

# Computer Vision, and Digital Image Processing

Prepared by Dr. Mohamed Mostafa

AI 612

## Lecture 1



The background features a series of vertical panels with rounded ends. The leftmost panel shows a person's hands typing on a laptop. The subsequent panels contain various white line-art icons on a semi-transparent background: a graduation cap, a play button, a target with an arrow, an open book, a magnifying glass, and a group of people. The rightmost panel is plain white.

# Digital Image Processing

## Lecture 1

AI 612

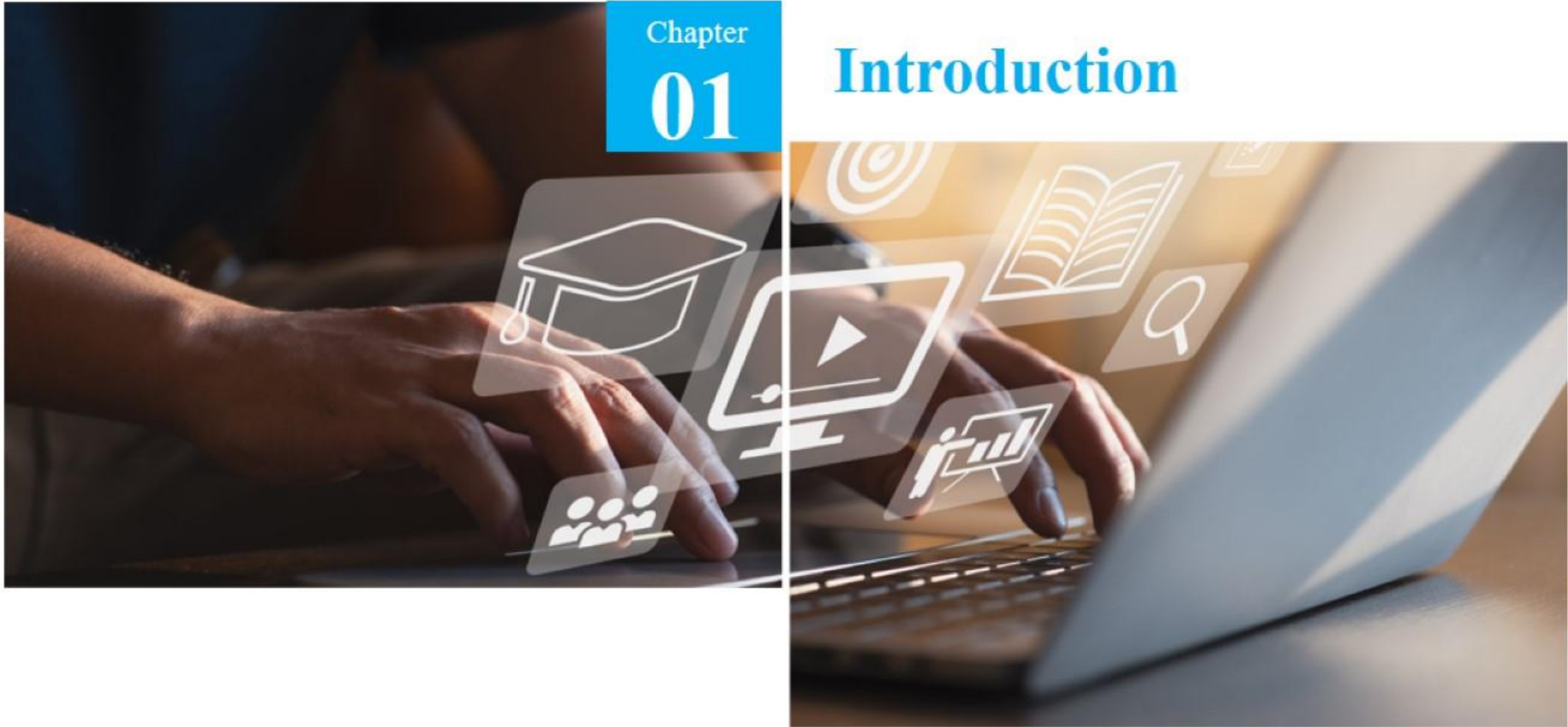
Prepared by  
**Dr. Mohamed Mostafa**

[www.midocean.ae](http://www.midocean.ae)

Chapter

01

# Introduction

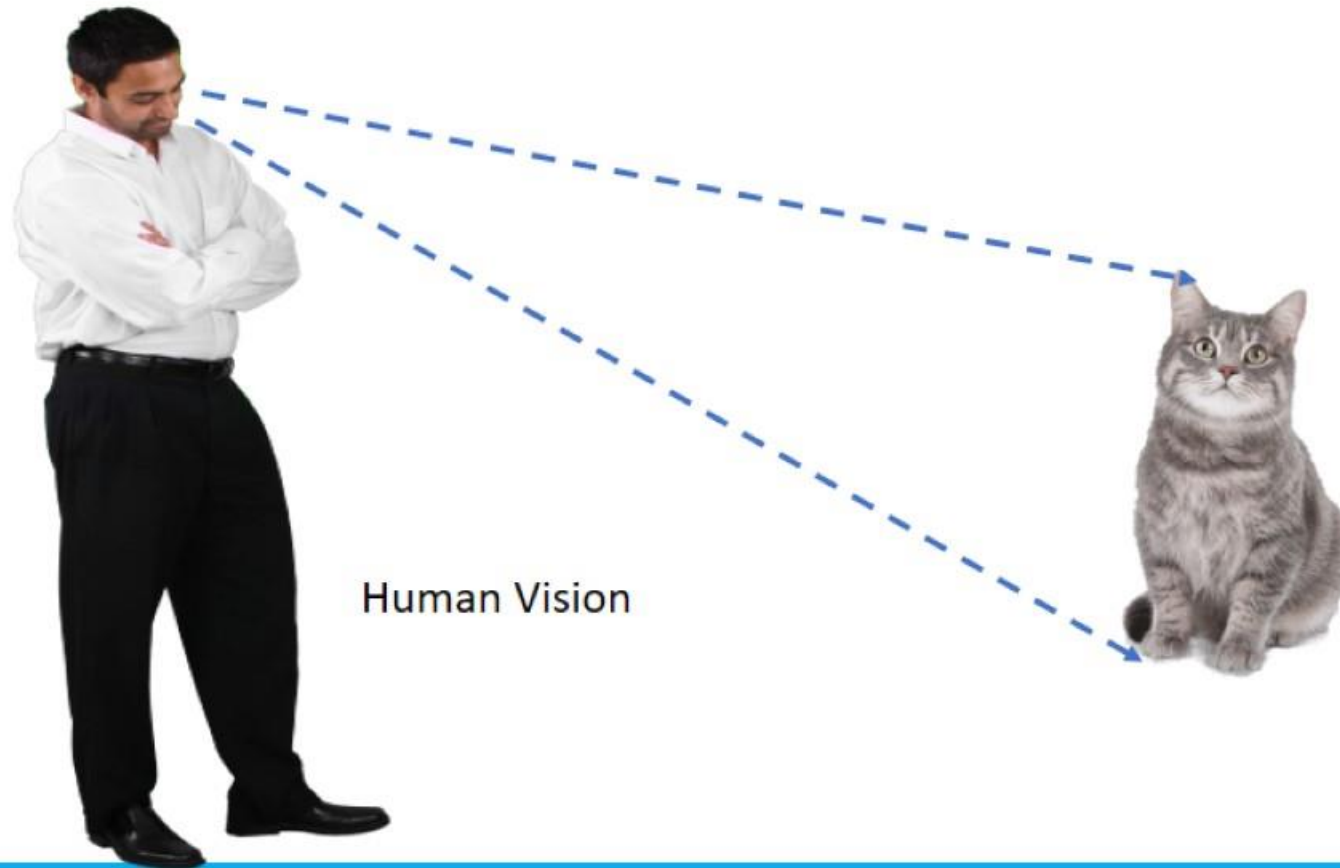


## What is Computer Vision?



Source:  
[Towarddatascience](https://towardsdatascience.com/)

## How Does Computer Vision Work?

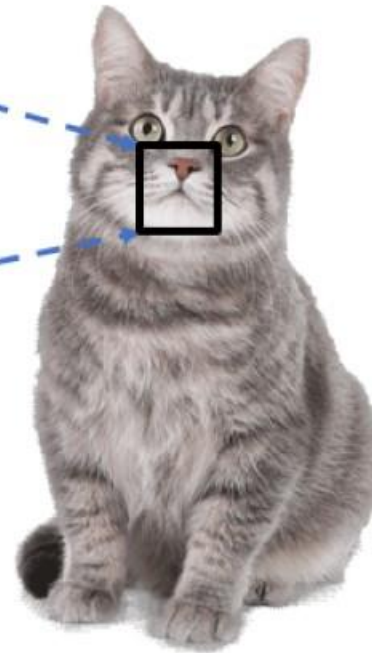


## How Does Computer Vision Work?

|   |   |   |   |   |   |   |   |
|---|---|---|---|---|---|---|---|
| 2 | 6 | 7 | 8 | 5 | 0 | 6 | 8 |
| 7 | 2 | 6 | 2 | 6 | 2 | 6 | 7 |
| 6 | 8 | 9 | 2 | 0 | 7 | 3 | 7 |
| 7 | 6 | 1 | 4 | 6 | 0 | 5 | 9 |
| 9 | 7 | 0 | 9 | 8 | 4 | 6 | 7 |
| 9 | 8 | 9 | 4 | 7 | 1 | 7 | 8 |
| 7 | 3 | 5 | 5 | 1 | 3 | 5 | 7 |
| 5 | 8 | 8 | 4 | 6 | 2 | 7 | 6 |

Computer Vision

Class: **Cat** (92%)  
**Rabbit** (30%)



## What is Computer Vision?

One of the computer vision fields is **Image Analysis**.

