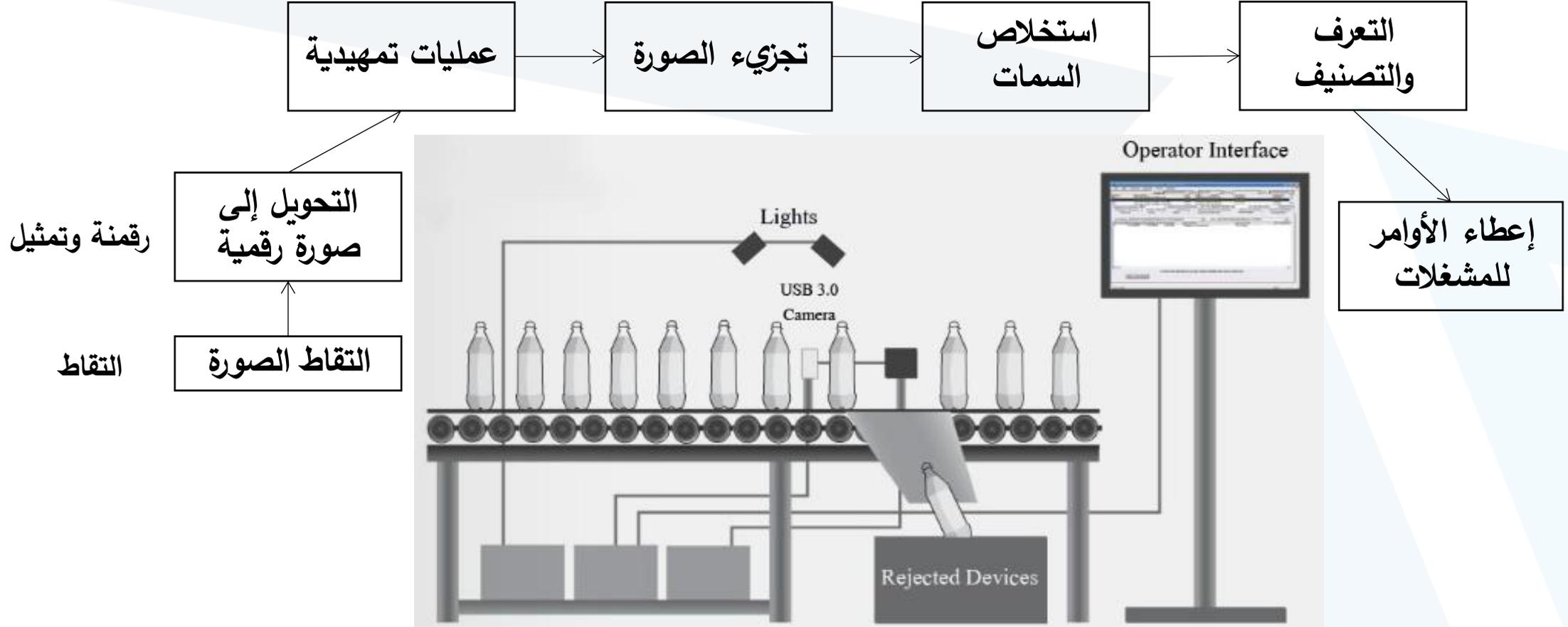


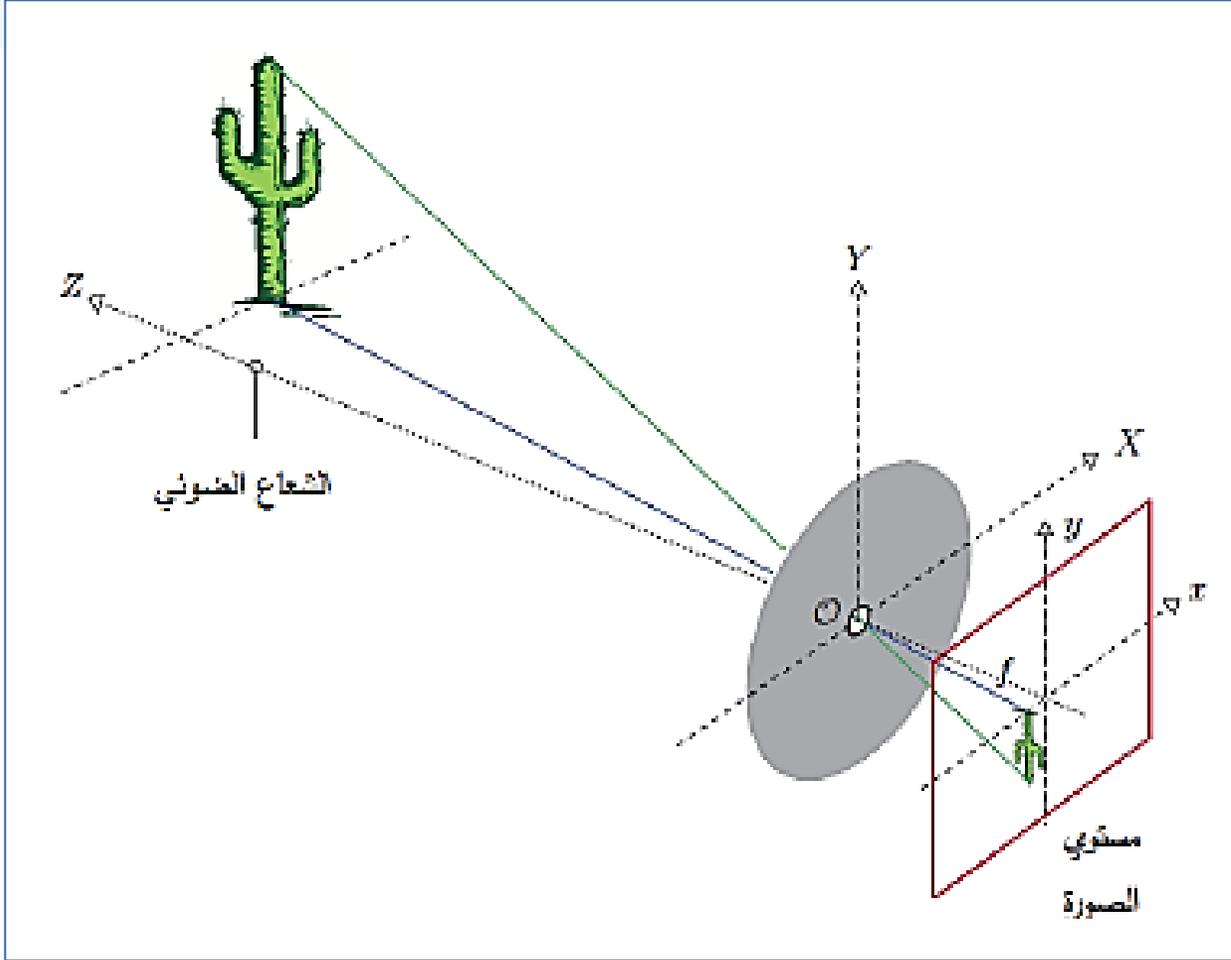
Computer vision

المحاضرة الثانية Digital Image Fundamental

د. عيسى الغنام د. إياد حاتم



التقاط الصور



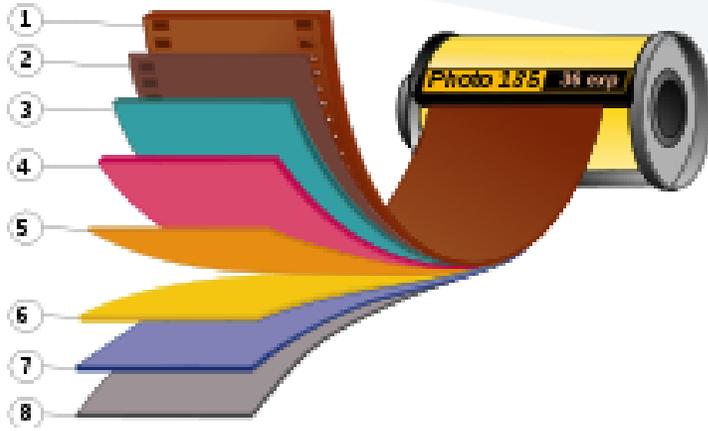
□ يعرف التقاط الصور بأنه عملية الحصول على الصورة
 من مصدر ما بحيث تصبح هذه الصور جاهزة لأي عملية
 معالجة قادمة

□ أبسط نموذج للحصول على الصور هو الكاميرا ذات الثقب

▪ يعكس نموذج هذه الكاميرا العلاقة الرياضية بين
 إحداثيات نقطة في الفراغ وانعكاس هذه النقطة على
 مستوي الصورة

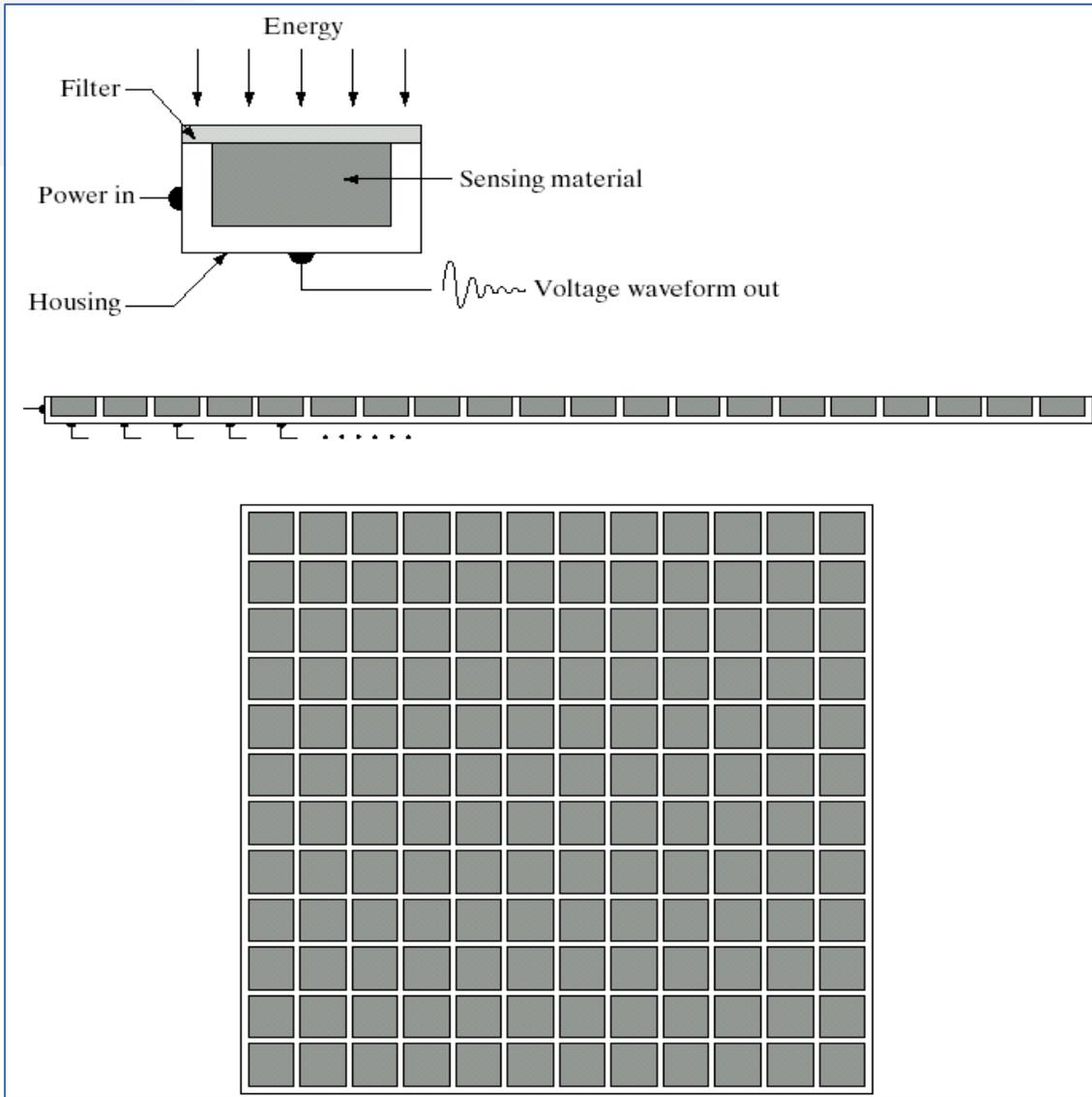
$$x = -fX/Z$$

$$y = -fY/Z$$



تلتقط الصور في المجال المرئي بواسطة الكاميرا العادية
تسجل الصور على فيلم مؤلف من قطعة بلاستيكية تحمل طبقة رقيقة
من الجيلتين الذي يحوي مواد كيميائية حساسة للضوء
تسجل المعلومات بما يسمى الصورة السلبية التي تعالج للحصول على
الصورة الأصلية

