *quantization*.

لتحويل الدالة المستمرة(القياسية)
الى متقطعة (الرقمية) نحتاج الى نمذجة
الدالة لكلا
الاحداثي وتسمى العملية (sampling)
والسعة (قيمة الدالة) وتسمى العملية
ال(quantization)

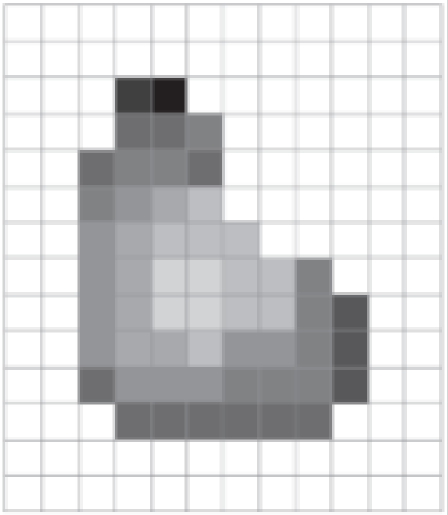


Figure 2.3 Digital image resulted from sampling and quantization

Note that:

- The number of selected values in the sampling process is known as the image *spatial resolution*. This is simply the number of pixels relative to the given image area.
- The number of selected values in the quantization process is called the *grey-level (color level) resolution*. This is expressed in terms of the number of bits allocated to the color levels.
- The quality of a digitized image depends on the resolution parameters on both processes.

Example:

For an 8-bit image of size 512×512, determine its gray-scale and storage size.

Solution $\therefore k = 8$, $M = N = 512$

Number of gray levels $L = 2^k = 2^8 = 256$

The gray scale is [0 , 255]

Storage size (b) = $M * N * k = 512 * 512 * 8 = 2{,}097{,}152$ bits

M=512 عدد الصفوف
N=512 عدد الاعمدة
K=عدد البتات
L=عدد الالوان

2.1 Digital Image File Formats

Types of image data are divided into two primary categories: bitmap and vector.

- Bitmap images (also called raster images) can be represented as 2-dimensional functions f(x,y), where they have pixel data and the corresponding gray-level values stored in some file format.
- Vector images refer to methods of representing lines, curves, and shapes by storing only the key points. These key points are sufficient to define the shapes.

- Most of the types of file formats fall into the category of bitmap images, for example:
- PPM (Portable Pix Map) format
- TIFF (Tagged Image File Format)
- GIF (Graphics Interchange Format)
- JPEG (Joint Photographic Experts Group) format
- BMP (Windows Bitmap)
- PNG (Portable Network Graphics)
- XWD (X Window Dump)

2.2 Types of Image processing

The processing operation will transform image pixels or gray values into different values and/or data class depending on the information required to perform this transformation. Generally we can divide image processing into three types:

2.2.1 Point Processing

A pixel gray value is changed without any knowledge about pixel's neighbours, like image matrix addition, subtraction, multiplication..., etc.

2.2.2 Neighbourhood processing

To change the pixel or gray level value we only need to know the interested pixel neighbour's values, like image filtering for noise removal and features extraction.

2.2.3 Transforms

The entire image is processing and transforming as a single large block. We may need to transform an image from its spatial domain into another domain like frequency domain. Many image transforms will be consider next chapters like, Fourier, Wavelet, or Cosine transform

Arithmetic operations

- **Addition/Subtraction**

The arithmetic operations like addition, subtraction, multiplication, and division can be implemented on image pixels individually. The result of all these operations will effect on the pixel intensity $f(x,y)$. So,

$$f(x,y)_{new} = f(x,y)_{old} +/- C$$

C: is any constant value

If image matrix in the range of (0 ... 255) like uint8 data class, we should rounding and clipping all values that fill out of the range. i.e;

$$f(x,y)_{new} = \begin{Bmatrix} 255 & if\ f(x,y) > 255 \\ 0 & if\ f(x,y) < 0 \end{Bmatrix}$$

- **Multiplication/Division**

Lightning or darkening of an image can be done by multiplication operation

Ex: Sketch the relation between the old and new pixel values for the following operations.

a. $f(x,y)_{new} = f(x,y)_{old} * 2$
b. $f(x,y)_{new} = f(x,y)_{old} \div 2$
c. $f(x,y)_{new} = (f(x,y)_{old} \div 2) + 128$

Ex: sub image with 4- bits/pixel ,increase the brightness by 2 then increase the darkness of the original image by 3.

15	2	14
1	0	1
14	2	14

Sol:

C=2

L= 16 =(0-15)

To increase the brightness perform the addition or multiplication

15+2	2+2	14+2
1+2	0+2	1+2
14+2	2+2	14+2

Check the result

Pixel +c>15 so it will be 15

15	4	15
3	2	3
15	4	15

To increase the darkness perform the subtraction or division

15-3	2-3	14- 3
1-3	0-3	1-3
14-3	2-3	14-3

Check the result

Pixel – c<0 so it will be 0

12	0	11
0	0	0
11	0	11

- **Enhancement using basic gray level transformations**

The term *spatial domain* refers to the image plane itself, i.e. the total number of pixels composing an image. To enhance an image in the spatial domain we transform an image by changing pixel values or moving them around. A spatial domain process is denoted by the expression:

- s=T(r)

- where *r* is the input image, *s* is the processed image, and ***T*** is an operator on *r*. The operator ***T*** is applied at each location (x, y) in *r* to yield the output, *s*, at that location.

Basic gray level transformation functions can be divided into:

§ Linear: e.g. image negatives and piecewise-linear transformation

§ Non-linear: e.g. logarithm and power-law transformations

- **Image negatives**

The negative of an image with gray levels in the range [0, L-1] is obtained by using the following expression:

$$s = L - 1 - r$$

where L=number of gray level

r: constant

This type of processing is useful for enhancing white or gray detail embedded in dark regions of an image, especially when the black areas are dominant in size.

Ex: perform negative transform on image 8-bits/pixel by 10.

$L = 2^8 = 256$

$$s = 256 - 1 - 10$$

$$s = 245$$

•Piecewise-linear transformation

The form of piecewise linear functions can be arbitrarily complex. Some important transformations can be formulated only as piecewise functions, for example thresholding:

For any $0 < t < 255$ the threshold transform Thr_t can be defined as:

$$s = Thr_t(r) = \begin{cases} 0 & if\ r < t \\ r & otherwise \end{cases}$$

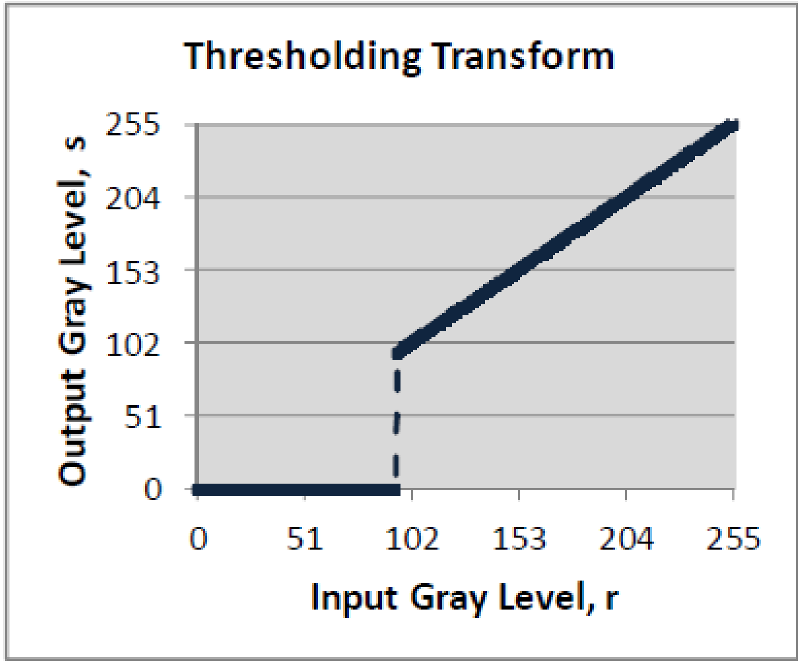


Figure 4.2 Form of thresholding transform

Thresholding has another form used to generate binary images from the gray-scale images, i.e.:

$$s = Thr_t(r) = \begin{cases} 0 & if\ r < t \\ 255 & otherwise \end{cases}$$

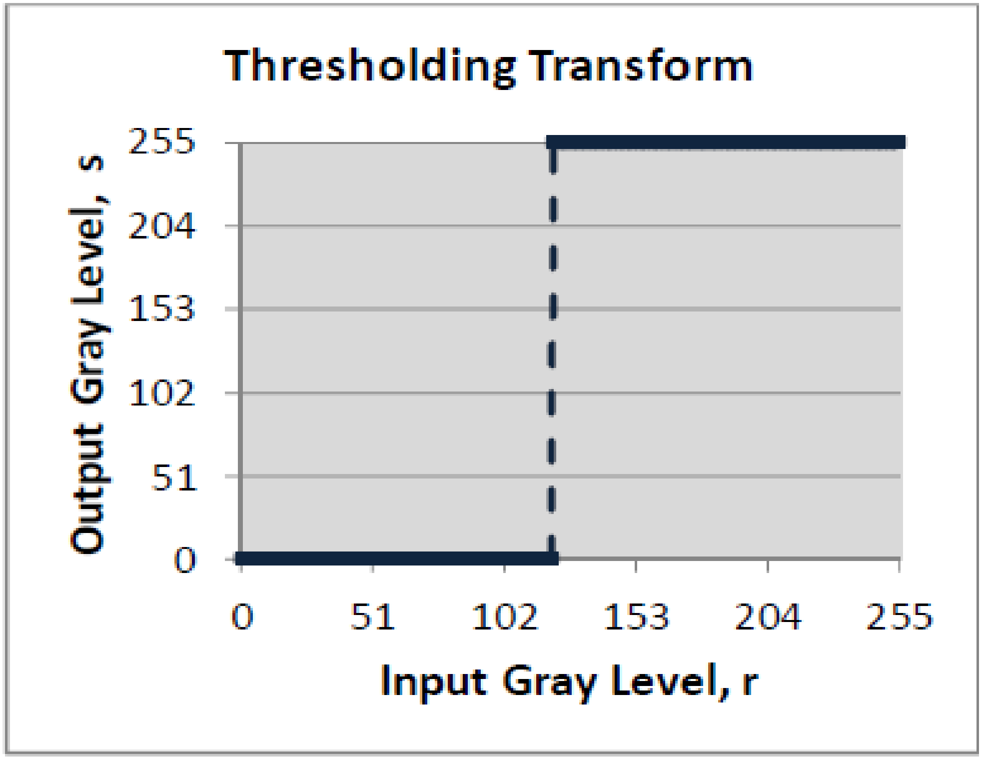


Figure 4.4 Form of thresholding transform to produce binary images

Another more complex piecewise linear function can be defined as:

$$s = \begin{cases} 2 * r & if \ r \leq 110 \\ r & if \ 110 < r \leq 200 \\ 255 & if \ r > 200 \end{cases}$$

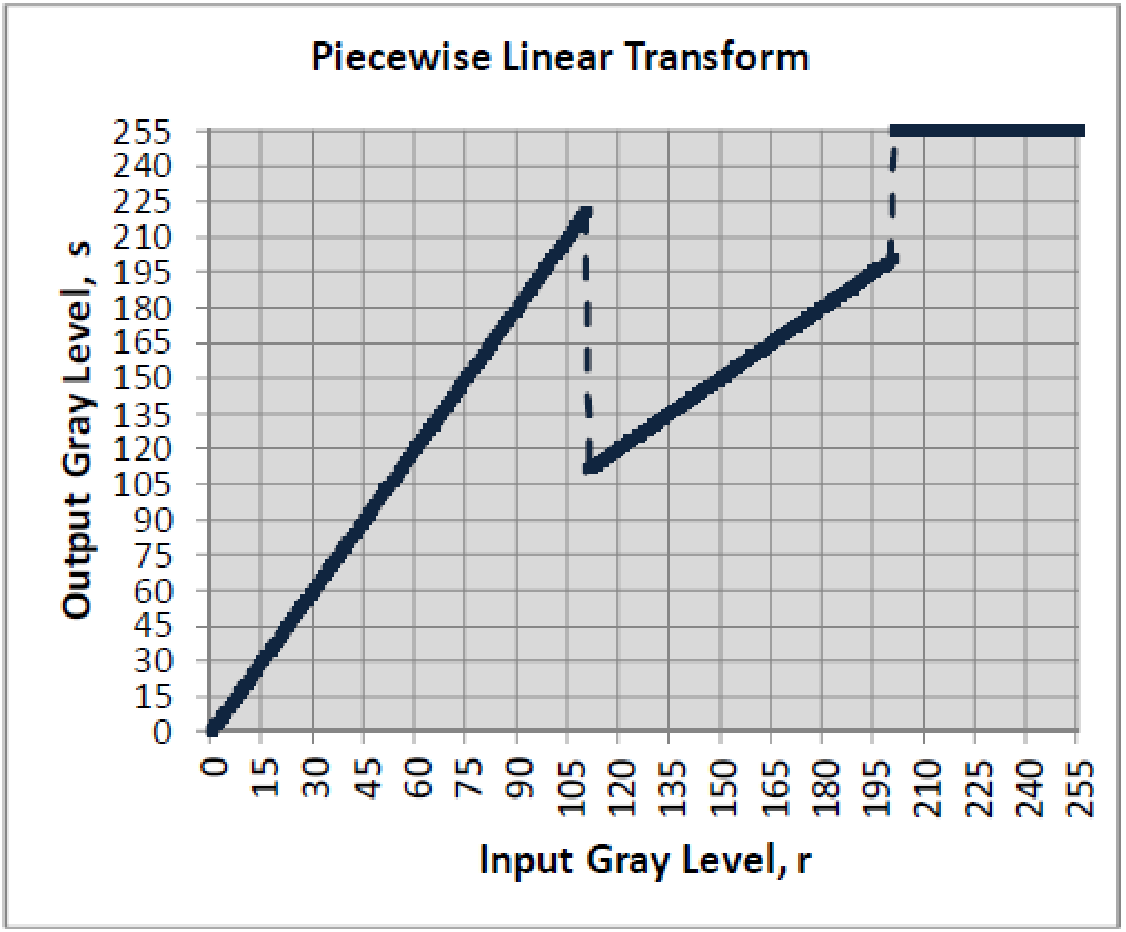


Figure 4.6 Form of previous piecewise linear transform

Log transformation

The general form of the log transformation is

$$s = c * \log(1 + r)$$

where c is a constant, and it is assumed that $r \geq 0$. This transformation is used to expand the values of dark pixels in an image while compressing the higher-level values as shown in the figure below.

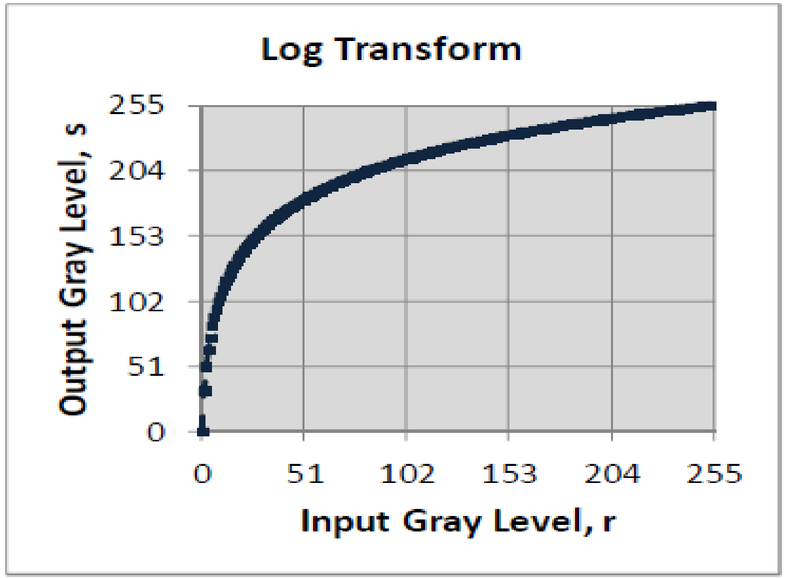


Figure 4.8 Form of Log transform

Power-law (Gamma) transformation :