It has two topics:

- **Feature Extraction**
  - The process of transforming raw data into numerical features that can be processed while preserving the information in the original data set.
- **Pattern Recognition**
  - A data analysis method that uses machine learning algorithms to automatically recognize patterns and regularities in data.

## What is Digital Image Processing?

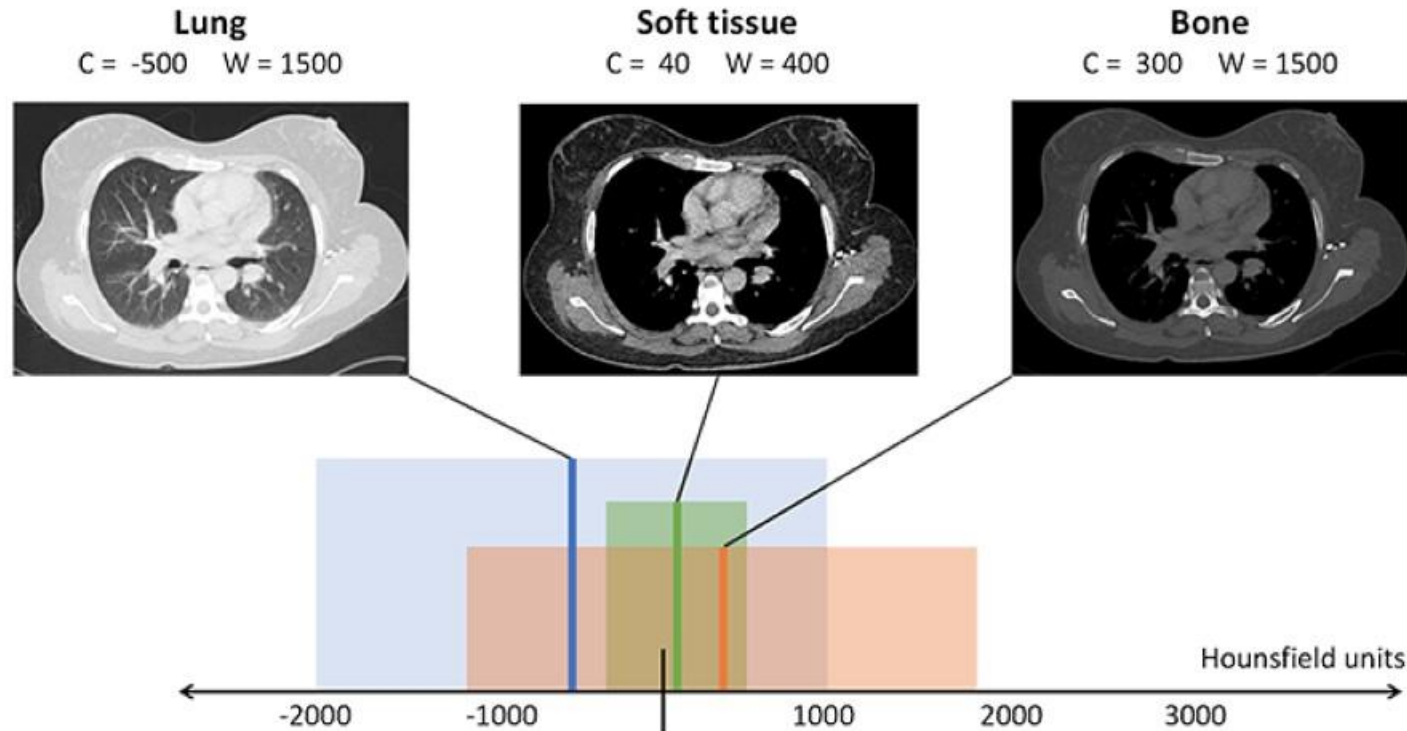


## What is Digital Image Processing?



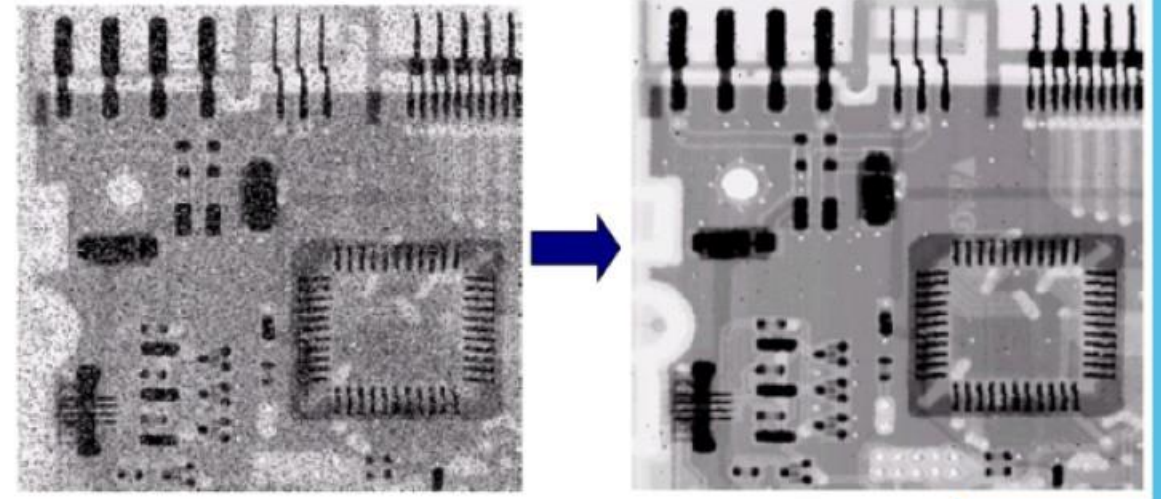
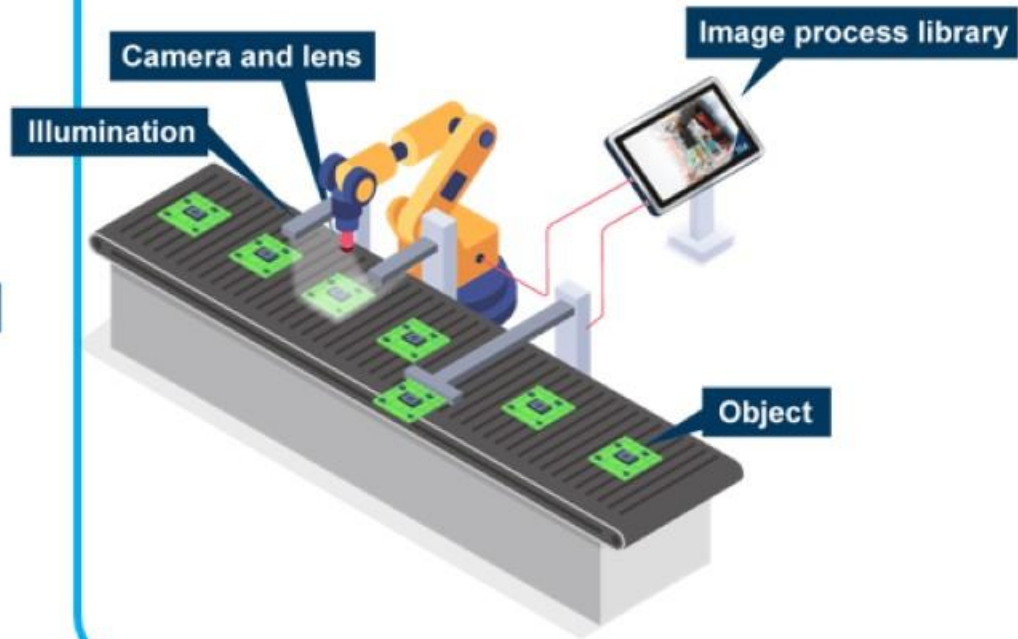
**X-ray Image Enhancement**

## What is Digital Image Processing?



### Gamma-ray Image Enhancement

## What is Digital Image Processing?



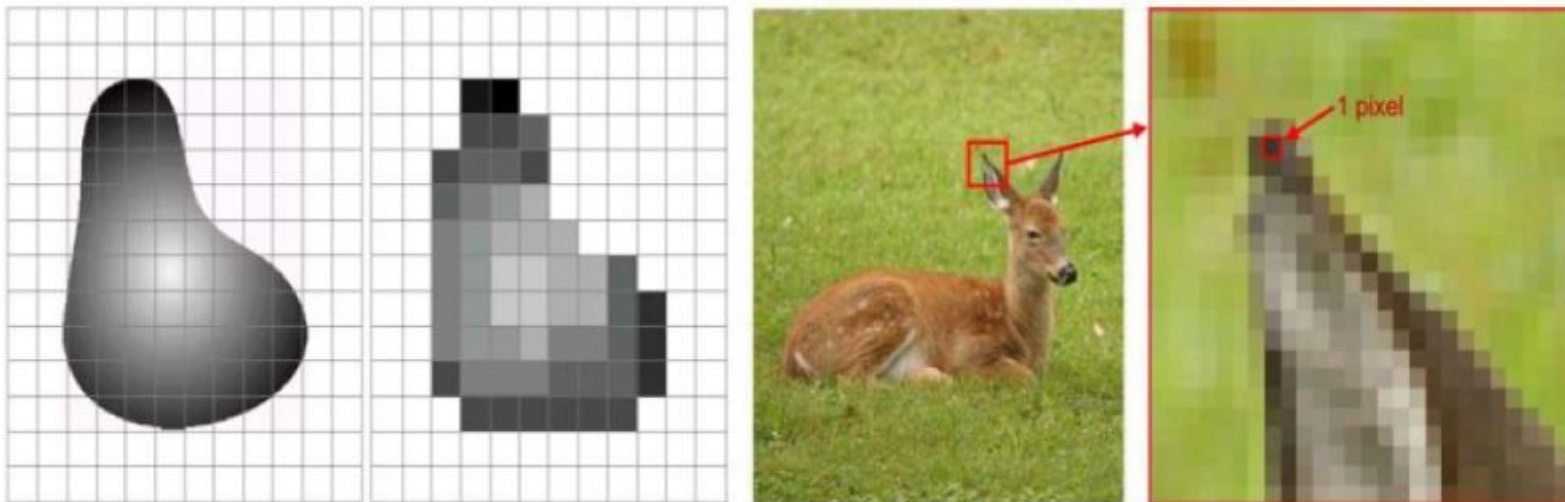
Robot Vision

## What is Digital Image?

Digital Image : a two-dimensional function  $f(x,y)$ ,

–x and y are spatial coordinates

–The amplitude of f is called intensity or gray level at the point (x, y)