Image Sensors



Single sensor

Line sensor

Array sensor

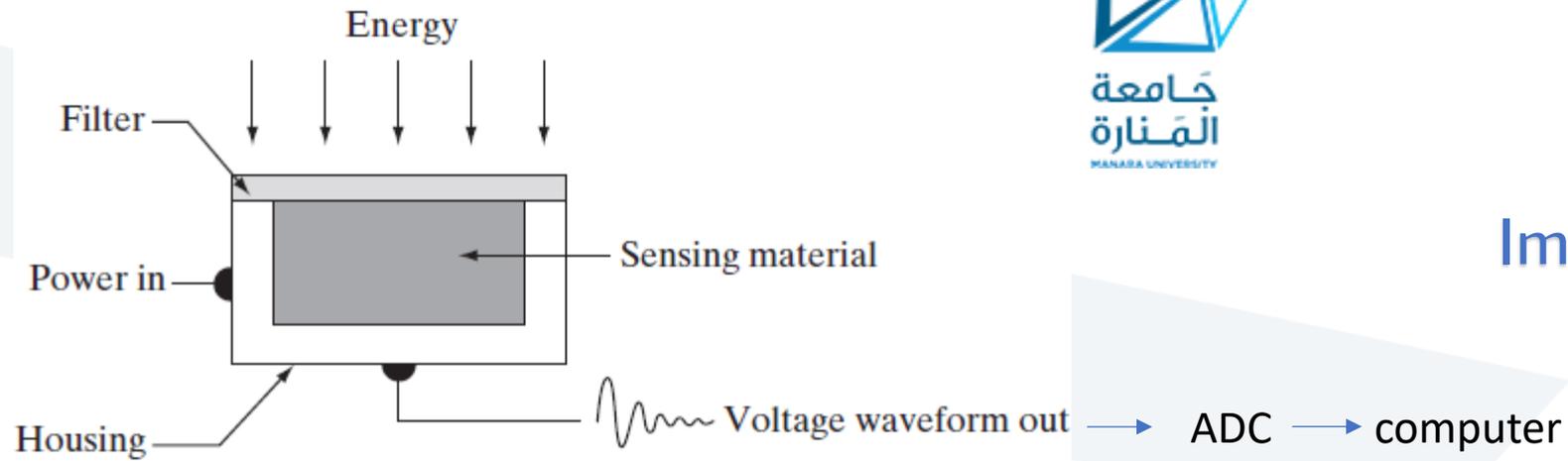


Image Sensors : Single Sensor

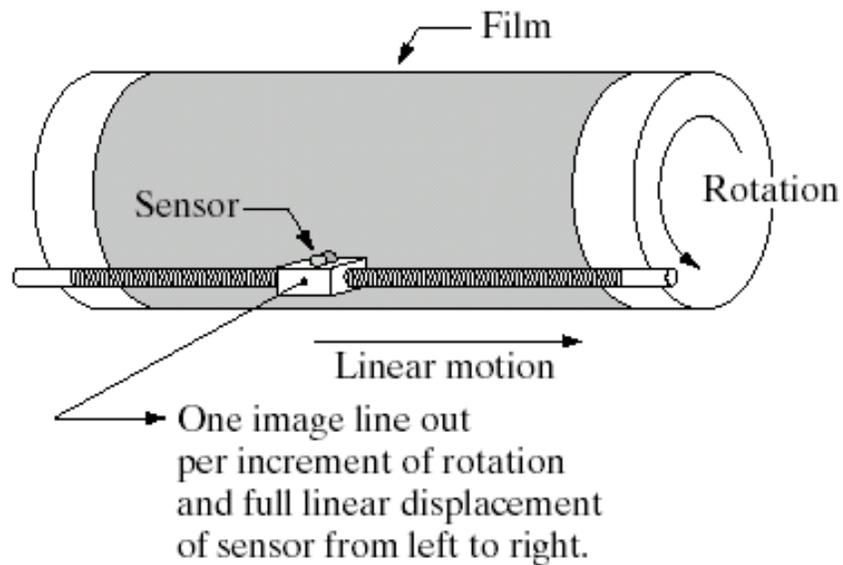
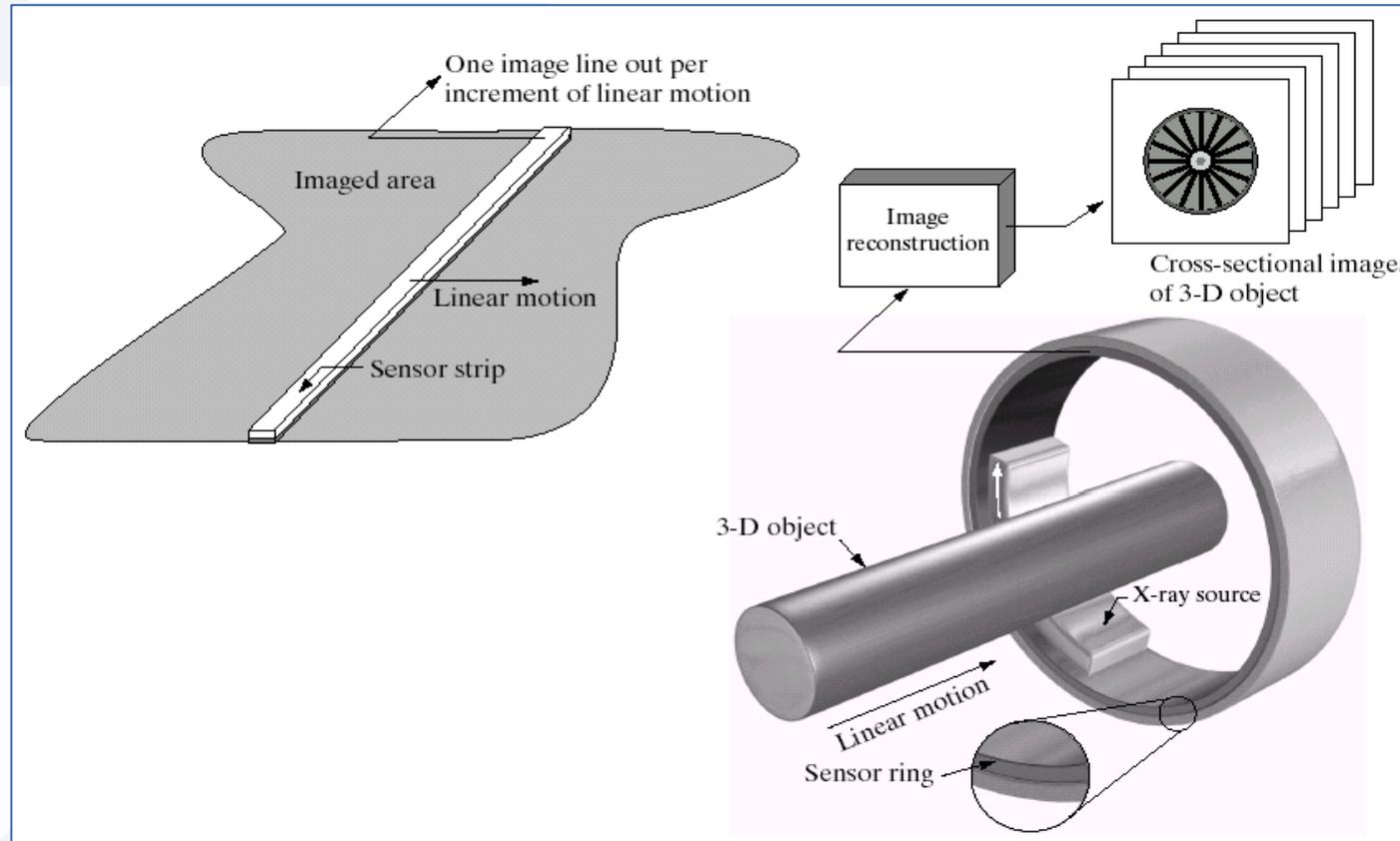
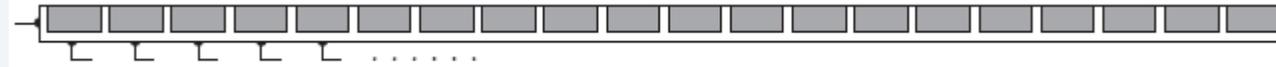


FIGURE 2.13 Combining a single sensor with motion to generate a 2-D image.