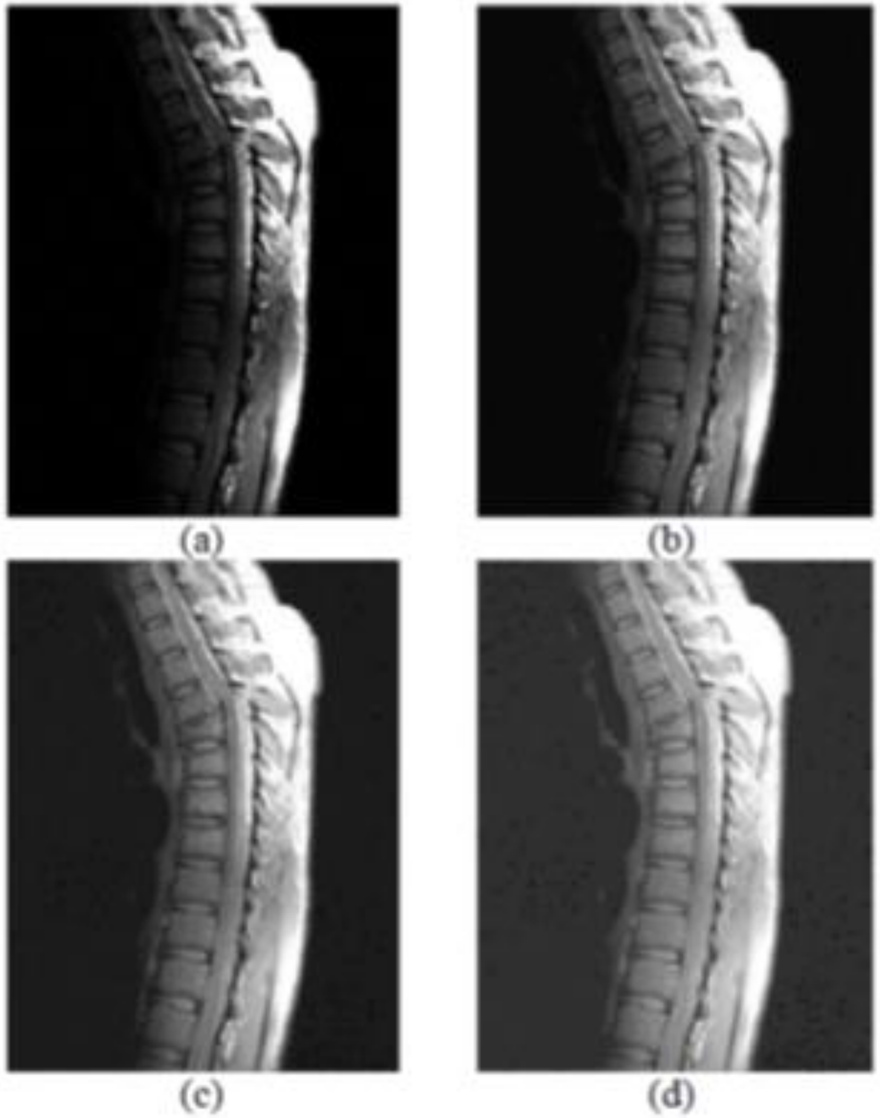
The general form of Power law (Gamma) transformation function is

$s = c*r^{\gamma}$

s:output

r:input

'c' and γ are the positive constants.



(a) Original MRI image of a human spine. (b)-(d) Results of applying power-law transformation with c = 1 and y = 0.6,0.4, and 0.3, respectively.

We note that, as gamma decreased from 0.6 to 0.4, more detail became visible. A further decrease of gamma to 0.3 enhanced a little more detail in the background, but began to reduce contrast ("washed-out" image).

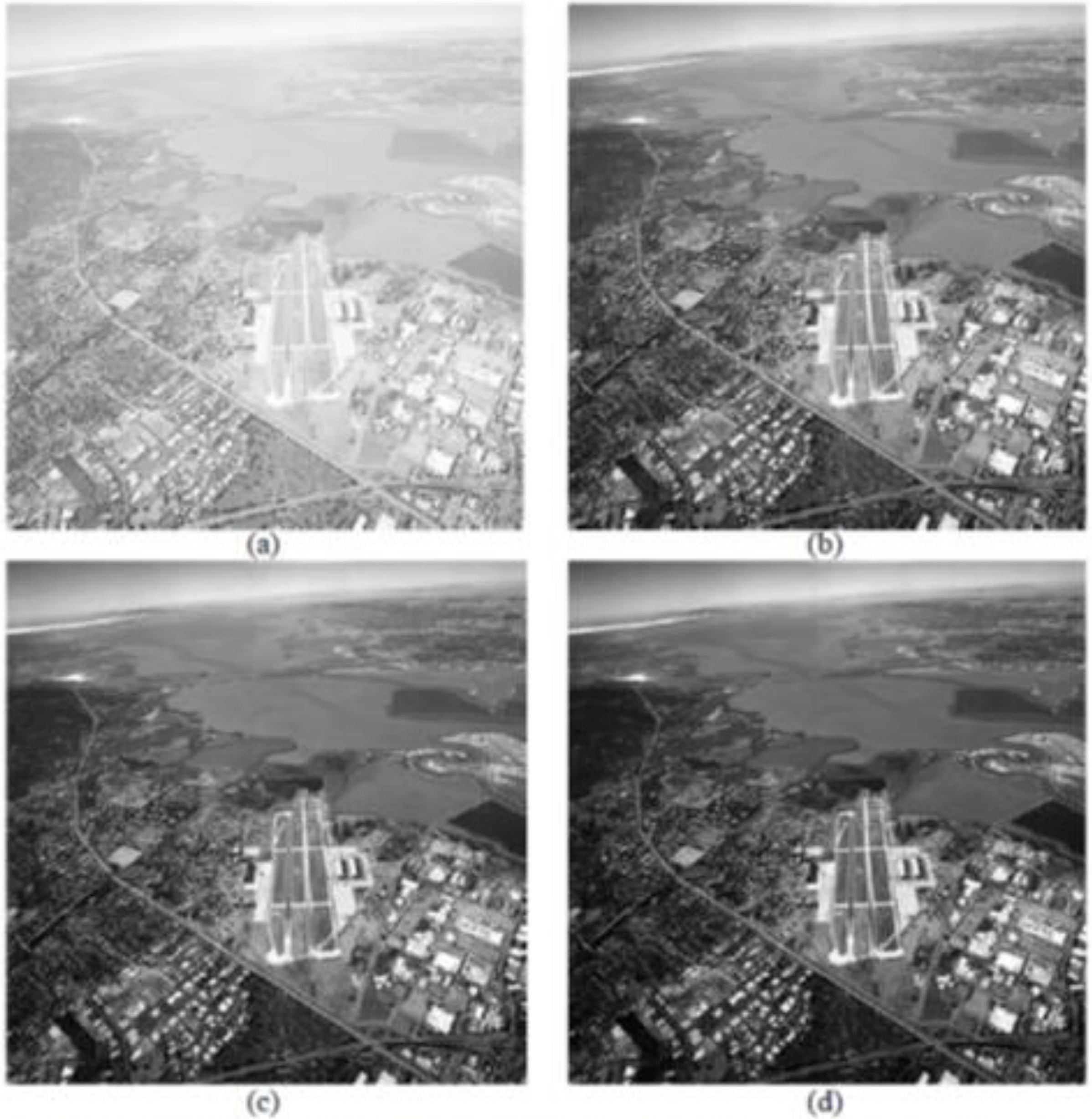


Figure 4.12 (a) Original bright image. (b)-(d) Results of applying power-law transformation with $c = 1$ and $y = 3$, 4, and 5, respectively.

H.W:

Block from image with 9-bits/pixel , perform the following transformation :

- non linear log transform on this block by using c=1 .
- perform on the original image block the piecewise linear transform by using this function

122	245	193
80	89	80
111	111	122

$$s = \begin{cases} r & if \ \ r < 90 \\ 2r - 150 & if \ 90 \le r \le 180 \\ 255 & if \ r > 180 \end{cases}$$

Log transformation

The general form of the log transformation is

$$s = c * \log(1 + r)$$

If c=1
S1=1*log(1+122)=
S2=1*log(1+245)=
S3=1*log(1+193)=
S4=1*log(1+80)=
S5=1*log(1+89)=
S6=1*log(1+80)=
S7=1*log(1+111)=
S8=1*log(1+111)=
S9=1*log(1+122)=

122	245	193
80	89	80
111	111	122

S1	S2	S3
S4	S5	S6
S7	S8	S9

122	245	193
80	89	80
111	111	122

- perform on the original image block the piecewise linear transform by using this function

$$s = \begin{cases} r & if\ \ r < 90 \\ 2r - 150 & if\ 90 \le r \le 180 \\ 255 & if\ r > 180 \end{cases}$$

- 90<= 122<=180
  (2*122)-150=94
- 245>180 =255
- 193>180=255

- 80<90=80
- 89<90=89
- 80<90=80

- 90<=111<=180
(2*111)-150=72
- 90<=111<=180
(2*111)-150=72
- 90<= 122<=180
(2*122)-150=94

القيم اصغر من ٩٠ تبقى نفسها بدون تغيير
القيم اكبر من ١٨٠ تتحول وتصبح ٢٥٥
اما القيم من ٩٠ ولغاية ١٨٠ تطبق المعادلة
٢*القيمة -١٥٠

94	255	255
80	89	80
72	72	94

2.5 Image Restoration: Image restoration methods are used to improve the appearance of an image by application of a restoration process that use mathematical model for image degradation.

استرجاع الصور

Example of the type of degradation:

1. Blurring caused by motion or atmospheric disturbance.
2. Geometrics distortion caused by imperfect lenses.

What is noise?