## What is Digital Image?

**Image Processing**

### Low-level Processes

- Noise Reduction
- Contrast Enhancement
- Image Sharpening

Image in → Image out

**Image Analysis**

### Mid-level Processes

- Segmentation
- Classification

Image in → Measurements out

**Vision**

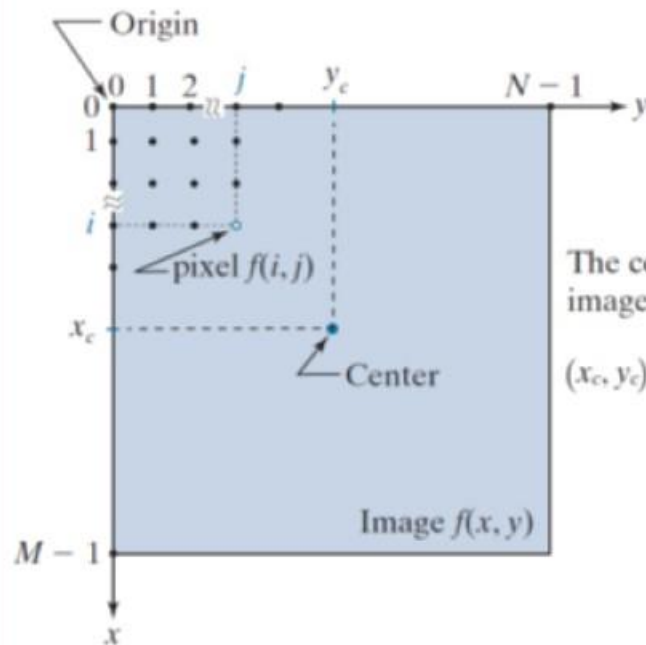
### High-level Processes

- Scene Interpretation
- Object Recognition

Image in → high-level  
descriptions (features)

## Digital image representation

An image is said to be of size  $(M \times N)$ , where  $(0,0)$  is the top left hand corner,  $(0,1)$  the next pixel in the top row etc.



The coordinates of the image center are

$$(x_c, y_c) = \left( \text{floor}\left(\frac{M}{2}\right), \text{floor}\left(\frac{N}{2}\right) \right)$$

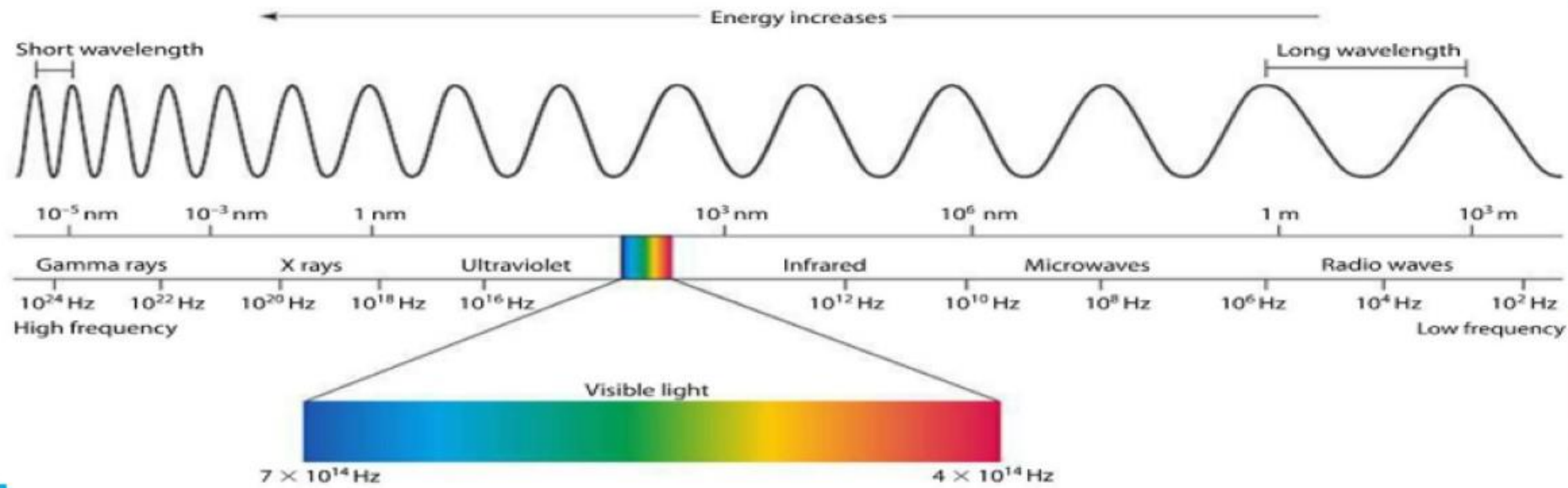
$$f(x,y) = \begin{bmatrix} f(0,0) & f(0,1) & f(0,2) & \dots & f(0,N-1) \\ f(1,0) & f(1,1) & f(1,2) & \dots & f(1,N-1) \\ \vdots & \vdots & \vdots & & \vdots \\ f(M-1,0) & f(M-1,1) & f(M-1,2) & \dots & f(M-1,N-1) \end{bmatrix}$$

**Images as matrices**

- ❑ Each entry is called a picture element "pel" or "pixel"  $f(x, y)$
- ❑ In 3D case, each entry is called a volume element "voxel"  $f(x, y, z)$

## Sources for Images

- Electromagnetic (EM) energy spectrum
- Acoustic
- Ultrasonic
- Electronic
- Synthetic images produced by computer



## Sources for Images

- Acoustic



**Structural MRI scan**

Structural magnetic resonance imaging (MRI) is a non-invasive technique for examining the anatomy and pathology of the brain.



**Functional MRI scan**

Functional magnetic resonance imaging (fMRI) is a non-invasive technique for examining brain activity.

## Sources for Images

- Ultrasonic



Source: [livescience](https://www.livescience.com)

## Sources for Images

- Electronic



## Sources for Images

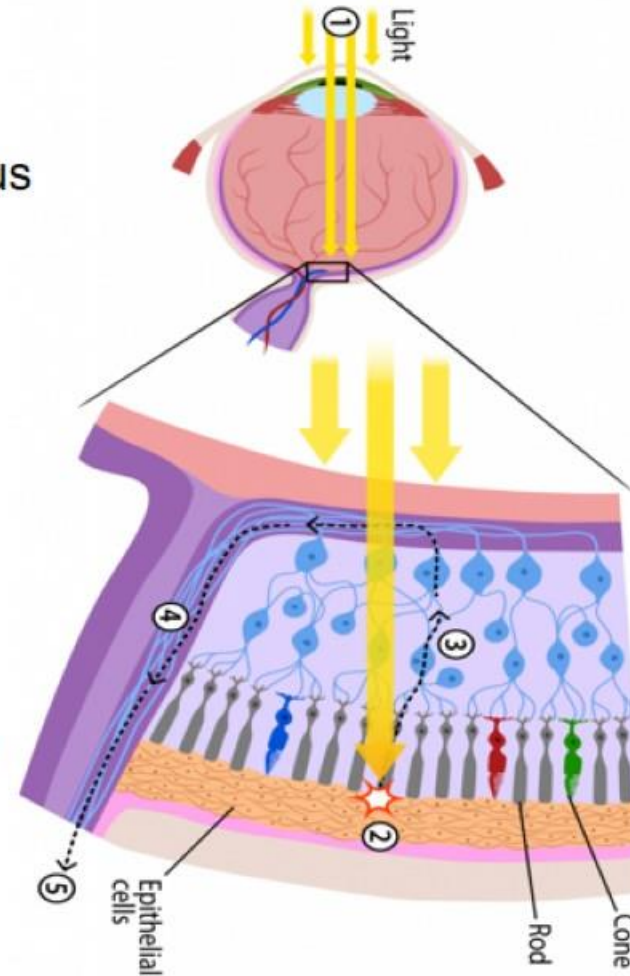
- Synthetic images produced by computer



Source: [midjourney](#)

## Human Visual System

- The best vision model we have!
- Knowledge of how images form in the eye can help us with processing digital images
- The lens focuses light from objects onto the retina
- The retina is covered with light receptors called *cones* and *rods*.
- Cones are (6-7 million)
  - concentrated at the central portion of the retina and high sensitive to color.
- Rods are (75-150 million)
  - distributed at retina surface and are sensitive to low levels of illumination.

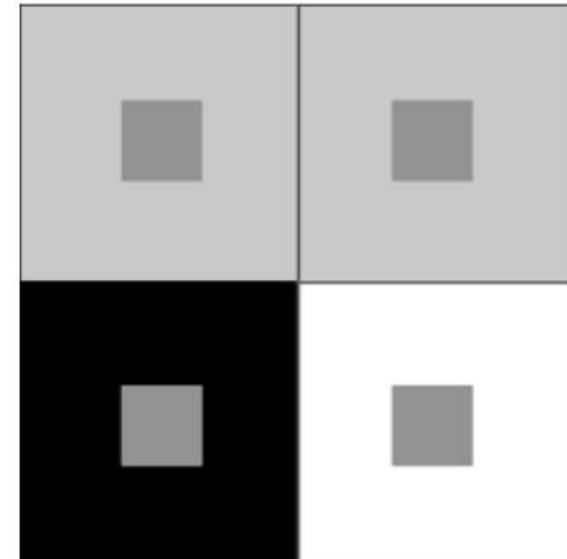


## Human Visual System

- ***Simultaneous Contrast***

- Is related to the fact that a region's perceived brightness does not depend on its intensity.