Image Sensors : Line Sensor



Fingerprint sweep sensor

Computerized Axial Tomography

Image Sensors : Array Sensor

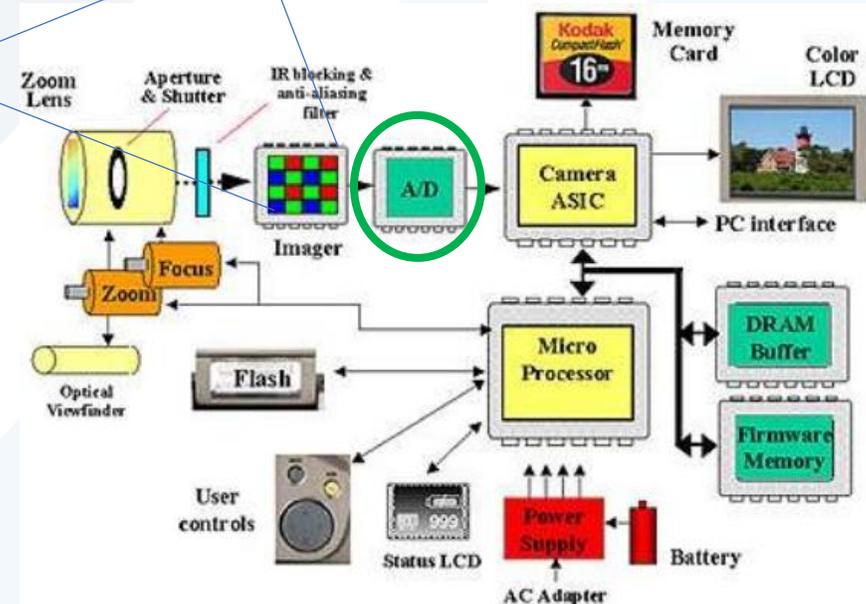
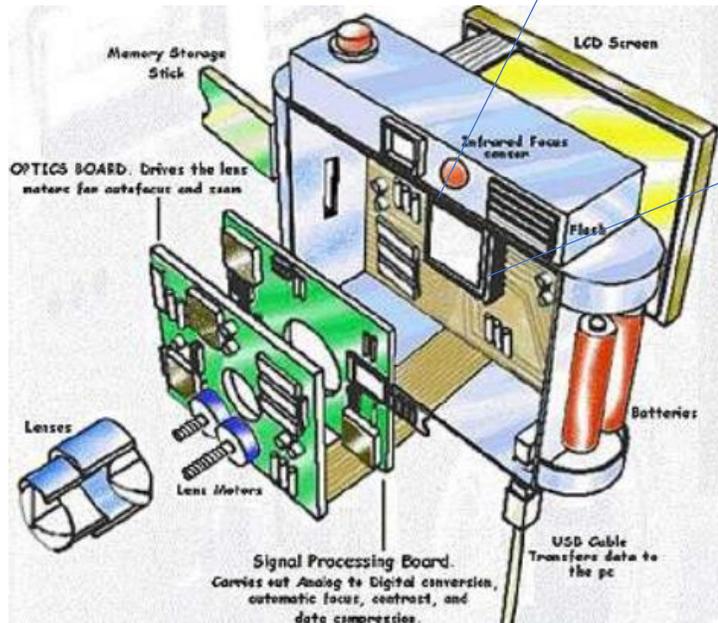
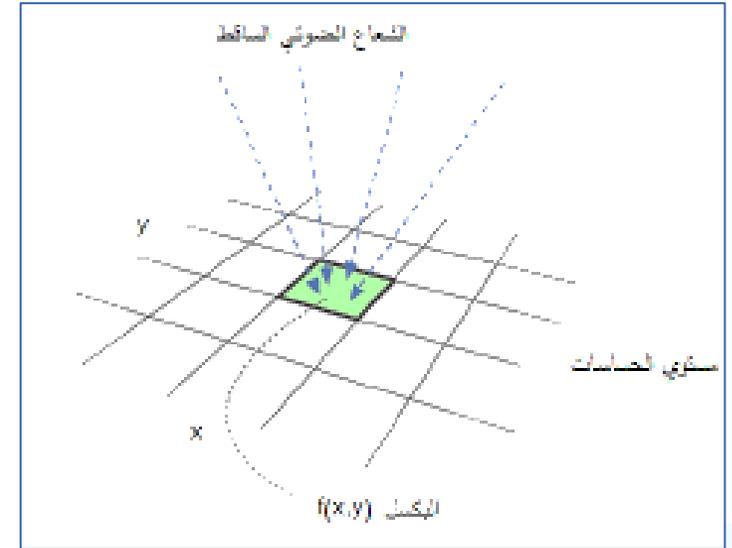
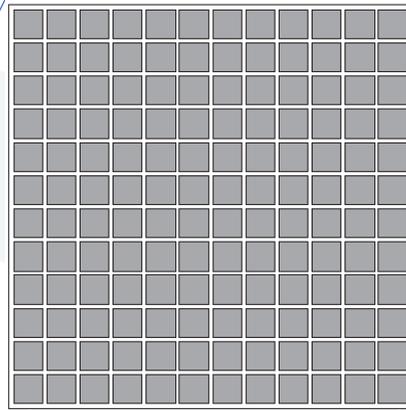
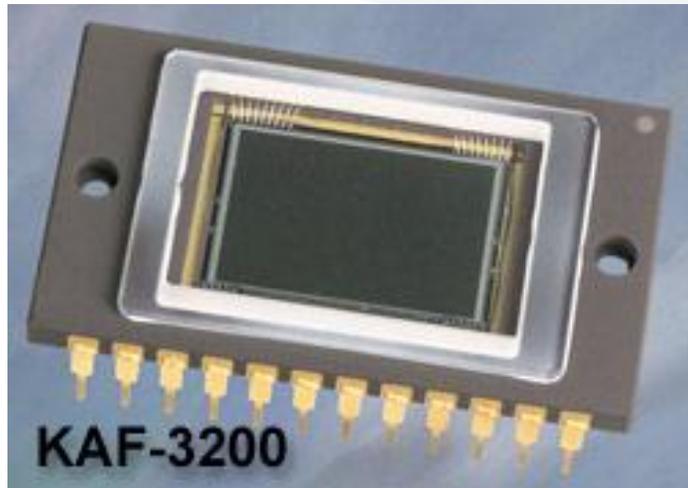


Image Sensors : Array Sensor Charge-Coupled Device (CCD)



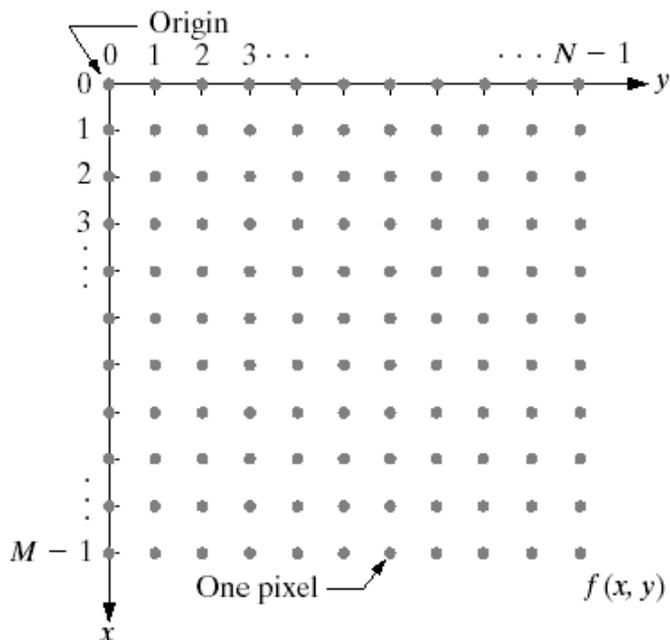
CCD KAF-3200E from Kodak.
(2184 x 1472 pixels,
Pixel size 6.8 microns²)

- Used for convert a continuous image into a digital image
- Contains an array of light sensors
- Converts photon into electric charges accumulated in each sensor unit

تمثيل الصورة الرقمية

تمثل الصورة الرقمية بالمصفوفة الآتية

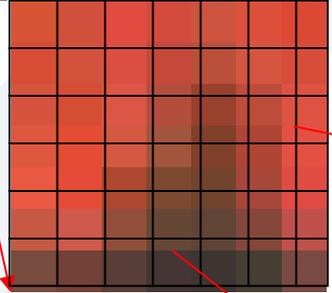
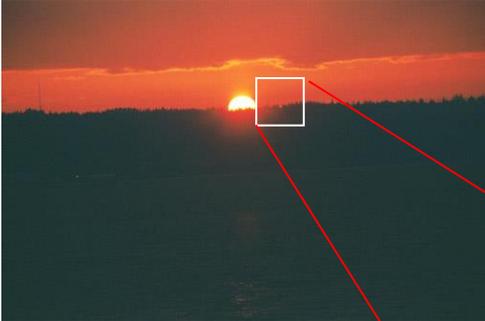
Digital image: an image that has been discretized both in Spatial coordinates and associated value.



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

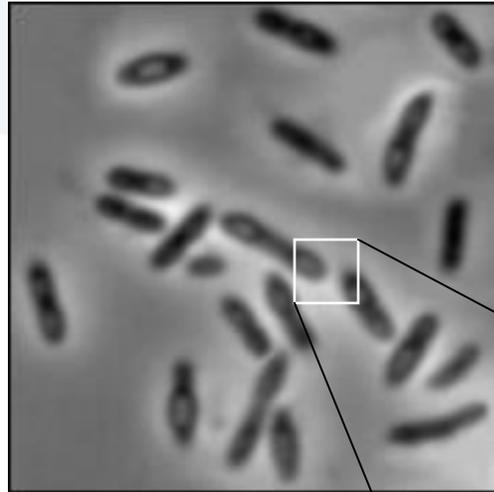


Digital Image Types : RGB Image Digital Colored Image


$$\begin{bmatrix} 10 & 10 & 16 & 28 \\ 9 & 65 & 70 & 56 & 43 \\ 15 & 32 & 99 & 26 & 70 & 37 & 56 & 78 \\ 32 & 21 & 69 & 13 & 90 & 22 & 96 & 67 \\ 54 & 15 & 85 & 87 & 85 & 39 & 43 & 92 \\ & & 32 & 65 & 87 & 99 \end{bmatrix}$$

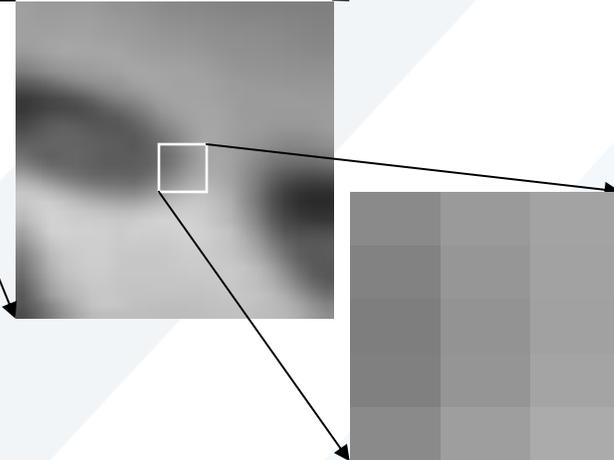
Digital Image Types :

Intensity Image or gray image



Intensity image or monochrome image

each pixel corresponds to light intensity normally represented in gray scale (gray level).

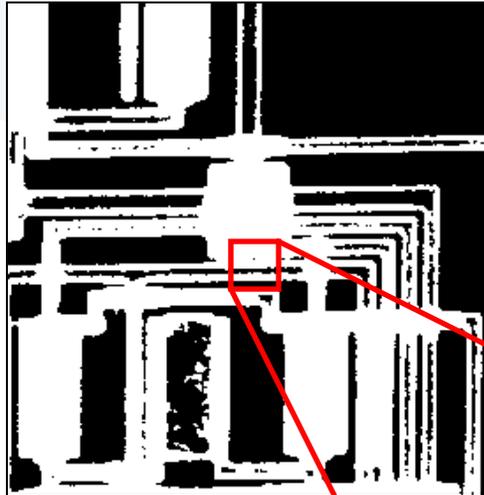


Gray scale values



10	10	16	28
9	6	26	37
15	25	13	22
32	15	87	39

Image Types : Binary Image



Binary image or black and white image

Each pixel contains one bit :

1 represent white

0 represents black



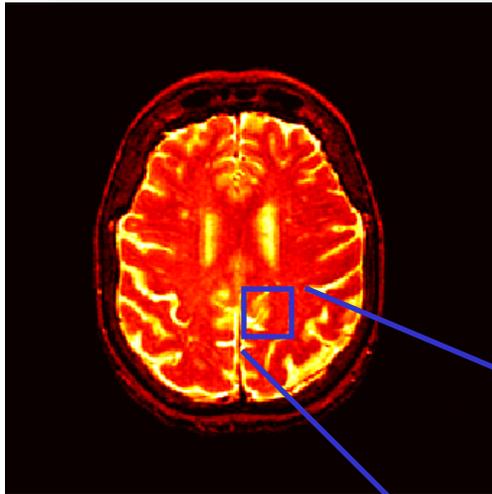
Binary data

$$\begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 \end{bmatrix}$$

Image Types : Index Image

Index image

Each pixel contains index number pointing to a color in a color table



$$\begin{bmatrix} 1 & 4 & 9 \\ 6 & 4 & 7 \\ 6 & 5 & 2 \end{bmatrix}$$

Index value

Color Table

Index No.	Red component	Green component	Blue component
1	0.1	0.5	0.3
2	1.0	0.0	0.0
3	0.0	1.0	0.0
4	0.5	0.5	0.5
5	0.2	0.8	0.9
...