Noise is any undesired information that contaminates an image. Noise appears in image from a variety of source.

In typical image the noise can be modeled with one of the following distribution:

1. Gaussian (“normal”) distribution.
2. Uniform distribution.
3. Salt _and _pepper distribution.

2.5.2 Noise Removal using Spatial Filters:

Spatial filtering is typically done for:

1. Remove various types of noise in digital images.
2. Perform some type of image enhancement.

[These filters are called spatial filter to distinguish them from frequency domain filter].

The three types of filters are:

1. Mean filters
2. Median filters (order filter)
3. Enhancement filters

Spatial filters are implemented with convolution masks. Because convolution mask operation provides a result that is weighted sum of the values of a pixel and its neighbours, it is called a linear filter.

Overall effects the convolution mask can be predicated based on the general pattern. For example:

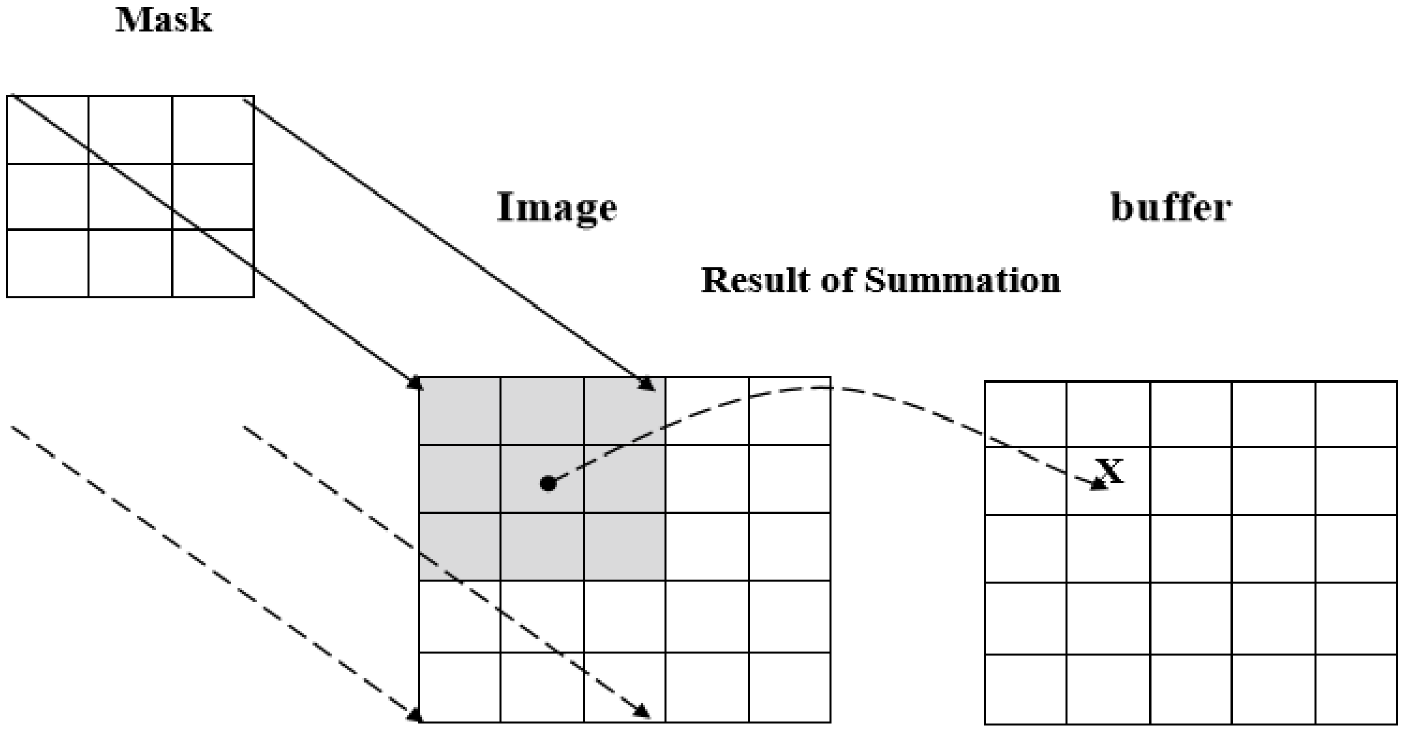
- If the coefficients of the mask sum to one, the average brightness of the image will be retained.
- If the coefficients of the mask sum to zero, the average brightness will be lost and will return a dark image.
- If the coefficients of the mask are alternatively positive and negative, the mask is a filter that returns edge information only.
- If the coefficients of the mask are all positive, it is a filter that will blur the image.

The mean filters, are essentially averaging filter. They operate on local groups of pixel called neighbourhoods and replace the centre pixel with an average of the pixels in this neighbourhood. This replacement is done with a convolution mask such as the following 3X3 mask

Arithmetic mean filter smoothing or low-pass filter.

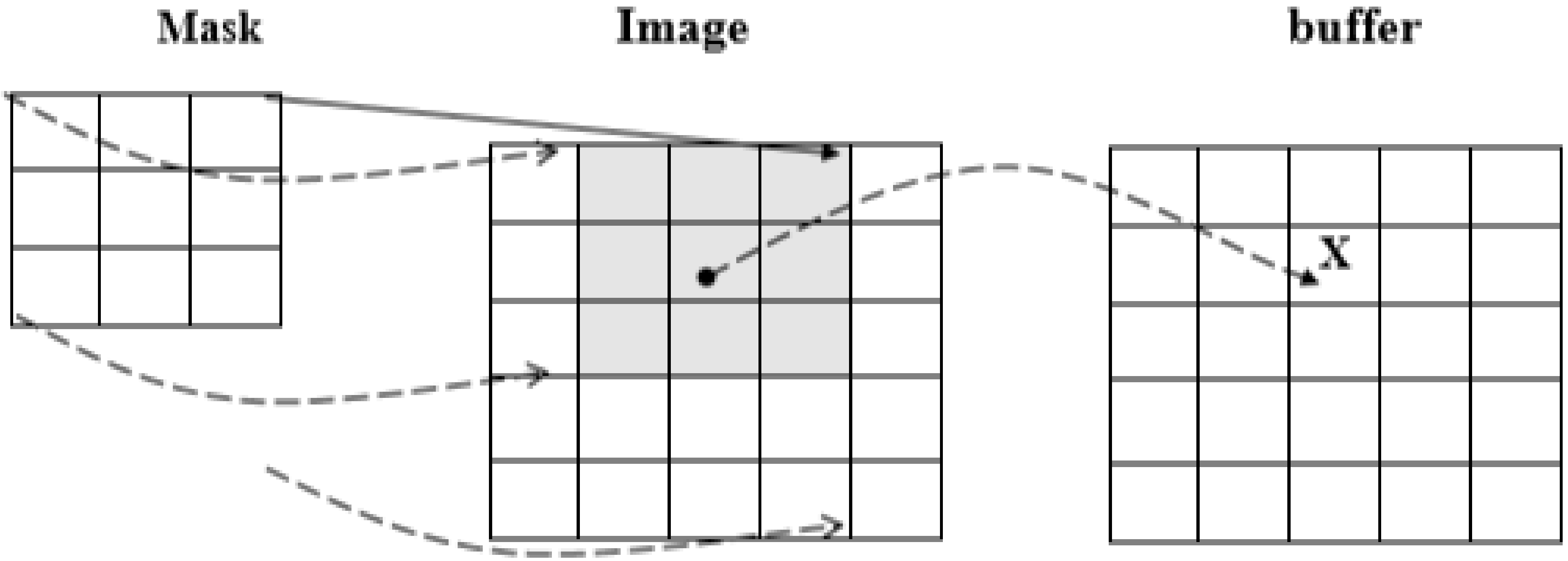
$$\begin{pmatrix} 1/9 & 1/9 & 1/9 \\ 1/9 & 1/9 & 1/9 \\ 1/9 & 1/9 & 1/9 \end{pmatrix}$$