Ex, All the inner squares have the same intensity, but they appear progressively darker as the background becomes lighter.



## Human Visual System

- *Optical Illusions*

- In which the eye fills in non-existing information or wrongly perceives geometrical properties of objects

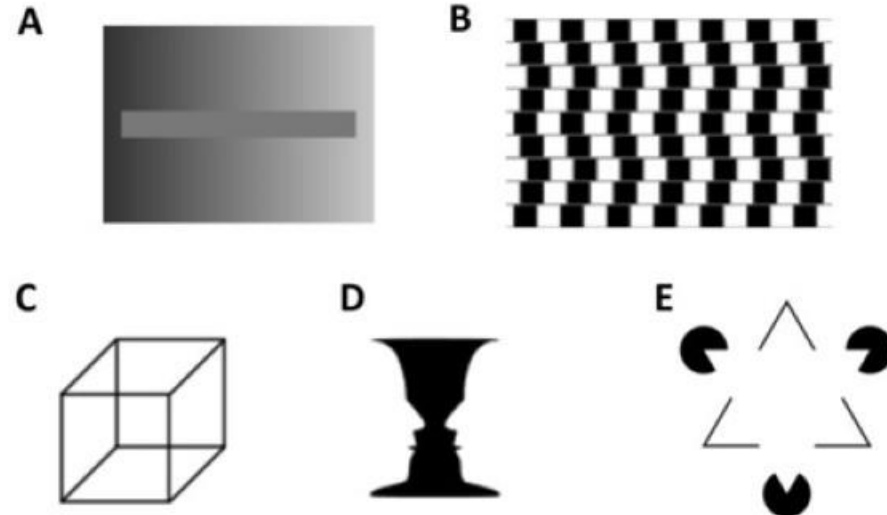
Ex, (A) Although the bar in the middle is uniformly filled by the same grey color, the right side of the bar appears to be darker.

(B) The set of parallel horizontal lines appears to be tilted.

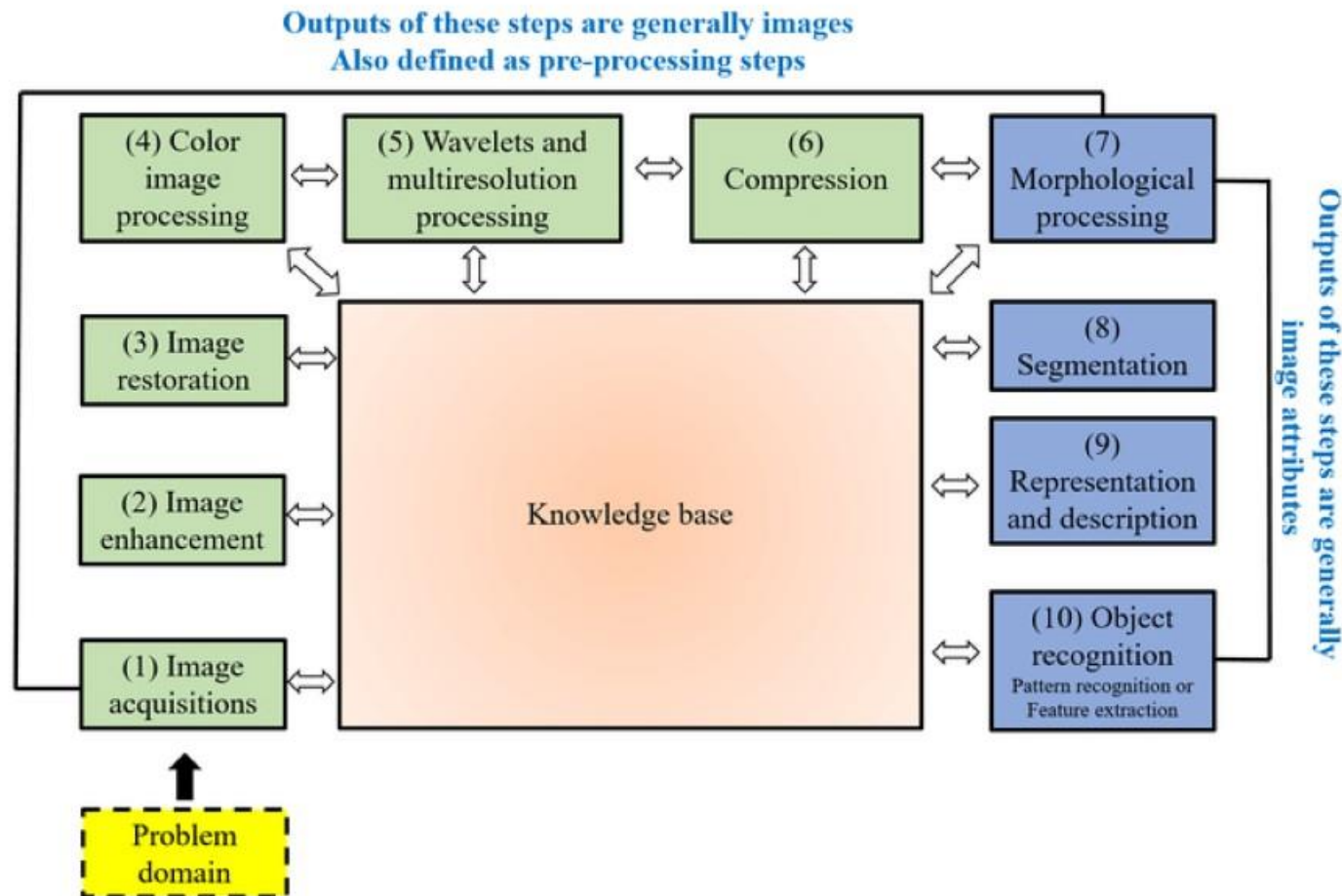
(C) The Necker cube.

(D) The Rubin vase, which can be perceived as an image of either two faces or a vase, simultaneously.

(E) The Kanizsa triangle.

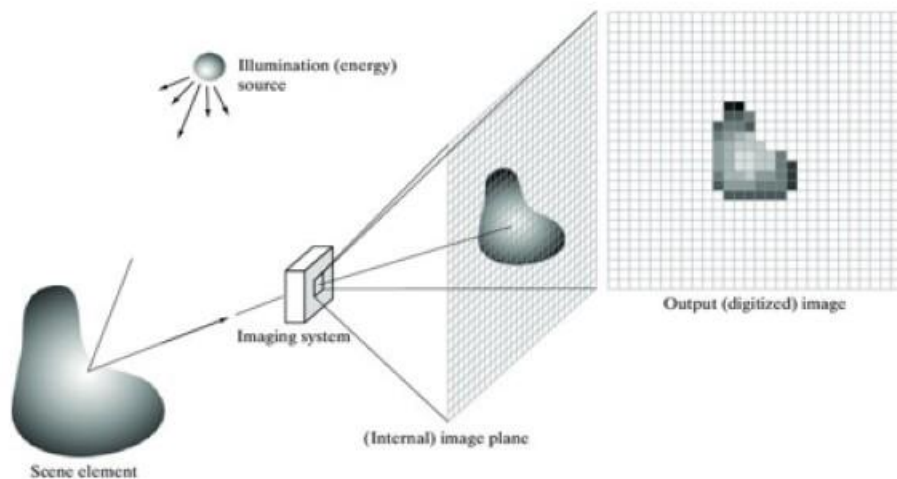


## Key Stages in Digital Image Processing



## Digital Image Acquisition

Images are generated by the combination of *illumination source* and reflection of energy by the objects in that scene.