أمثلة عن أنواع الصور المختلفة



صورة ثنائية



صورة رمادية



صورة مفهرسة



صورة ملونة



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التحويل بين أنواع الصور في Matlab

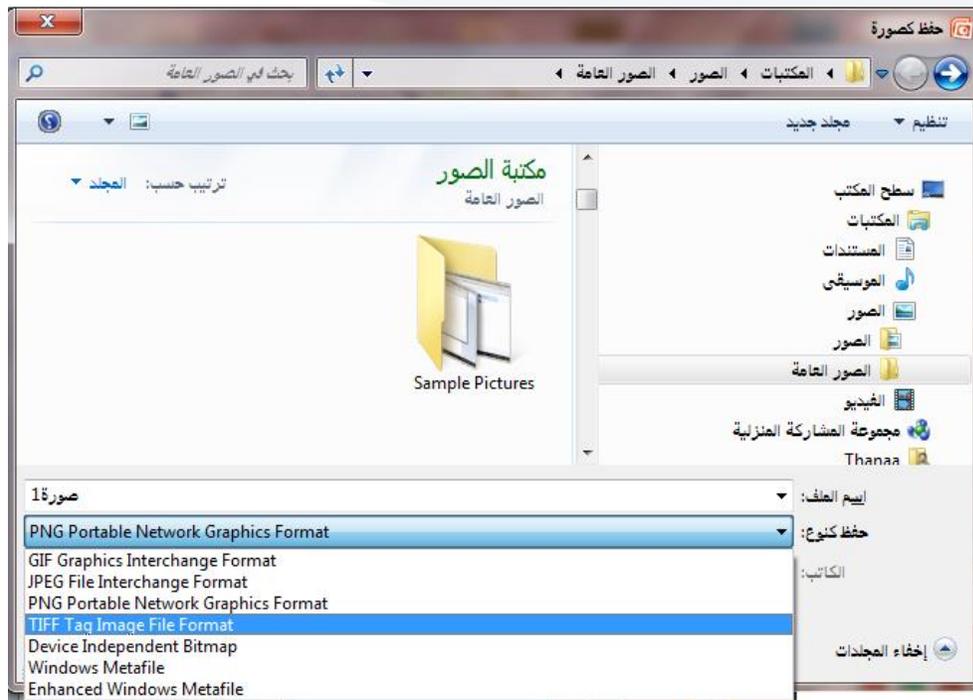
	Binary BW	Grayscale I	Truecolor RGB	Indexed X, map
BW	-	x	x	gray2ind
I	im2bw	-	x	gray2ind
RGB	im2bw	rgb2gray	-	rgb2ind
X, map	im2bw	rgb2gray	ind2rgb	-

صيغ ملفات الصور

□ يعطي نوع ملف الصورة معلومات عن التخزين في الذاكرة والأرشفة وتبادل بيانات الصور

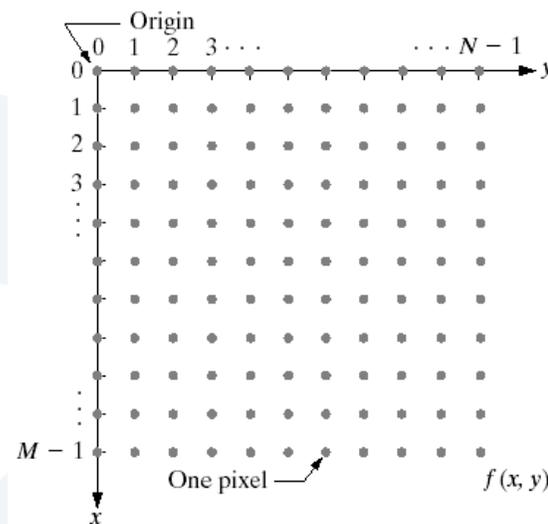
□ معايير اختيار صيغة مناسبة لصورة ما:

- نوع وحجم الصورة
- المساحة التخزينية وضغط الصورة (Lossy, Lossless)
- التوافق
- مجال التطبيق





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$$f(x,y) \equiv \begin{matrix} f(0,0) & f(0,1) & \dots & f(0,N-1) \\ f(1,0) & f(1,1) & \dots & f(1,N-1) \\ \vdots & \vdots & \dots & \vdots \\ f(M-1,0) & f(M-1,1) & \dots & f(M-1,N-1) \end{matrix}$$

An image that has been discretized both in Spatial coordinates and associated value.

An image: a multidimensional function of spatial coordinates.

- ❖ Spatial coordinate (point set): (x,y) for 2D case such as photograph, (x,y,z) for 3D case such as color image
- ❖ The function f (value set) may represent intensity (for monochrome images) or color (for color images) or other associated values.

An element of the image, $(x,y), f(x,y)$ is called a pixel

where:

- x,y is called the pixel location and
- $f(x,y)$ is the pixel value at the location x,y

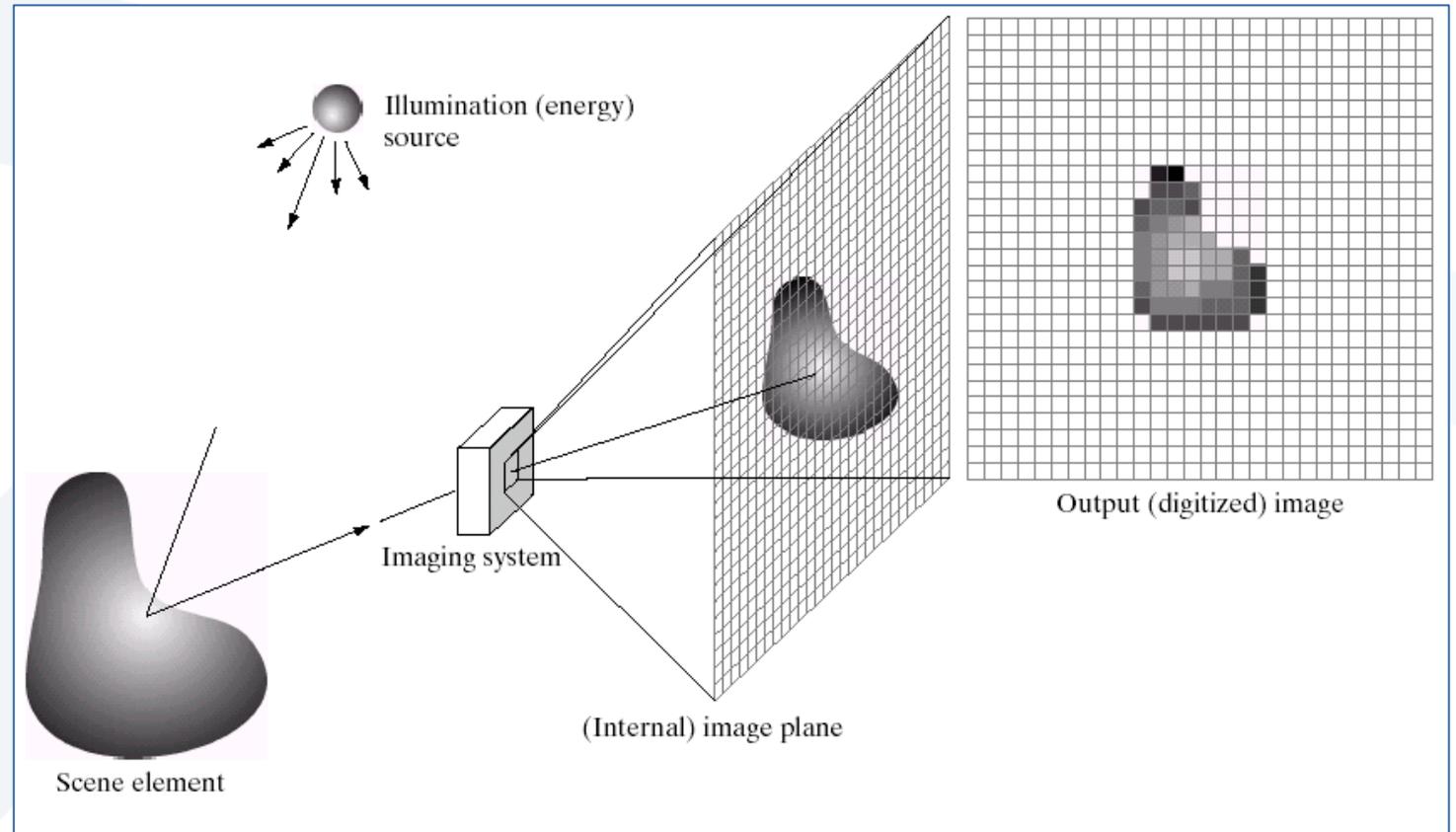
Digitization Process

To convert continuous image (in real life) to digital image (in computer) we use Two processes:

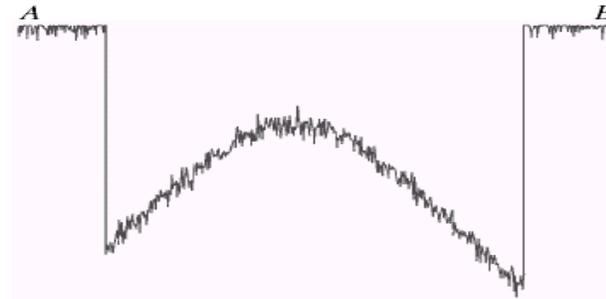
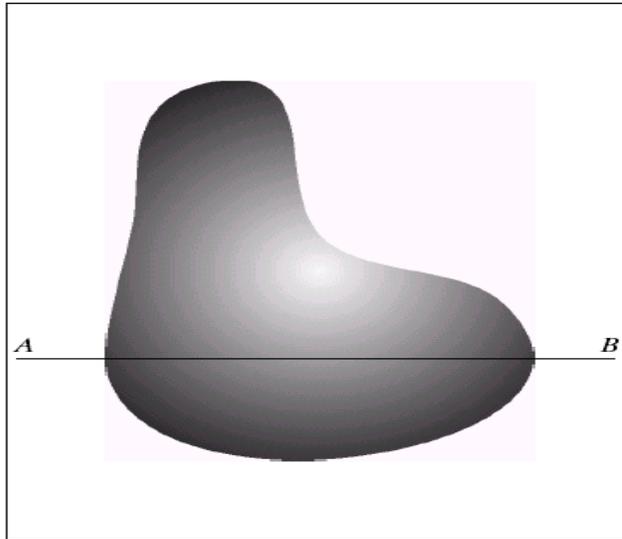
Sampling: digitizing the coordinate values

Quantization: digitizing the amplitude values or intensities.