The convolution process

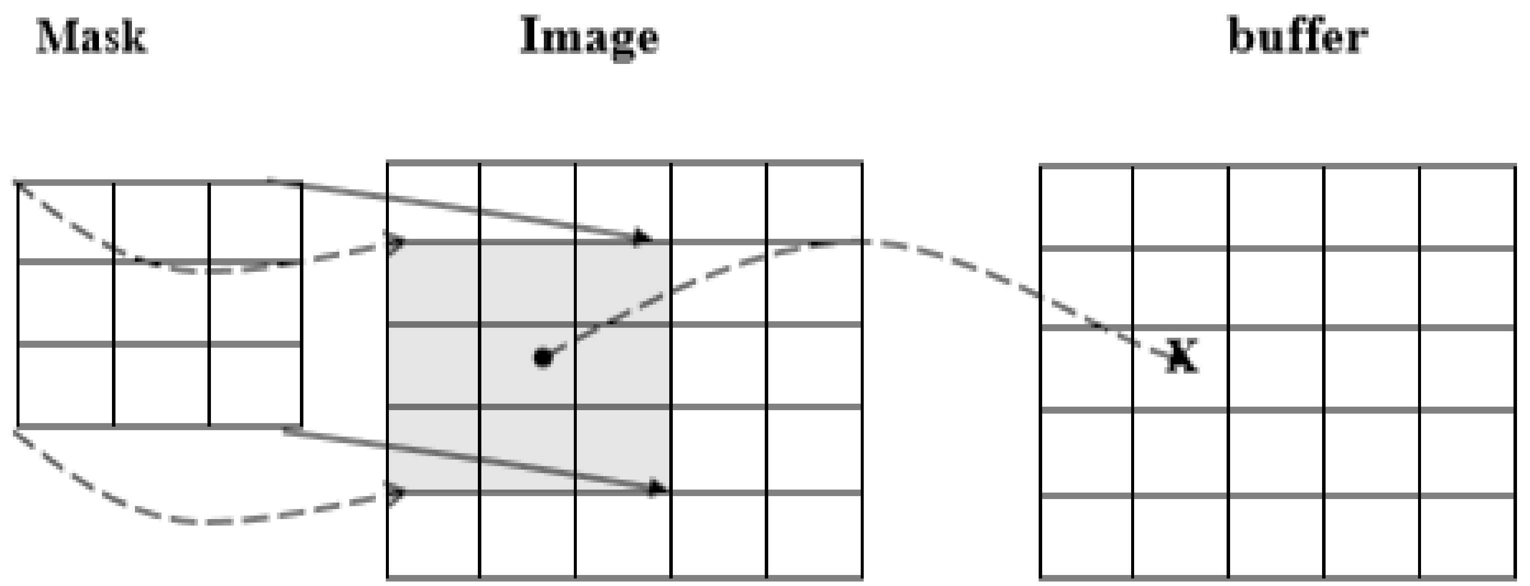


X= m1*p1 + m2*p2 + m3*p3 +
m4*p4 + m5*p5 + m6*p6 +
m7*p7 + m8*p8 + m9*p9

a. Overlay the convolution mask in the upper-left corner of the image. Multiply coincident terms, sum, and put the result into the image buffer at the location that corresponds to the masks current center, which is (r,c)=(1,1).



b. Move the mask one pixel to the right , multiply coincident terms sum , and place the new results into the buffer at the location that corresponds to the new center location of the convolution mask which is now at (r,c)=(1,2), continue to the end of the row.



c. Move the mask down on row and repeat the process until the mask is convolved with the entire image. Note that we lose the outer row(s) and columns(s).

1/9	1/9	1/9
1/9	1/9	1/9
1/9	1/9	1/9

mask

2	7	8	8	3	7	8
5	6	3	3	5	5	3
3	7	2	2	3	7	2
3	7	8	4	3	7	8
8	3	7	8	5	5	3
3	5	5	3	3	7	2

image

(2*1+7*1+8*1+
5*1+6*1+3*1+
3*1+7*1+2*1)/9=43/9=4.7=5

New image(buffer)

	5					

1/9	1/9	1/9
1/9	1/9	1/9
1/9	1/9	1/9

mask

3	7	8	8	3	7	8
5	5	3	3	5	5	3
3	7	2	2	3	7	2
3	7	8	4	3	7	8
8	3	7	8	5	5	3
3	5	5	3	3	7	2

image

(7*1+8*1+8*1+
5*1+3*1+3*1+
7*1+2*1+2*1)/9=45/9=5

New image(buffer)

	5	5				

2	7	8	8	3	7	8
5	6	3	3	5	5	3
3	7	2	2	3	7	2
3	7	8	4	3	7	8
8	3	7	8	5	5	3
3	5	5	3	3	7	2

2	7	8	8	3	7	8
5	6	3	3	5	5	3
3	7	2	2	3	7	2
3	7	8	4	3	7	8
8	3	7	8	5	5	3
3	5	5	3	3	7	2

2	7	8	8	3	7	8
5	6	3	3	5	5	3
3	7	2	2	3	7	2
3	7	8	4	3	7	8
8	3	7	8	5	5	3
3	5	5	3	3	7	2

2	7	8	8	3	7	8
5	6	3	3	5	5	3
3	7	2	2	3	7	2
3	7	8	4	3	7	8
8	3	7	8	5	5	3
3	5	5	3	3	7	2

2	7	8	8	3	7	8
5	6	3	3	5	5	3
3	7	2	2	3	7	2
3	7	8	4	3	7	8
8	3	7	8	5	5	3
3	5	5	3	3	7	2

2	7	8	8	3	7	8
5	6	3	3	5	5	3
3	7	2	2	3	7	2
3	7	8	4	3	7	8
8	3	7	8	5	5	3
3	5	5	3	3	7	2

2	7	8	8	3	7	8
5	6	3	3	5	5	3
3	7	2	2	3	7	2
3	7	8	4	3	7	8
8	3	7	8	5	5	3
3	5	5	3	3	7	2

2	7	8	8	3	7	8
5	6	3	3	5	5	3
3	7	2	2	3	7	2
3	7	8	4	3	7	8
8	3	7	8	5	5	3
3	5	5	3	3	7	2

2	7	8	8	3	7	8
5	6	3	3	5	5	3
3	7	2	2	3	7	2
3	7	8	4	3	7	8
8	3	7	8	5	5	3
3	5	5	3	3	7	2

2	7	8	8	3	7	8
5	6	3	3	5	5	3
3	7	2	2	3	7	2
3	7	8	4	3	7	8
8	3	7	8	5	5	3
3	5	5	3	3	7	2

2	7	8	8	3	7	8
5	6	3	3	5	5	3
3	7	2	2	3	7	2
3	7	8	4	3	7	8
8	3	7	8	5	5	3
3	5	5	3	3	7	2

2	7	8	8	3	7	8
5	6	3	3	5	5	3
3	7	2	2	3	7	2
3	7	8	4	3	7	8
8	3	7	8	5	5	3
3	5	5	3	3	7	2

2	7	8	8	3	7	8
5	6	3	3	5	5	3
3	7	2	2	3	7	2
3	7	8	4	3	7	8
8	3	7	8	5	5	3
3	5	5	3	3	7	2

2	7	8	8	3	7	8
5	6	3	3	5	5	3
3	7	2	2	3	7	2
3	7	8	4	3	7	8
8	3	7	8	5	5	3
3	5	5	3	3	7	2

2	7	8	8	3	7	8
5	6	3	3	5	5	3
3	7	2	2	3	7	2
3	7	8	4	3	7	8
8	3	7	8	5	5	3
3	5	5	3	3	7	2

2	7	8	8	3	7	8
5	6	3	3	5	5	3
3	7	2	2	3	7	2
3	7	8	4	3	7	8
8	3	7	8	5	5	3
3	5	5	3	3	7	2

2	7	8	8	3	7	8
5	6	3	3	5	5	3
3	7	2	2	3	7	2
3	7	8	4	3	7	8
8	3	7	8	5	5	3
3	5	5	3	3	7	2

2	7	8	8	3	7	8
5	6	3	3	5	5	3
3	7	2	2	3	7	2
3	7	8	4	3	7	8
8	3	7	8	5	5	3
3	5	5	3	3	7	2

	5	5				

New image(buffer)

5	5			

New image(buffer)

2.5 Image Restoration: Image restoration methods are used to improve the appearance of an image by application of a restoration process that use mathematical model for image degradation.

استرجاع الصور

Example of the type of degradation:

1. Blurring caused by motion or atmospheric disturbance.
2. Geometrics distortion caused by imperfect lenses.

What is noise?

Noise is any undesired information that contaminates an image. Noise appears in image from a variety of source.

In typical image the noise can be modeled with one of the following distribution:

1. Gaussian ("normal") distribution.
2. Uniform distribution.
3. Salt _and _pepper distribution.

2.5.2 Noise Removal using Spatial Filters:

Spatial filtering is typically done for:

1. Remove various types of noise in digital images.
2. Perform some type of image enhancement.

[These filters are called spatial filter to distinguish them from frequency domain filter].

The three types of filters are:

1. Mean filters
2. Median filters (order filter)
3. Enhancement filters

Spatial filters are implemented with convolution masks. Because convolution mask operation provides a result that is weighted sum of the values of a pixel and its neighbours, it is called a linear filter.