$F(x,y)$  characterized by  $i(x,y)$  and  $r(x,y)$  as following

$$f(x,y) = i(x,y) r(x,y)$$

Where,

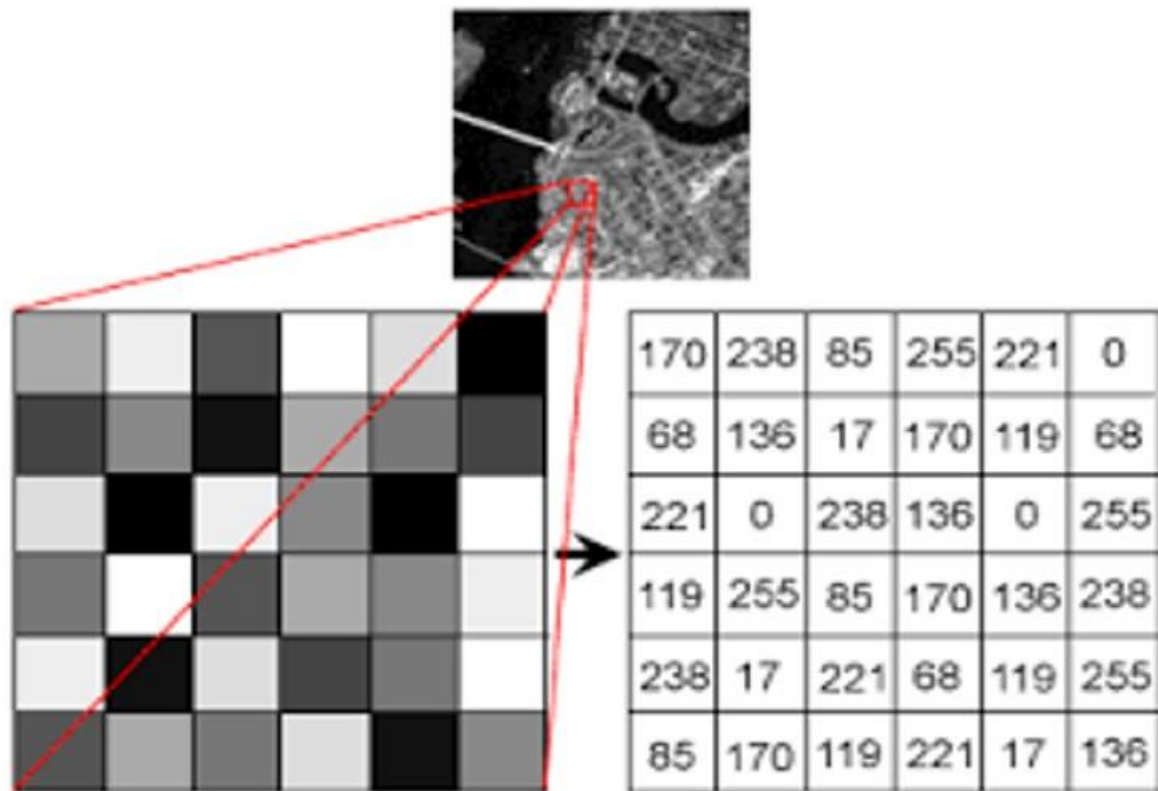
$$0 < i(x,y) < \infty$$

$$0 < r(x,y) < 1$$

- Reflectance is bounded by 0 (total absorption) and 1 (total reflectance).

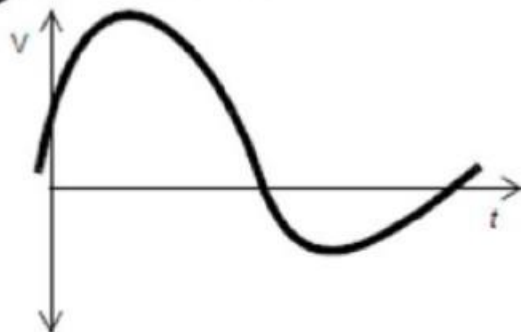
## Greyscale Image

The standard greyscale image uses 256 shades of grey from 0 (black) to 255 (white).

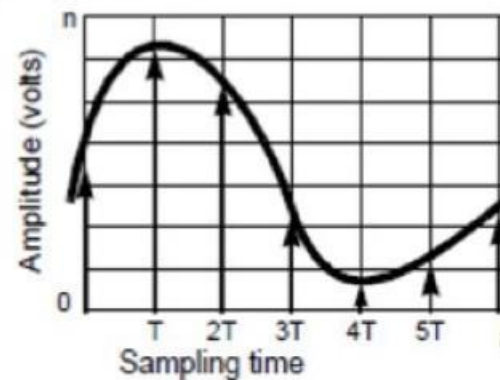


## Sampling and Quantization

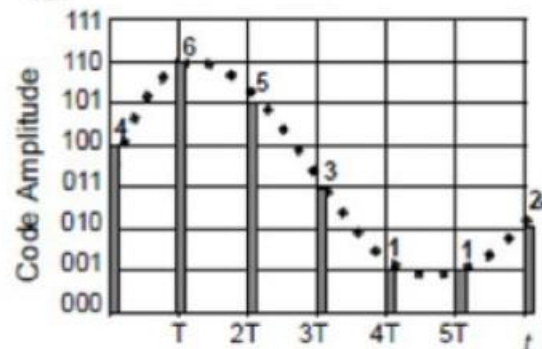
**0** Analog Signal



**1** Sampling



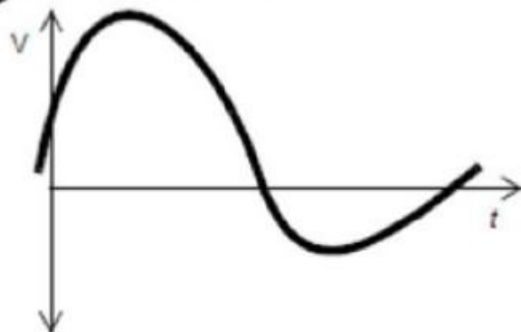
**2** Quantization



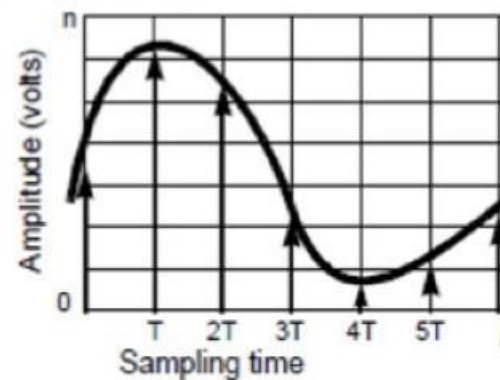
8 levels =  $2^3$ : uses 3 bits to represent the value of the function