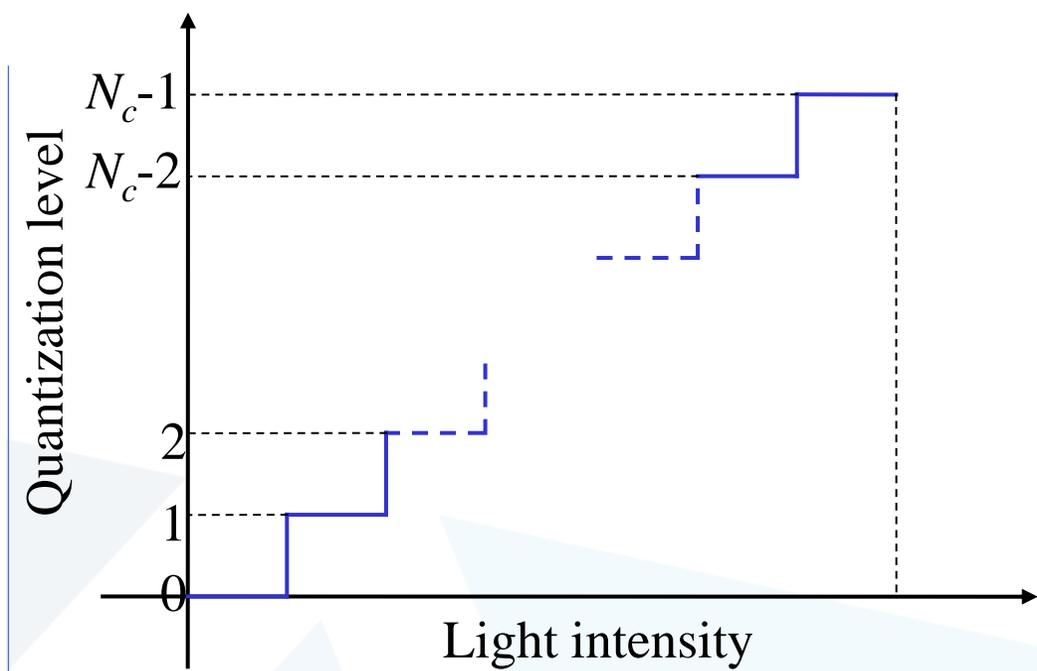
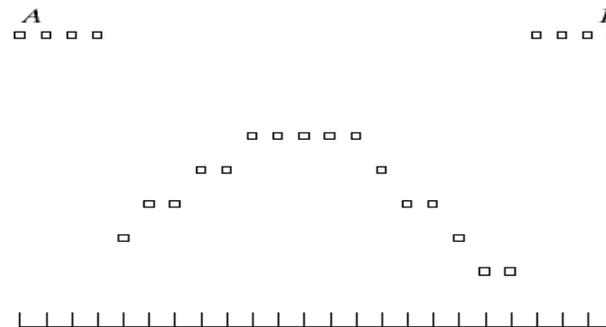
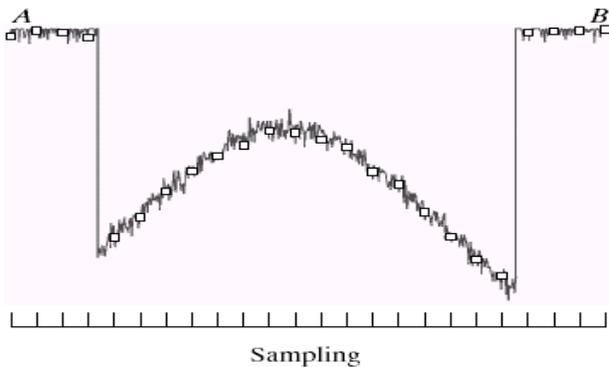
- Thus, when x , y and f are all finite, discrete quantities, we call the image a digital image.



Digitization Process- Sampling and Quantization function



Gray-level scale that divides gray-level into 8 discrete levels from $b(0)$ to $w(7)$

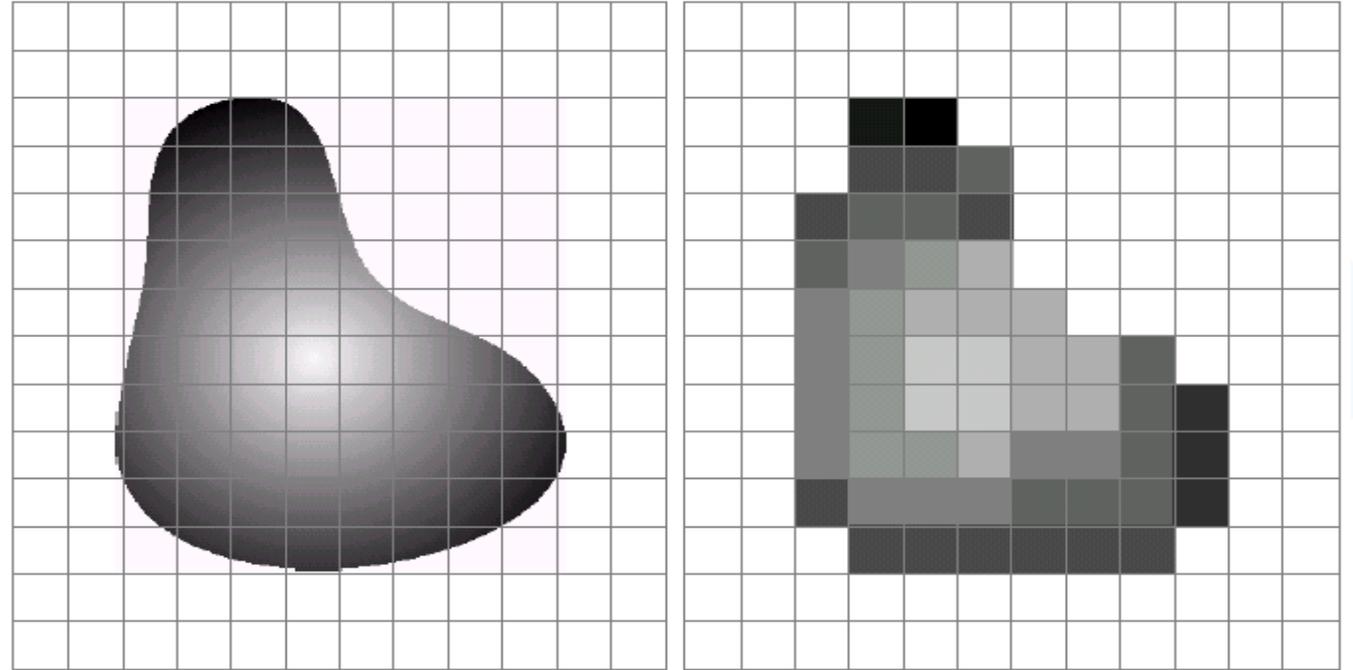


- **Image sampling:** discretize an image in the spatial domain (digitizing coordinates)
- **Image quantization:** discretize or convert **continuous pixel values** (each sample gray level value) into **discrete numbers** (digital quantity) -> digitizing intensities

sample is a small white square, located by a vertical tick mark as a point x,y

Digitization Process- Sampling and Quantization function

The continuous image VS the result of digital image after sampling and quantization



a b

FIGURE 2.17 (a) Continuous image projected onto a sensor array. (b) Result of image sampling and quantization.

عمق البت bit depth أو عمق البكسل pixel depth

- **BIT DEPTH** is determined by the number of bits used to define each pixel. The **greater the bit depth**, the greater **the number of tones (grayscale or color)** that can be represented.
- **Pixel depth**, also known as bit depth, refers to the **amount of information stored in each pixel of a digital image**. It is typically measured in **bits per pixel (bpp)**, with common values being 1 bpp (black and white), 8 bpp (grayscale)

يعتمد عدد سويات الشدة الضوئية المستخدمة L لتمثيل الصورة على k عدد البتات المخصصة لترميز كل بكسل، وهو ما يدعى عمق البت أو عمق البكسل

$$k=8$$

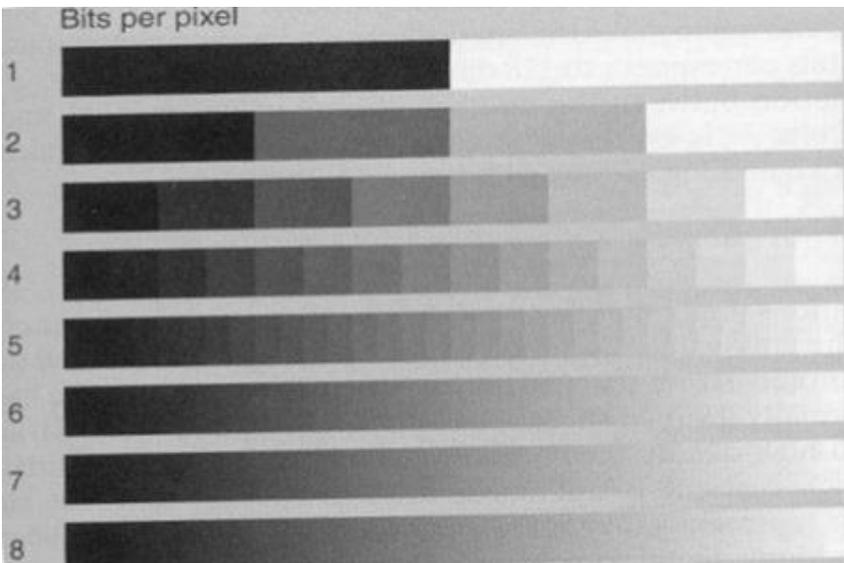
مثال:

$$L = 2^k \text{ where } k = \text{No. of bits representing each pixel value}$$

$L=256$; $[0-255]$ No. of colors or gray levels OR **Color resolution/ color depth/ levels:**

- **Color depth** refers to the maximum number of colors an image can contain. Color depth is determined by the bit depth of an image (the number of binary bits that define the shade or color of each pixel in a bitmap). For example, a pixel with a bit depth of 1 can have two values: black and white.

$$b = M * N * K \quad \text{حجم الصورة بالبتات}$$



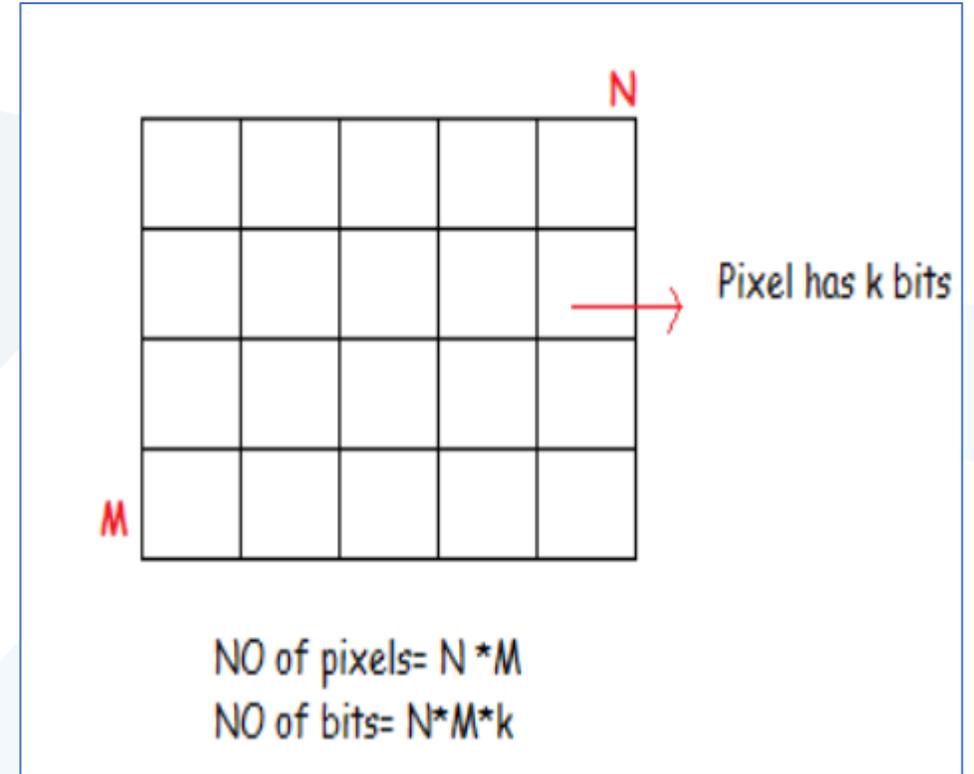
Number of storage of bits:

- $N * M$: the no. of pixels in all the image.
- K : no. of bits in each pixel
- L : grayscale levels the pixel can represent: $L = 2^K$
- all bits in image = $N * M * k$

EX: Here: $M=N=32$, $K=3$, $L = 2^3=8$

of pixels = $N * M = 1024$. (because in this example: $M=N$)

of bits = $N * M * K = 1024 * 3 = 3072$ bits.