Overall effects the convolution mask can be predicated based on the general pattern. For example:

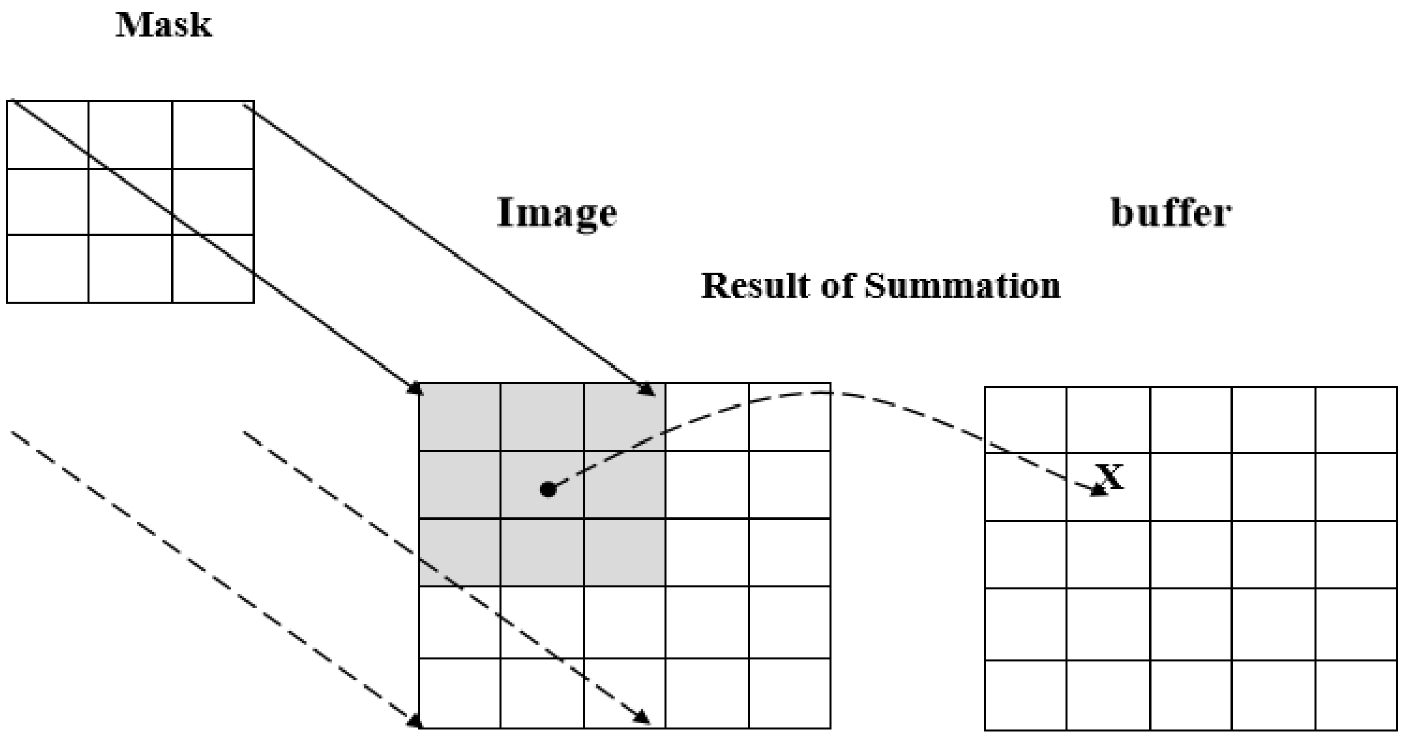
- If the coefficients of the mask sum to one, the average brightness of the image will be retained.
- If the coefficients of the mask sum to zero, the average brightness will be lost and will return a dark image.
- If the coefficients of the mask are alternatively positive and negative, the mask is a filter that returns edge information only.
- If the coefficients of the mask are all positive, it is a filter that will blur the image.

The mean filters, are essentially averaging filter. They operate on local groups of pixel called neighbourhoods and replace the centre pixel with an average of the pixels in this neighbourhood. This replacement is done with a convolution mask such as the following 3X3 mask

Arithmetic mean filter smoothing or low-pass filter.

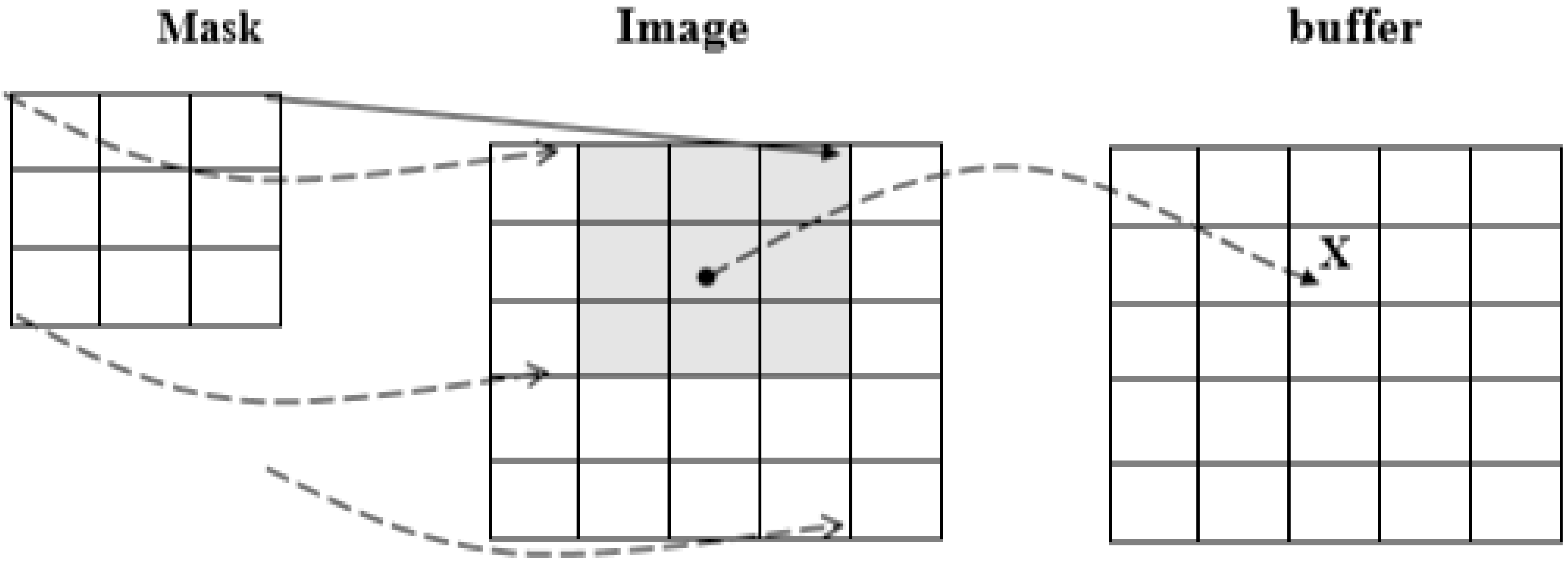
$$\begin{pmatrix} 1/9 & 1/9 & 1/9 \\ 1/9 & 1/9 & 1/9 \\ 1/9 & 1/9 & 1/9 \end{pmatrix}$$