## Sampling and Quantization

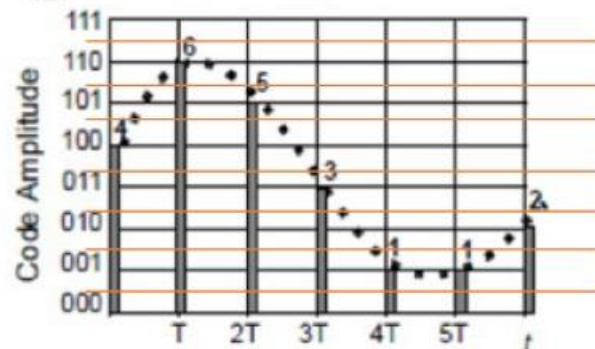
**0** Analog Signal



**1** Sampling



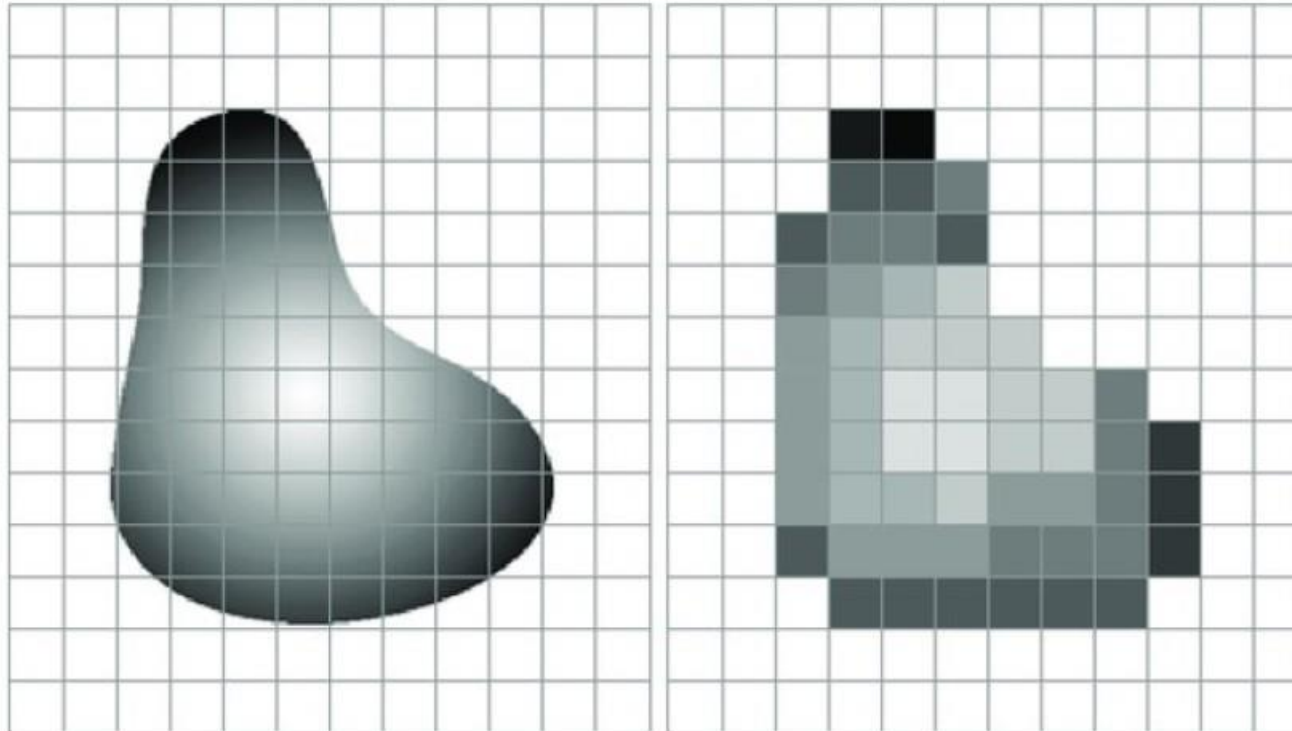
**2** Quantization



16 levels =  $2^4$ : uses 4 bits to represent the value of the function

## Sampling and Quantization

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



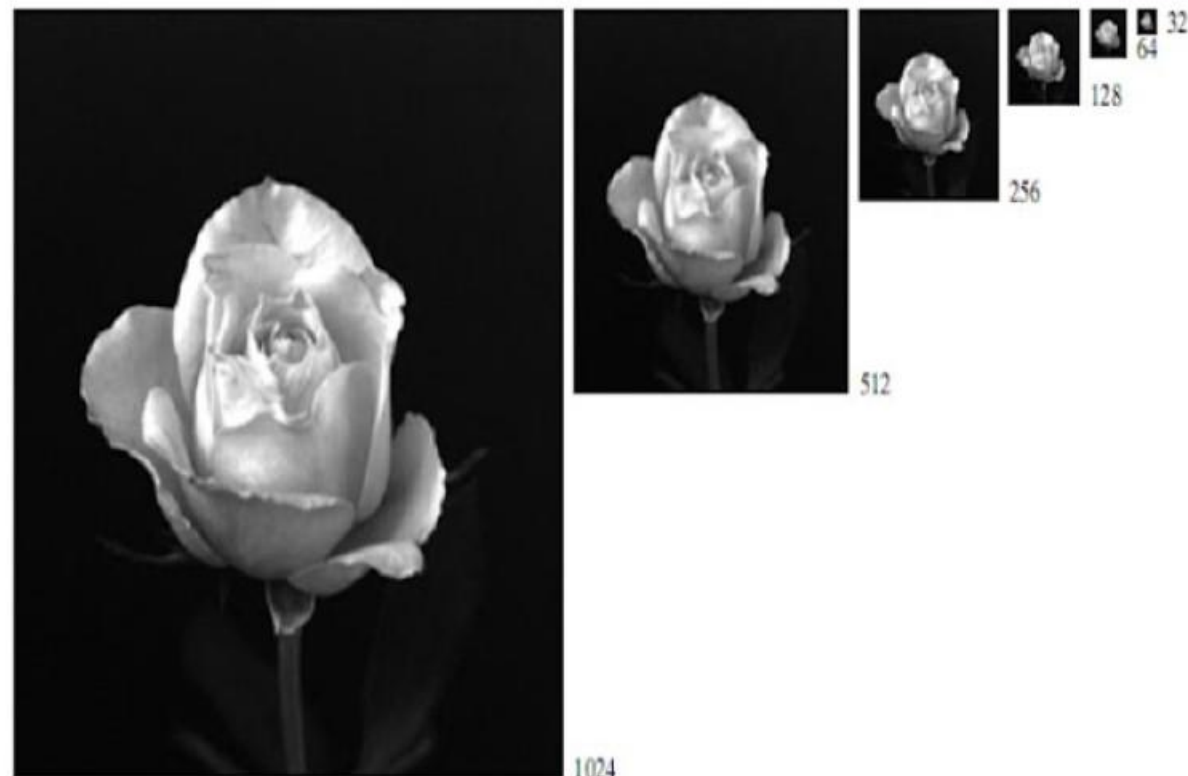
## Spatial & Intensity Resolution

### Spatial Resolution (Sampling):

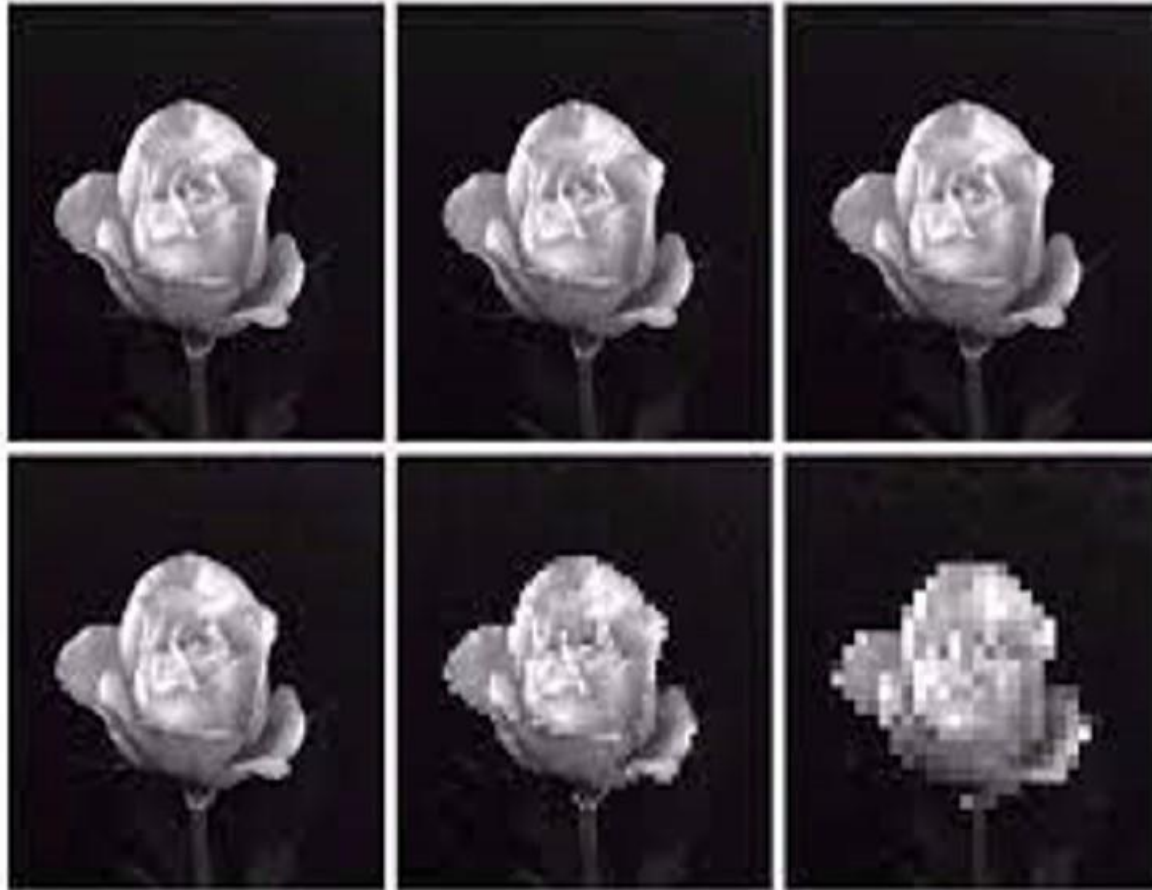
**Definition:** Refers to the level of detail or clarity in an image. It is determined by the number of pixels in the image and their arrangement, affecting the ability to discern (separate) fine details.

**Measurement:** Typically measured in terms of dots per inch (DPI) or pixels per unit length (e.g., pixels per inch or pixels per centimeter, dots per inch (dpi)), or stated in line pairs per unit distance

**Higher Resolution:** Higher spatial resolution means finer details can be captured, resulting in sharper and more detailed images.



## Spatial & Intensity Resolution



|   |   |   |
|---|---|---|
| a | b | c |
| d | e | f |

(a) 1024x1024

(b) 512x512

(c) 256x256

(d) 128x128

(e) 64x64

(f) 32x32

**Checkboard Effect**

## Spatial & Intensity Resolution

### **Intensity Resolution (Quantization):**

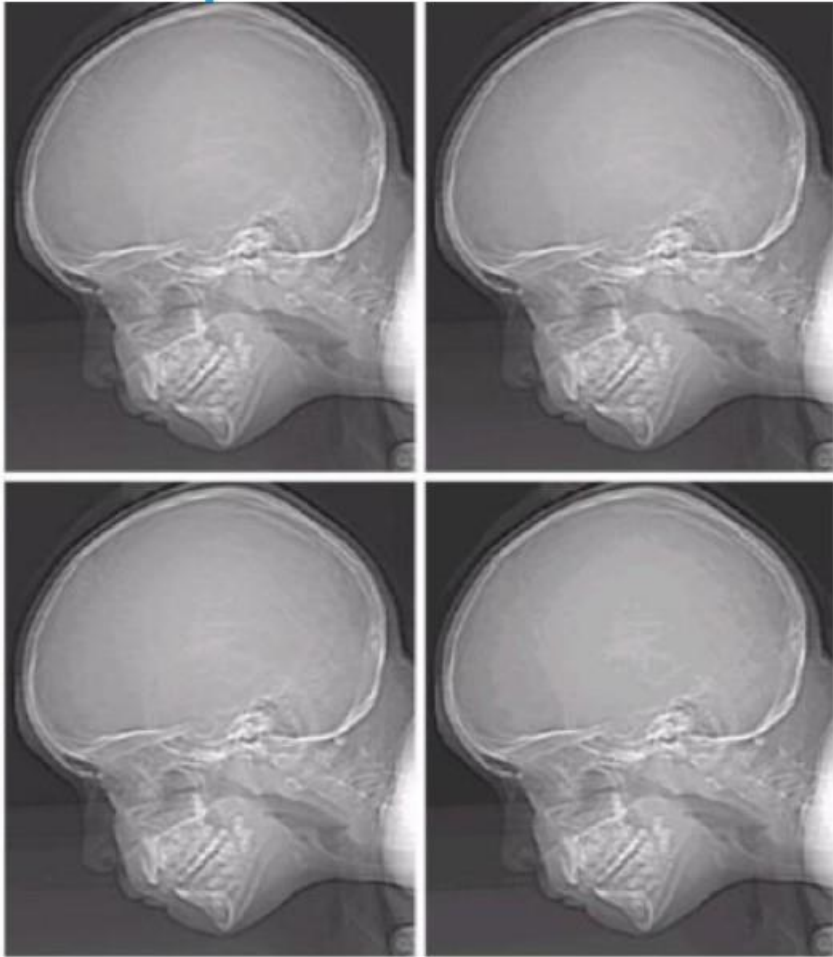
*Definition:* Intensity resolution deals with the ability to distinguish between different levels of brightness or color in an image.

*Measurement:* Expressed in bits, where the number of bits determines the number of possible intensity levels. For example, 8-bit intensity resolution allows for 256 levels ( $2^8$ ), while 16-bit allows for 65,536 levels ( $2^{16}$ ).

*Higher Resolution:* Higher intensity resolution allows for a more extensive range of distinguishable brightness or color levels, leading to smoother transitions between shades.

.