تصنيف الصور اعتمادا على عمق البت

الصور الملونة			
الاستخدامات	مجال القيم	بت/البكسل	عدد القيم في البكسل
النسخ. التصوير والطباعة الشائعة: RGB	$[0 \dots 255]^3$	24	3
النسخ. التصوير والطباعة عالية الدقة: RGB	$[0 \dots 4095]^3$	36	3
النسخ. التصوير والطباعة الاحترافية: RGB	$[0 \dots 16383]^3$	42	3
النسخ. الطباعة الملونة: CMYK	$[0 \dots 255]^4$	32	4

الصور الرمادية (صور الشدة الضوئية)			
الاستخدامات	مجال القيم	بت/البكسل	عدد القيم في البكسل
النسخ. التصوير والطباعة عرض الخطوط والرسوم. صورة ثنائية: المستندات والفاكس	$1 \dots 0$	1	1
النسخ. التصوير والطباعة الشائعة: RGB	$255 \dots 0$	8	1
النسخ. التصوير والطباعة عالية الدقة: RGB	$4095 \dots 0$	12	1
النسخ. التصوير والطباعة احترافية: RGB	$16383 \dots 0$	14	1
النسخ. الطباعة الصور الأعلى دقة: مجالي الطب والفلك.	$65535 \dots 0$	16	1

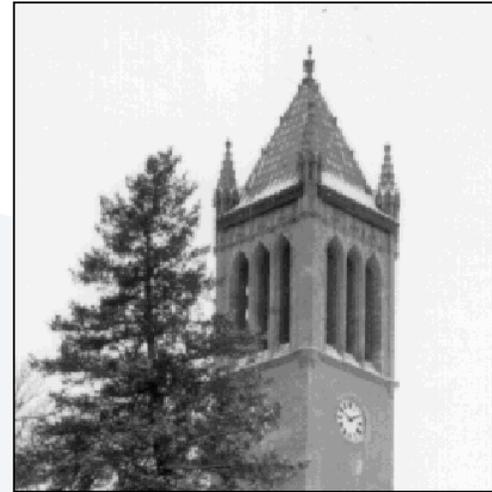
Effect of Quantization Levels



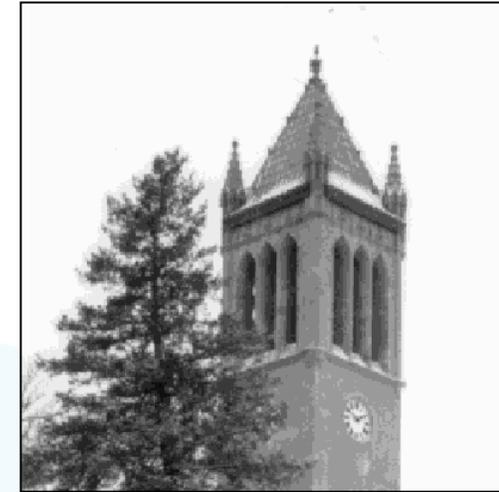
256 levels



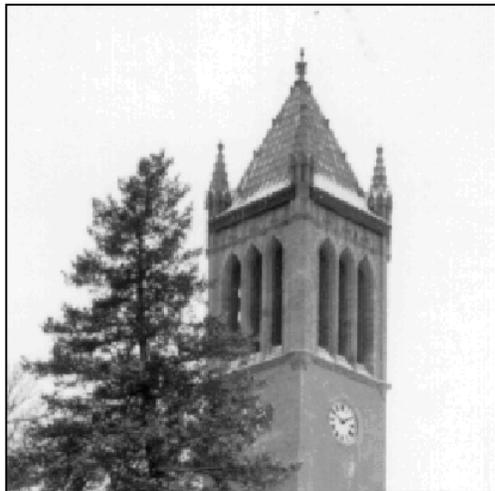
128 levels



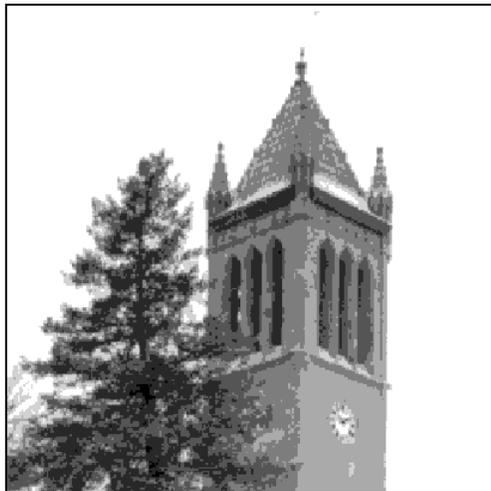
16 levels



8 levels

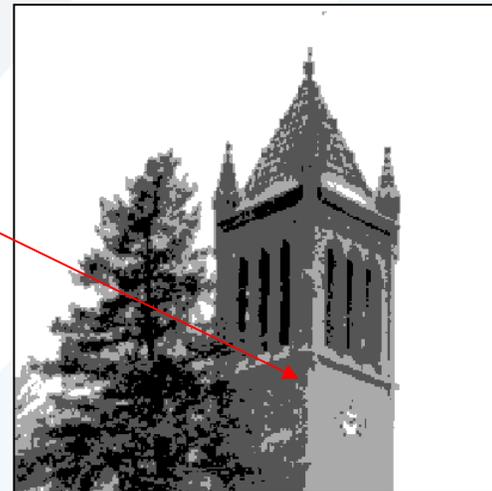


64 levels

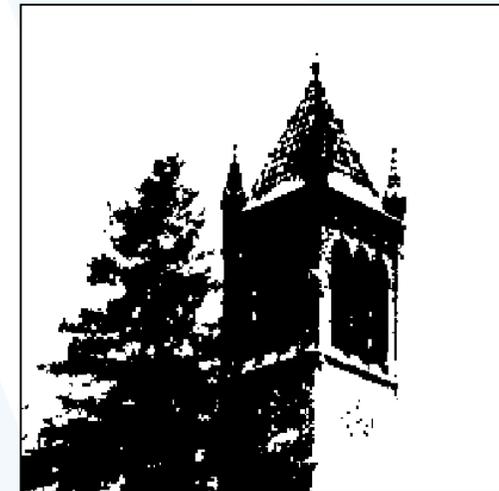


32 levels

In this image, it is easy to see false contour.