The convolution process

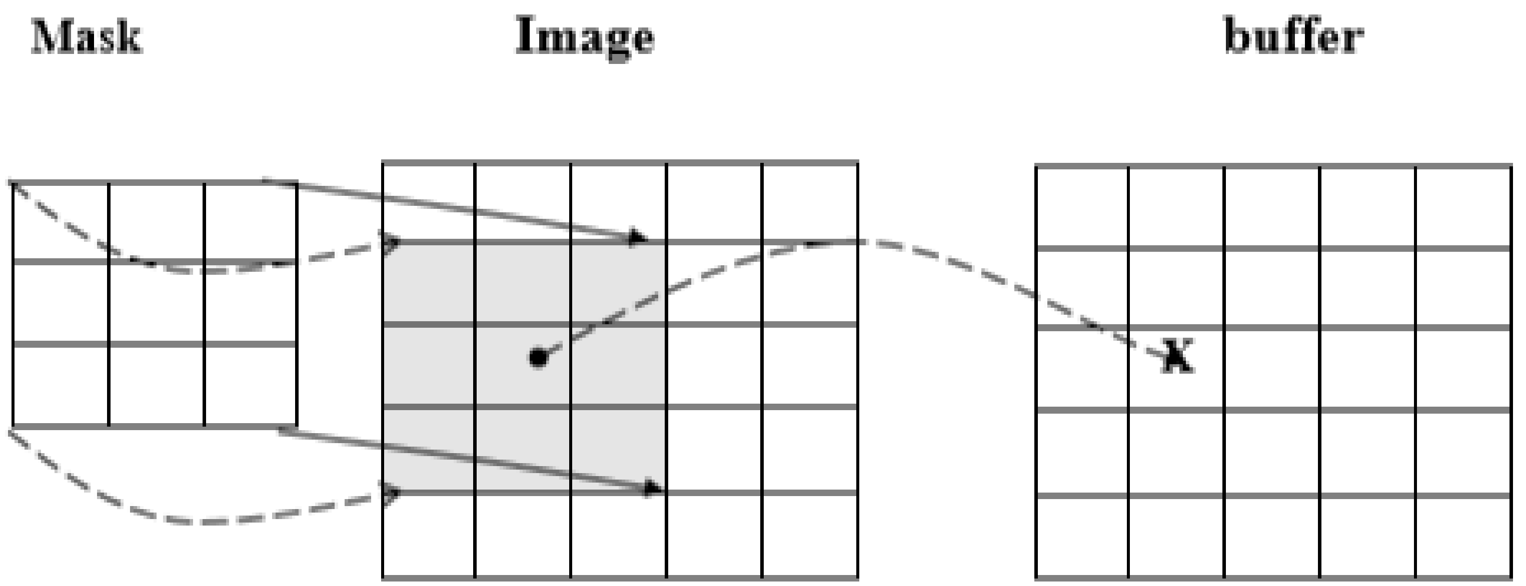


X= m1*p1 + m2*p2 + m3*p3 +
m4*p4 + m5*p5 + m6*p6 +
m7*p7 + m8*p8 + m9*p9

a. Overlay the convolution mask in the upper-left corner of the image. Multiply coincident terms, sum, and put the result into the image buffer at the location that corresponds to the masks current center, which is (r,c)=(1,1).



b. Move the mask one pixel to the right , multiply coincident terms sum , and place the new results into the buffer at the location that corresponds to the new center location of the convolution mask which is now at (r,c)=(1,2), continue to the end of the row.



c. Move the mask down on row and repeat the process until the mask is convolved with the entire image. Note that we lose the outer row(s) and columns(s).

1/9	1/9	1/9
1/9	1/9	1/9
1/9	1/9	1/9

mask

2	7	8	8	3	7	8
5	6	3	3	5	5	3
3	7	2	2	3	7	2
3	7	8	4	3	7	8
8	3	7	8	5	5	3
3	5	5	3	3	7	2

image

(2*1+7*1+8*1+
5*1+6*1+3*1+
3*1+7*1+2*1)/9=43/9=4.7=5

New image(buffer)

	5					

1/9	1/9	1/9
1/9	1/9	1/9
1/9	1/9	1/9

mask

3	7	8	8	3	7	8
5	5	3	3	5	5	3
3	7	2	2	3	7	2
3	7	8	4	3	7	8
8	3	7	8	5	5	3
3	5	5	3	3	7	2

image

(7*1+8*1+8*1+
5*1+3*1+3*1+
7*1+2*1+2*1)/9=45/9=5

New image(buffer)

	5	5				

2	7	8	8	3	7	8
5	6	3	3	5	5	3
3	7	2	2	3	7	2
3	7	8	4	3	7	8
8	3	7	8	5	5	3
3	5	5	3	3	7	2

2	7	8	8	3	7	8
5	6	3	3	5	5	3
3	7	2	2	3	7	2
3	7	8	4	3	7	8
8	3	7	8	5	5	3
3	5	5	3	3	7	2

2	7	8	8	3	7	8
5	6	3	3	5	5	3
3	7	2	2	3	7	2
3	7	8	4	3	7	8
8	3	7	8	5	5	3
3	5	5	3	3	7	2

2	7	8	8	3	7	8
5	6	3	3	5	5	3
3	7	2	2	3	7	2
3	7	8	4	3	7	8
8	3	7	8	5	5	3
3	5	5	3	3	7	2

2	7	8	8	3	7	8
5	6	3	3	5	5	3
3	7	2	2	3	7	2
3	7	8	4	3	7	8
8	3	7	8	5	5	3
3	5	5	3	3	7	2

2	7	8	8	3	7	8
5	6	3	3	5	5	3
3	7	2	2	3	7	2
3	7	8	4	3	7	8
8	3	7	8	5	5	3
3	5	5	3	3	7	2

2	7	8	8	3	7	8
5	6	3	3	5	5	3
3	7	2	2	3	7	2
3	7	8	4	3	7	8
8	3	7	8	5	5	3
3	5	5	3	3	7	2

2	7	8	8	3	7	8
5	6	3	3	5	5	3
3	7	2	2	3	7	2
3	7	8	4	3	7	8
8	3	7	8	5	5	3
3	5	5	3	3	7	2

2	7	8	8	3	7	8
5	6	3	3	5	5	3
3	7	2	2	3	7	2
3	7	8	4	3	7	8
8	3	7	8	5	5	3
3	5	5	3	3	7	2

2	7	8	8	3	7	8
5	6	3	3	5	5	3
3	7	2	2	3	7	2
3	7	8	4	3	7	8
8	3	7	8	5	5	3
3	5	5	3	3	7	2

2	7	8	8	3	7	8
5	6	3	3	5	5	3
3	7	2	2	3	7	2
3	7	8	4	3	7	8
8	3	7	8	5	5	3
3	5	5	3	3	7	2

2	7	8	8	3	7	8
5	6	3	3	5	5	3
3	7	2	2	3	7	2
3	7	8	4	3	7	8
8	3	7	8	5	5	3
3	5	5	3	3	7	2

2	7	8	8	3	7	8
5	6	3	3	5	5	3
3	7	2	2	3	7	2
3	7	8	4	3	7	8
8	3	7	8	5	5	3
3	5	5	3	3	7	2

2	7	8	8	3	7	8
5	6	3	3	5	5	3
3	7	2	2	3	7	2
3	7	8	4	3	7	8
8	3	7	8	5	5	3
3	5	5	3	3	7	2

2	7	8	8	3	7	8
5	6	3	3	5	5	3
3	7	2	2	3	7	2
3	7	8	4	3	7	8
8	3	7	8	5	5	3
3	5	5	3	3	7	2

2	7	8	8	3	7	8
5	6	3	3	5	5	3
3	7	2	2	3	7	2
3	7	8	4	3	7	8
8	3	7	8	5	5	3
3	5	5	3	3	7	2

2	7	8	8	3	7	8
5	6	3	3	5	5	3
3	7	2	2	3	7	2
3	7	8	4	3	7	8
8	3	7	8	5	5	3
3	5	5	3	3	7	2

2	7	8	8	3	7	8
5	6	3	3	5	5	3
3	7	2	2	3	7	2
3	7	8	4	3	7	8
8	3	7	8	5	5	3
3	5	5	3	3	7	2

	5	5				

New image(buffer)

5	5			

New image(buffer)

The median filter is a non linear filter (order filter). These filters are based on as specific type of image statistics called order statistics. Typically, these filters operate on small sub image, "Window", and replace the centre pixel value (similar to the convolution process).

Order statistics is a technique that arranges the entire pixel in sequential order, given an NXN window (W) the pixel values can be ordered from smallest to the largest.

$$\mathbf{I_1 \leq I_2 \leq I_3 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots < I_N}$$

Where $\mathbf{I_1, I_2, I_3 \ldots\ldots\ldots, I_N}$ are the intensity values of the subset of pixels in the image.

2	7	8	8	3	7	8
5	6	3	3	5	5	3
3	7	2	2	3	7	2
3	7	8	4	3	7	8
8	3	7	8	5	5	3
3	5	5	3	3	7	2

image

2,2,3,3,5,6,7,7,8

	5					

New image(buffer)

Example:

Given the following 3X3 neighborhood

$$\begin{pmatrix} 5 & 5 & 6 \\ 3 & 4 & 5 \\ 3 & 4 & 7 \end{pmatrix}$$

We first sort the value in order of size (3,3,4,4,5,5,5,6,7) ; then we select the middle value , un this case it is 5. This 5 is then placed in centre location.

A median filter can use a neighbourhood of any size, but 3X3, 5X5 and 7X7 are typical. Note that the output image must be written to a separate image (a buffer); so that the results are not corrupted as this process is performed.

(The median filtering operation is performed on an image by applying the sliding window concepts, similar to what is done with convolution).

The midpoint filter is actually both order and mean filter because it rely on ordering the pixel values , but then calculated by an averaging process. This midpoint filter is the average of the maximum and minimum within the window as follows:

$$\text{Order set} = \mathbf{I_1 \leq I_2 \leq I_3 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \leq I_{N^2}}.$$

$$\textbf{Midpoint} = \mathbf{(I_1 + I_{N^2})/2}$$

The midpoint filter is most useful for Gaussian and uniform noise.

2.5.3 The Enhancement filter:

The enhancement filters are:

1. Laplacian type.
2. Difference filter.

These filters will tend to bring out, or enhance details in the image.