## Spatial & Intensity Resolution

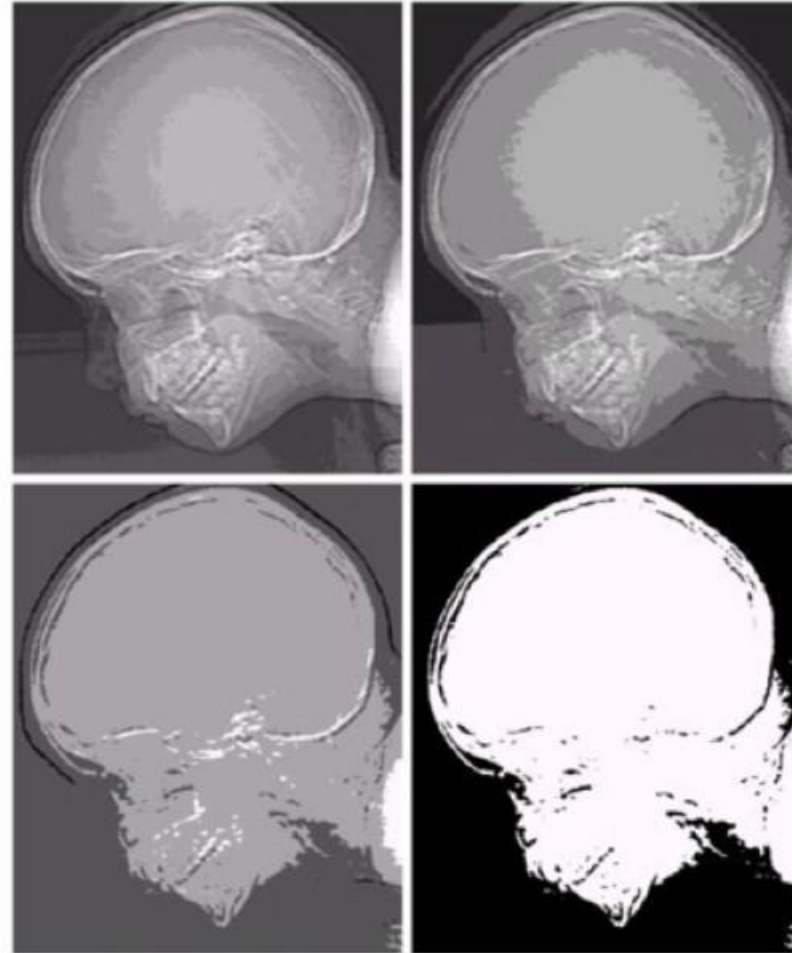


a b  
c d

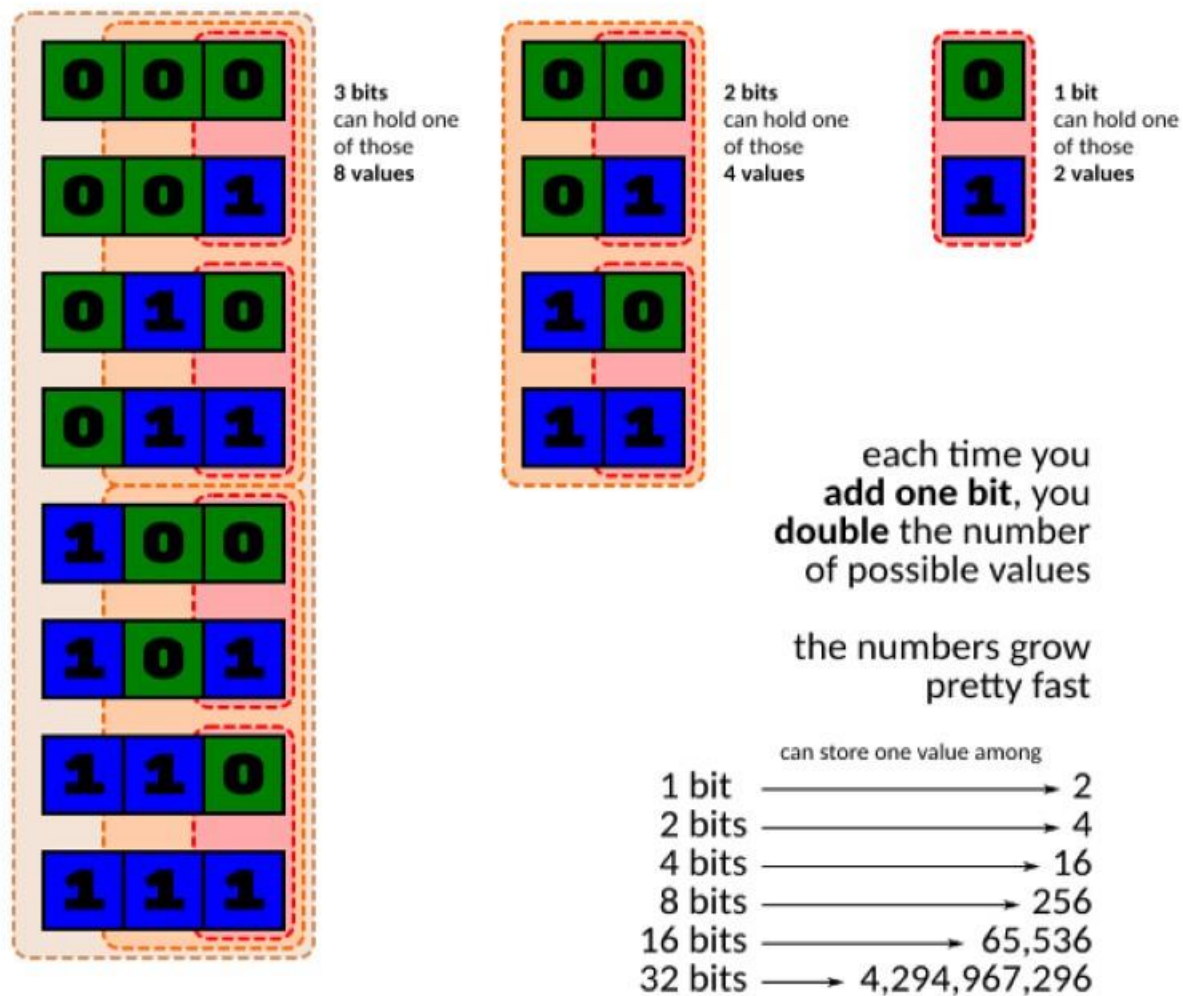
**FIGURE 2.21**  
(a) 452 × 374,  
256-level image.  
(b)–(d) Image  
displayed in 128,  
64, and 32 gray  
levels, while  
keeping the  
spatial resolution  
constant.

e f  
g h

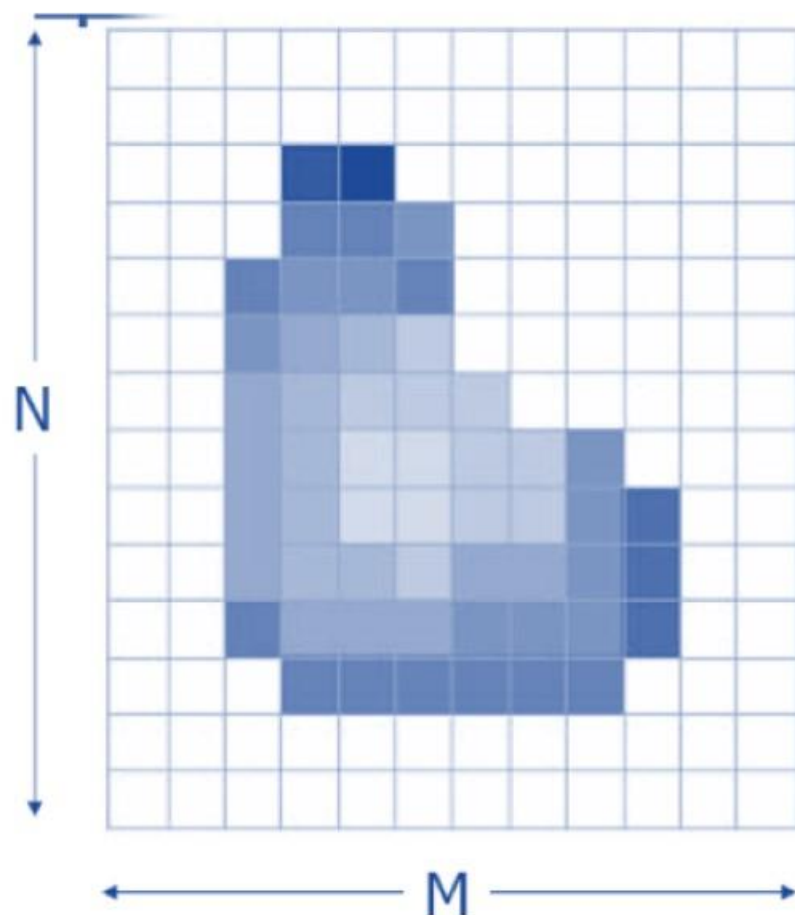
**FIGURE 2.21**  
(Continued)  
(e)–(h) Image  
displayed in 16, 8,  
4, and 2 gray  
levels. (Original  
courtesy of  
Dr. David  
R. Pickens,  
Department of  
Radiology &  
Radiological  
Sciences,  
Vanderbilt  
University  
Medical Center.)