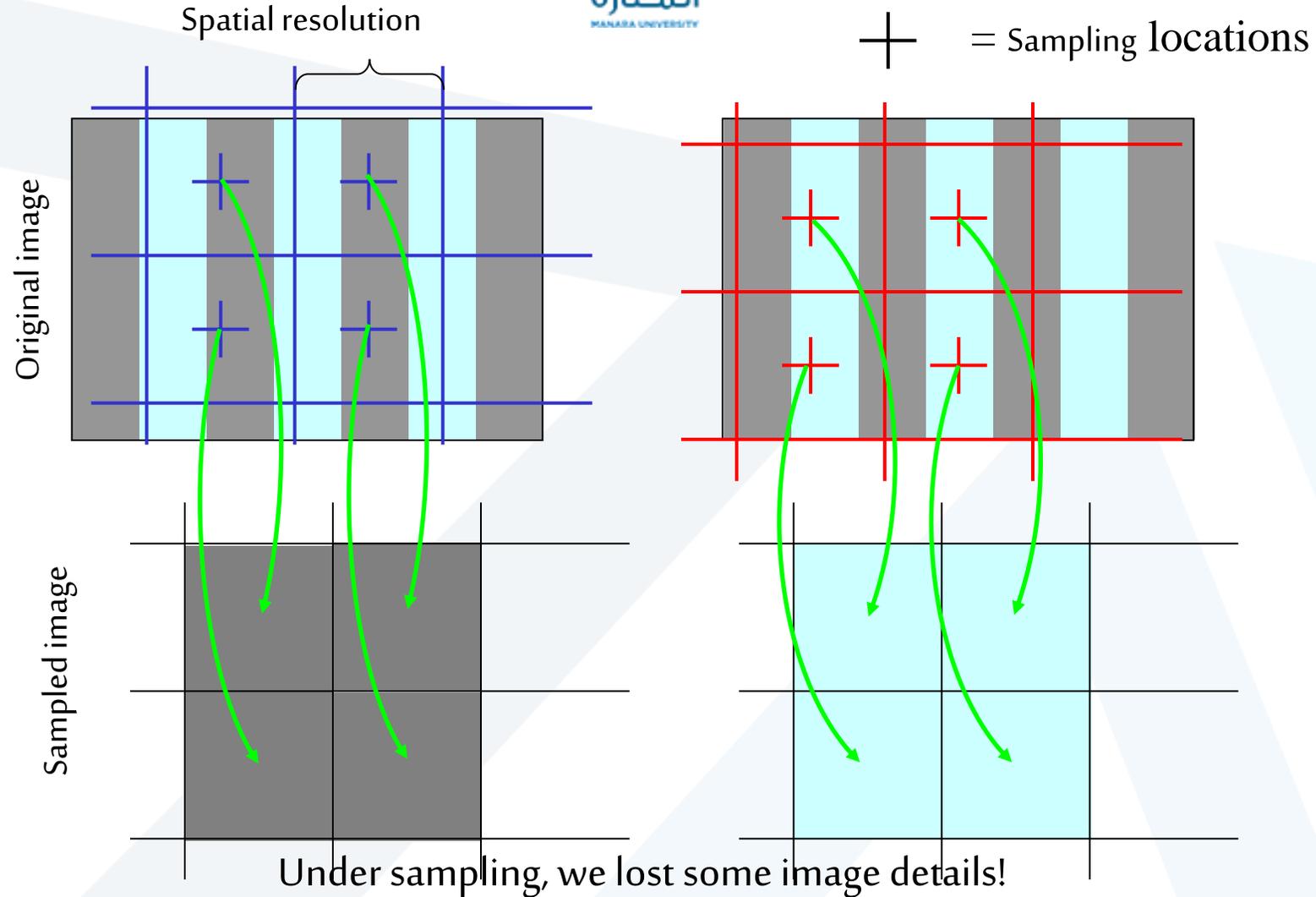
4 levels



2 levels

Effect of Spatial Resolution

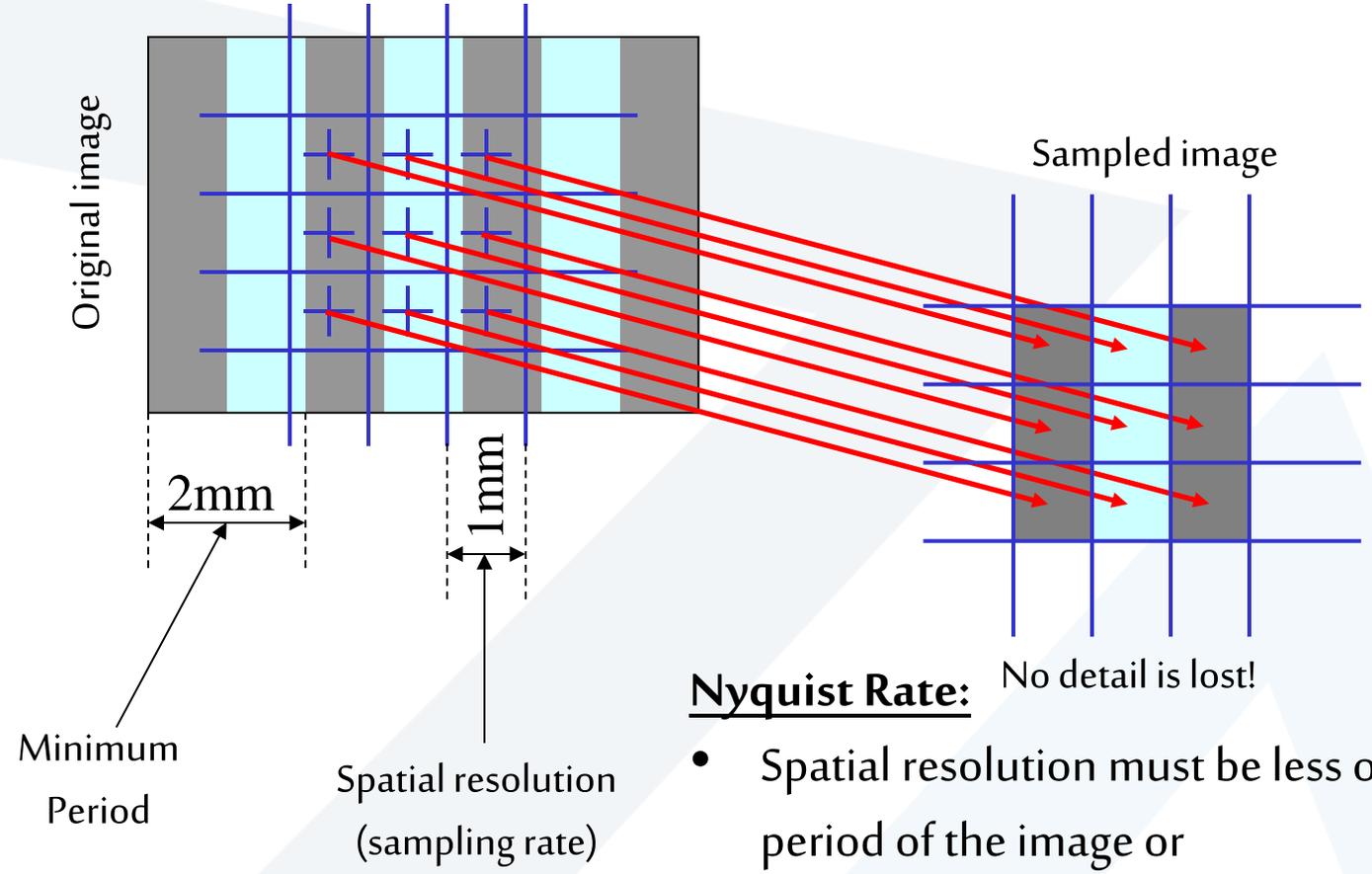
How to choose the spatial resolution



Effect of Spatial Resolution

How to choose the spatial resolution :

Nyquist Rate



Nyquist Rate:

No detail is lost!

- Spatial resolution must be less or equal half of the minimum period of the image or
- sampling frequency must be greater or Equal twice of the maximum frequency.

+ = Sampling locations

Effect of Spatial Resolution



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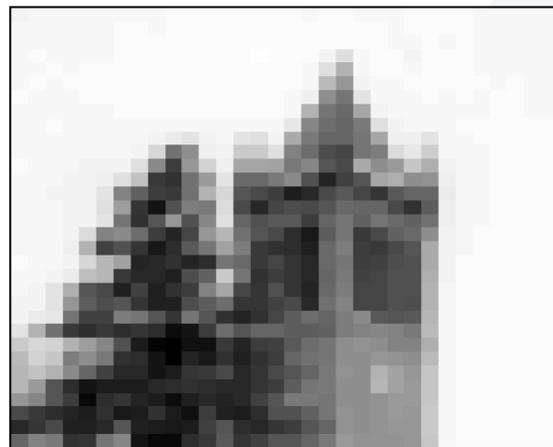
256x256 pixels



128x128 pixels



64x64 pixels



32x32 pixels



1X1



10X10



50X50



100X100

insufficient spatial
resolution-> appearance
of checkerboard pattern
in the image

Effect of Spatial Resolution Downsampling

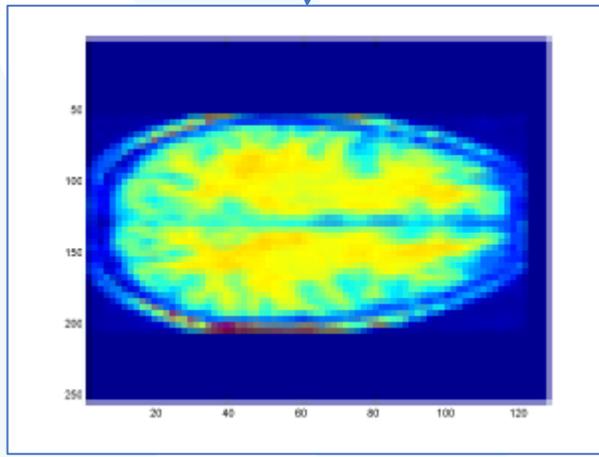
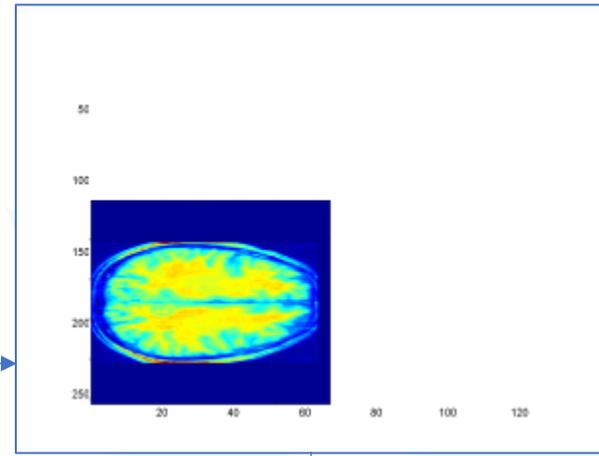
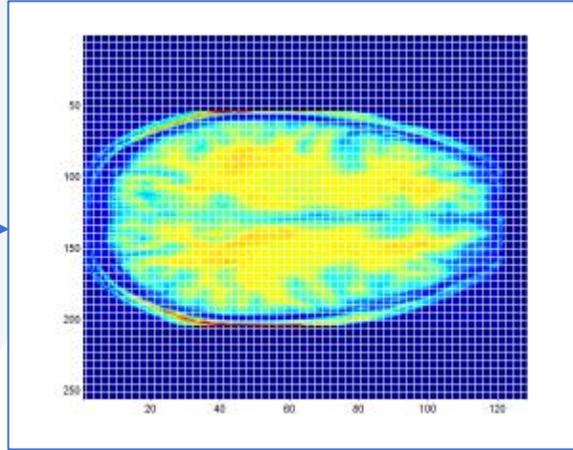
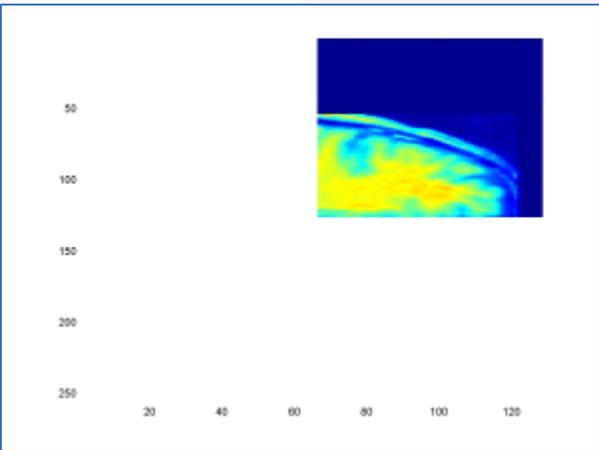
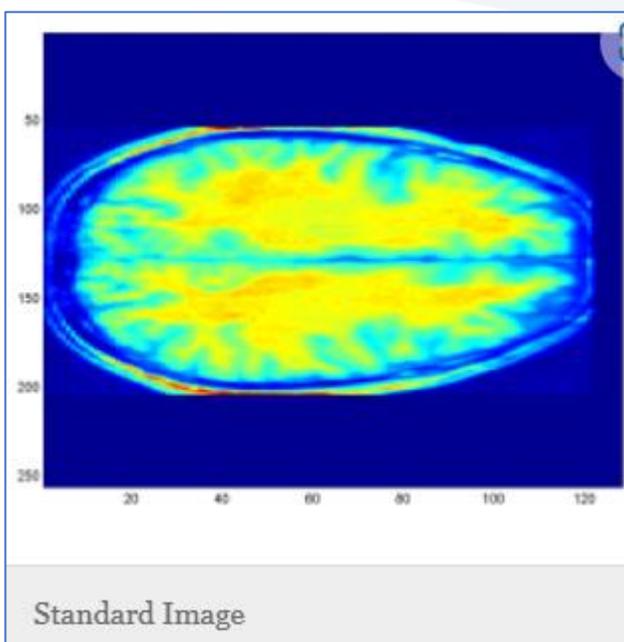
Downsampling:
“shrinking” an image’s dimensions you are essentially throwing away image information. (note: this is NOT the same as image compression),



- an image with dimensions $A \times B$,
- want to shrink it to the dimensions of $C \times D$, assuming that $A > C$ and $B > D$.
- The most straightforward way to do this is to discard entire columns/rows of data.
- delete $(A-C)$ columns, and $(B-D)$ rows.

FIGURE 2.19 A 1024×1024 , 8-bit image subsampled down to size 32×32 pixels. The number of allowable gray levels was kept at 256.

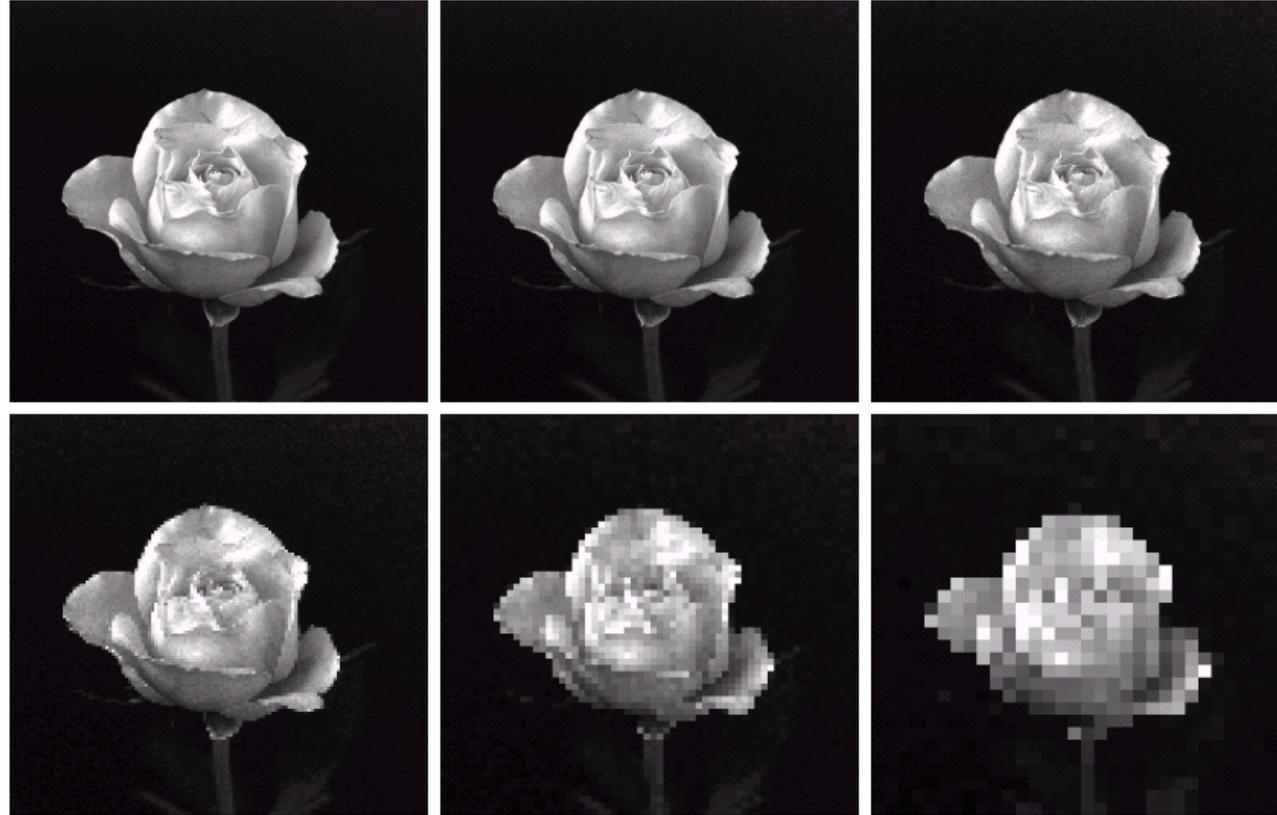
Effect of Spatial Resolution Downsampling