Example of convolution masks for the Laplacian-type filters are:

$$\begin{pmatrix} 0 & -1 & 0 \\ -1 & 5 & -1 \\ 0 & -1 & 0 \end{pmatrix} \quad \begin{pmatrix} -1 & -1 & -1 \\ -1 & 9 & -1 \\ -1 & -1 & -1 \end{pmatrix} \quad \begin{pmatrix} -2 & 1 & -2 \\ 1 & 5 & 1 \\ -2 & 1 & -2 \end{pmatrix}$$

The Laplacian type filters will enhance details in all directions equally.

a. Original image

b. Laplacian filtered image

The difference filters will enhance details in the direction specific to the mask selected. There are four different filter convolution masks, corresponding to lines in the vertical, horizontal and two diagonal directions.

Vertical

$$\begin{pmatrix} 0 & 1 & 0 \\ 0 & 1 & 0 \\ 0 & -1 & 0 \end{pmatrix}$$

Horizontal

$$\begin{pmatrix} 0 & 0 & 0 \\ 1 & 1 & -1 \\ 0 & 0 & 0 \end{pmatrix}$$

Diagonal 1

$$\begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & -1 \end{pmatrix}$$

Diagonal 2

$$\begin{pmatrix} 0 & 0 & 1 \\ 0 & 1 & 0 \\ -1 & 0 & 0 \end{pmatrix}$$

a. Original image

b. Difference filtered image

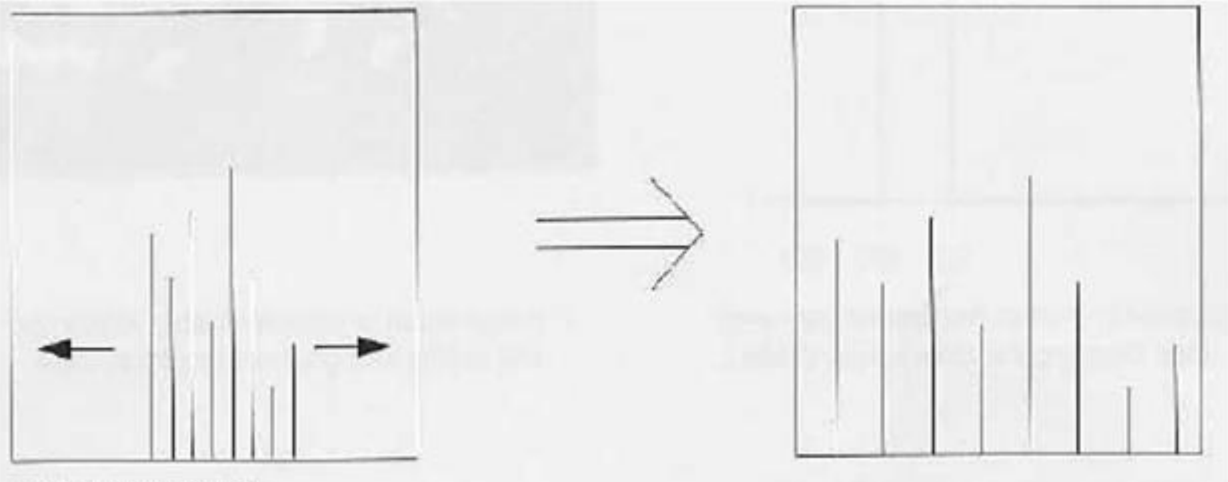
Image Enhancement: Image Histogram

Image Histogram is a graph that indicates the number of occurrence (times) of a gray level (intensity) in the image. It provides important information about:

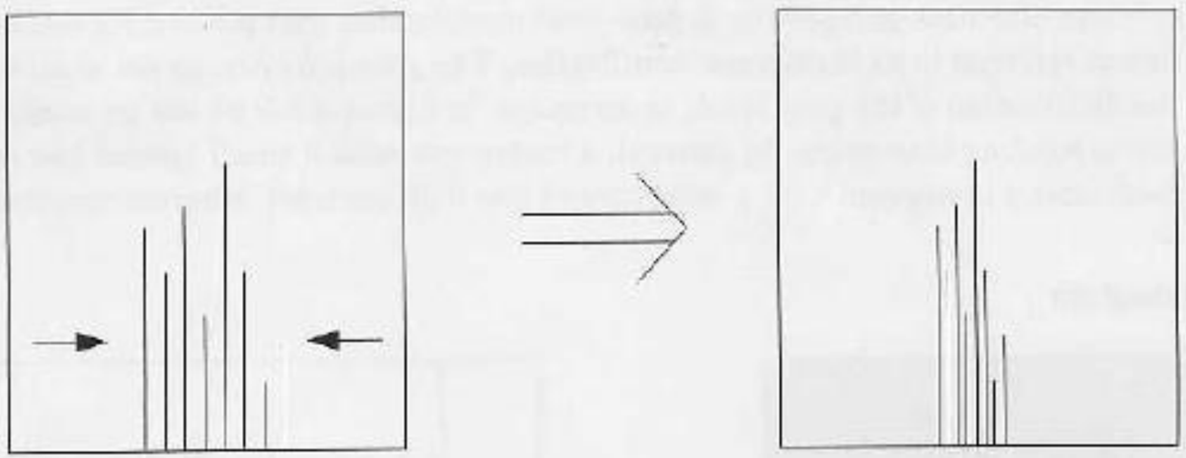
- In a dark image, the gray level would be clustered at the lowest level (left side of histogram)
- In a bright image, the gray level would be clustered at the highest level (right side of histogram)
- In a well contrasted image, the gray-level would be well spread out over the range

histogram can be modified by mapping functions, which will stretch, shrink

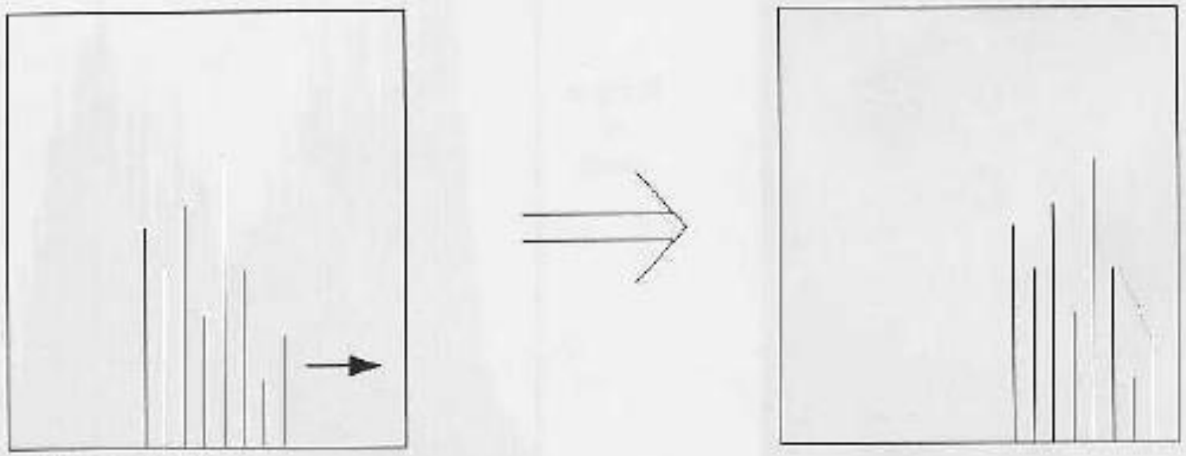
(compress), or slide the histogram. Figure illustrates a graphical representation of histogram stretch, shrink and slide.



ε. Histogram stretch



b. Histogram shrink.



c. Histogram slide.

- **RGB to Grey Image Converting:**

The RGB colored image like the pixel (r,g,b) = (**100,10,150**) could be converted to a gray image using one of the following formula,

1. The **Average** method, simply average the values: (R + G + B)/3

   $gray = (100+10+150)/3 = 86.6667 = 87$

2. The **Lightness** method, averages the most prominent and least prominent colors (max (R,G,B) + min (R,G,B)) /2

   $gray = (150 + 10)/2 = \mathbf{80}$

3. The **Luminosity** method 0.21R + 0.71G + 0.07B. It is a more sophisticated version of the average method. It also averages the values, but it forms a weighted average to account for human perception. The fact is the humans are more sensitive to green than other colors, so green is weighted most heavily. The formula is,

   $gray = 0.21\ R + 0.71\ G + 0.07\ B = 38.6 = 39$

   The Luminosity method tends to reduce contrast. It works best overall and it is the default method used in most applications. Some images look better using one of the other algorithms. Sometimes the four methods produce very similar result.

4. The **weighted average** method, 0.299R+ 0.587G+ 0.114B