Effect of Spatial Resolution Upsampling (duplication):

Upsampling (duplication):

basically expanding an image, and filling in “gaps” in rows and columns of the original image. For example, say we want to increase the width and height of an image by a factor of 4. We could simply “repeat/redraw” each row and column of the original image 4 times.



a	b	c
d	e	f

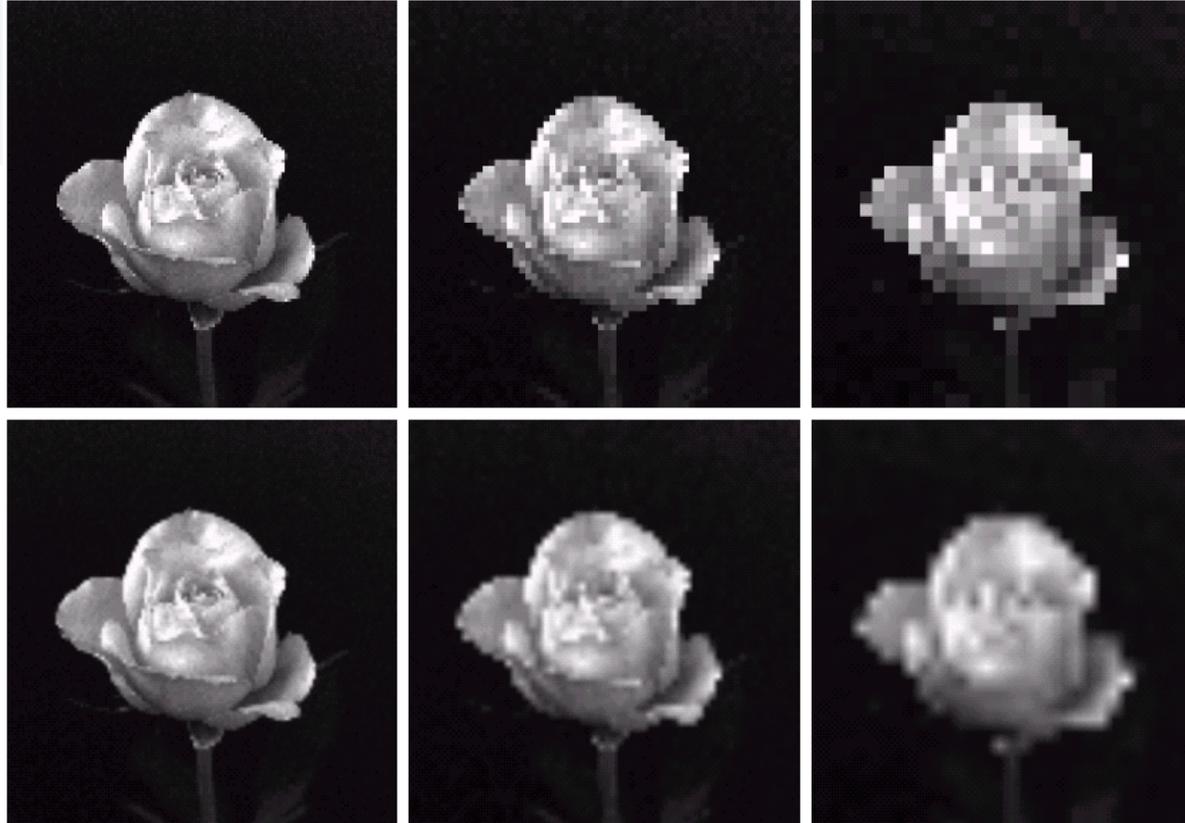
FIGURE 2.20 (a) 1024×1024 , 8-bit image. (b) 512×512 image resampled into 1024×1024 pixels by row and column duplication. (c) through (f) 256×256 , 128×128 , 64×64 , and 32×32 images resampled into 1024×1024 pixels.

A problem with this approach is that it only works when we want to increase the image dimensions by an integral factor (ie: 2, 4, 10), as it cannot deal with the case of image scaling by a fractional number (2.5, 10/3, etc).



Effect of Spatial Resolution Upsampling (interpolation):

Can we increase
spatial resolution by
interpolation ?



Down sampling is an
irreversible process.

- I - Nearest Neighbour Interpolation
- II – Bilinear Interpolation
- III - Bicubic Spline Interpolation
- IV - Generalized Bicubic Interpolation

a b c
d e f

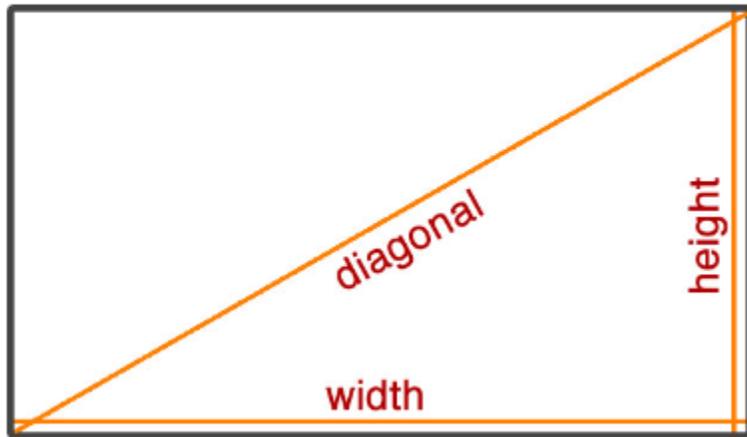
FIGURE 2.25 Top row: images zoomed from 128×128 , 64×64 , and 32×32 pixels to 1024×1024 pixels, using nearest neighbor gray-level interpolation. Bottom row: same sequence, but using bilinear interpolation.

- دقة الصورة هي وحدة قياس لأصغر جزء في الصورة يمكن تمييزه بالعين. تصبح معالم الصورة اوضح تبعا ل:
 1. حجم الصور ويحدد مباشرة من عدد الأسطر M وعدد الأعمدة N للمصفوفة الممثلة للصورة وبالتالي عدد البكسلات في الصورة وهو **لا يعطي معلومات دقيقة عن الدقة المكانية** ولا يحدد وضوحها لوحده.
 2. Spatial resolution الدقة المكانية: كلما كانت البكسلات متقاربة كانت الدقة أعلى. تحدد الدقة المكانية للصورة بعدد العناصر المميزة في واحدة القياس وتقاس بمقاييس مختلفة حسب التطبيق:
 - Dot per inch (dpi): monitors
 - Lines per inch (lpi): laser printers
 - Pixels per inch (ppi): tablets, Mobile- phones
 - Pixel per Km: satellite images
 - Samples per inch (spi): scanners
 3. **دقة الشدة الضوئية**: عدد القيم أو السويات اللونية الممكنة في الصورة (عمق البت)، كلما كانت اكثر كان لها قدرة اعلى على زيادة الدقة.

Spatial resolution: pixel size AND number of pixels

Calculate PPI

$$\text{diagonal} = \sqrt{\text{width}^2 + \text{height}^2}$$



$$\text{PPI} = \frac{\text{diagonal in pixels}}{\text{diagonal in inches}}$$

- A screen that is 1920 pixels wide by 1080 pixels high
- The diagonal is 10 inches= 25.4cm=254mm

$$\text{diagonal}_{\text{pixels}} = \sqrt{(1920^2 + 1080^2)}$$

$$\text{diagonal}_{\text{pixels}} = \sqrt{(3686400 + 1166400)}$$

$$\text{diagonal}_{\text{pixels}} = \sqrt{4852800}$$

$$\text{diagonal}_{\text{pixels}} = 2202.91 \text{ pixels}$$

$$\text{PPI} = \text{diagonal}_{\text{pixels}} / \text{diagonal}_{\text{inches}}$$

$$\text{PPI} = 2202.91 / 10$$

$$\text{PPI} = 220.29 \text{ pixels}$$

- So there are 220.29 pixels in a 1 inch line on the display (about 220.29/25.4=8.6 pixels per mm).
- $220.29^2 = 48528$ pixels per square inch
- So there are 48528 pixels in an area of the screen that is 1 inch wide by one inch high
- Screen length= 1920/220.29=8.71 inch=221.38 mm
- Screen width=1080/220.29=4.9 inch = 124.5 mm

How to Calculate the diagonal dot pitch



Diagonal dot pitch is the diagonal distance from the center of one pixel to the center of the next.

Dot pitch is calculated from the diagonal length in inches and pixels then converted from inches per pixel to millimeters per pixel but normally only expressed in millimeters (mm).

$$\text{PPI} = \frac{\text{diagonal in pixels}}{\text{diagonal in inches}}$$

$$\text{dot pitch} = \frac{\text{diagonal in inches}}{\text{diagonal in pixels}} \times \frac{25.4 \text{ mm}}{\text{inch}}$$

If a screen diagonal is 15.4 inches and has 3396 pixels. Dot pitch = $(15.4/3396) \times 25.4 \approx 0.1152$ mm.

Example

Pixel total	1000 x 1000 Pixel [1 Mpx]	Diagonal in pixels = $\sqrt{1000^2 + 1000^2}$ = 1414.2 pixels
Picture size	10inch*10inch	254 x 254 mm NOTE:1mm = 1000/254=4 pixels
dpi / ppi	100 dpi	Diagonal in inch = $\sqrt{10^2 + 10^2}$ = 14.142 inch
Color depth	8 Bit - MSX2 computer	
Disk space	1 MB	$PPI = diagonal_{pixels} / diagonal_{inches}$
Pitch	254 μm	PPI = 1414.2/14.142=100 pixel per inch = 100/25.4=4 pixel per mm
Pixel size	64516 μm^2	PITCH=(1/PPI)*25.4=(1/100)*25.4=0.254mm

Does smartphone having same camera sensor have different image quality?



There are several factors that can affect the quality of an image taken with a camera, even if they have the same number of pixels. Some of these factors include:

1. The resolution of the camera in megapixels.
2. The quality of the lens.
3. The sensor size AND The sensor technology used in the camera
4. the image processing software and algorithms used.
5. and the overall design and engineering of the camera.
6. lighting conditions: It's basically your camera's sensitivity to light. The higher the ISO sensitivity, the less light required to take a high-quality image. This is an important factor in determining your balance of settings in low or high light scenarios.
7. Additionally, external factors such as; movement, and subject matter can also play a role in the quality of the final image.
8. **Resolution 2880*2160 Aperture F1.7 Focal length:4.2mm Flash ISO Exposure time:1/50s**

Resolution: How Much Is Enough?

The word “suitable” is subjective: depending on “subject”.



The picture on the right is fine for counting the number of cars, but not for reading the number plate



Low detail image
Lena image



Medium detail image
Cameraman image



High detail image

نهاية المحاضرة