## Sampling and Quantization



## Sampling and Quantization



- The number of gray levels typically is an integer power of 2

$$L = 2^k$$

- Number of bits required to store a digitized image

$$b = M \times N \times k$$

## Assignment

Both the spatial and gray level resolutions determine the (storage) size of an image (bytes)

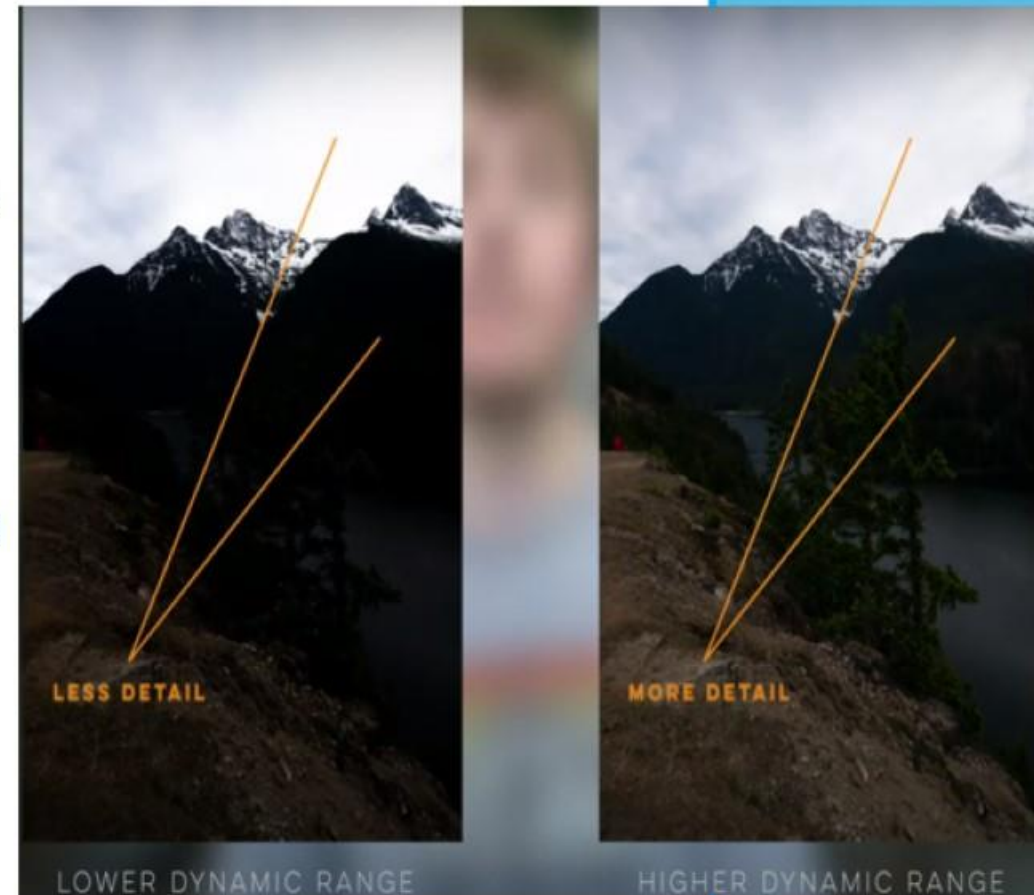
- Ex: scene area:  $1\text{km}^2$ , spatial resolution 20 lines/km, gray level resolution: 64

## Dynamic range

It can be defined as the ratio between maximum measurable intensity level and minimum detectable intensity level in an image.

As a rule, the upper limit is determined by the saturation and the lower limit by noise.

Image contrast : is the difference in intensity between the highest and lowest intensity level in image.



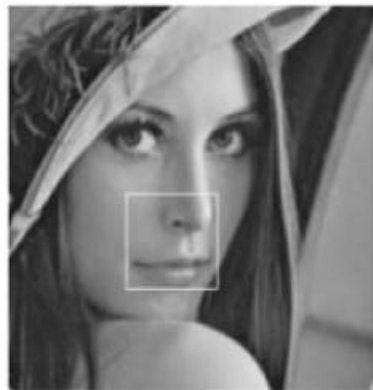
## Image Interpolation

Interpolation is used in tasks such as zooming, shrinking, rotating, and geometrically correcting digital images.

Some methods used in Image Interpolation:

- Pixel Replication/Nearest Neighbor
- Bilinear Interpolation
- Bicubic Interpolation

4X  
zooming



duplicate



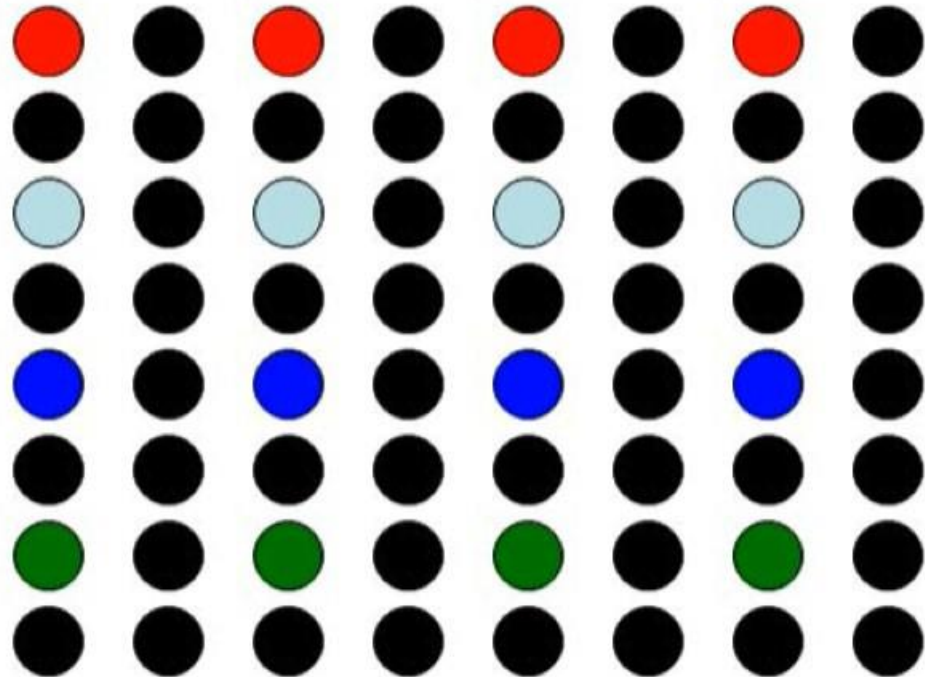
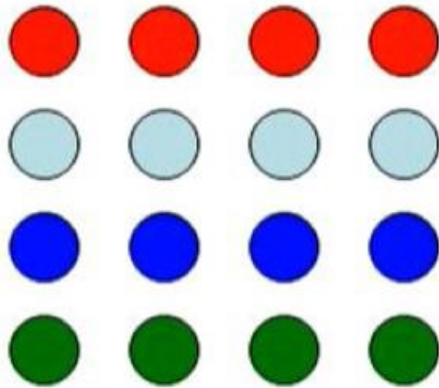
bilinear



cubic

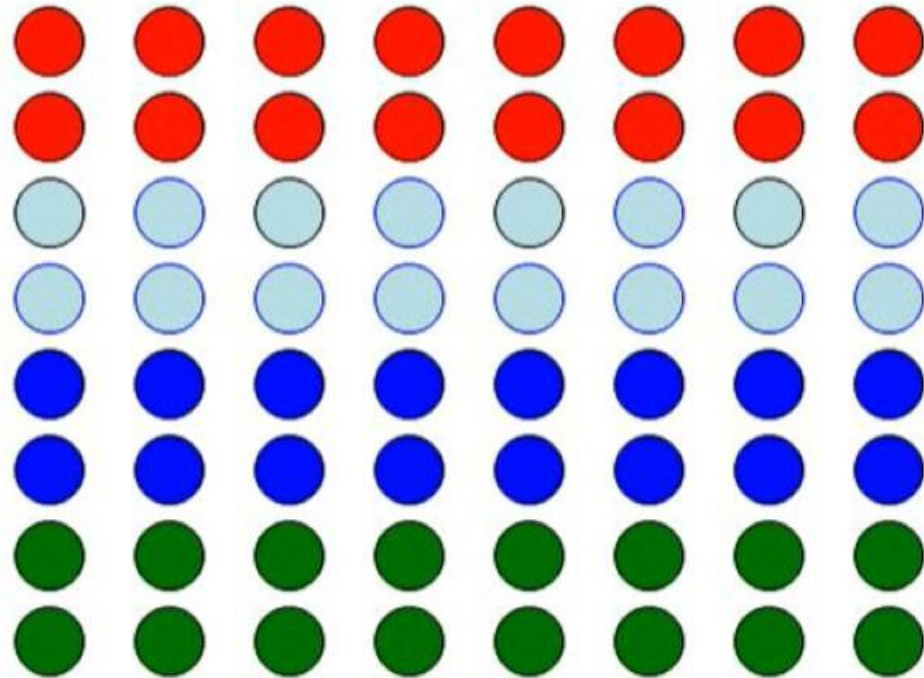
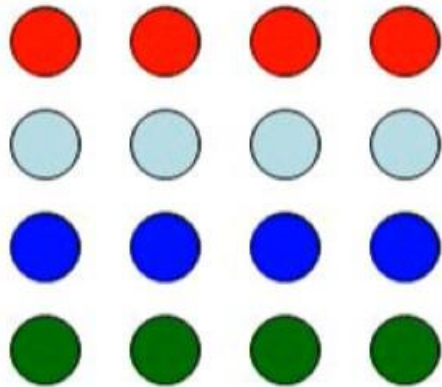
## Image Interpolation

Pixel Replication/Nearest Neighbor



## Image Interpolation

### Pixel Replication/Nearest Neighbor



Checkboard Effect

## Image Interpolation

### Pixel Replication/Nearest Neighbor Example

|    |     |
|----|-----|
| 30 | 85  |
| 45 | 105 |

**2 x 2**

**4 x 4**

|    |    |     |  |
|----|----|-----|--|
| 30 | 30 |     |  |
| 30 | 30 | 85  |  |
|    |    |     |  |
| 45 |    | 105 |  |

## Image Interpolation

Pixel Replication/Nearest Neighbor Example

|    |     |
|----|-----|
| 30 | 85  |
| 45 | 105 |

**2 x 2**

**4 x 4**

|    |    |     |     |
|----|----|-----|-----|
| 30 | 30 | 85  | 85  |
| 30 | 30 | 85  | 85  |
| 45 | 45 | 105 | 105 |
| 45 | 45 | 105 | 105 |

## Image Interpolation

### Pixel Replication/Nearest Neighbor Example

|    |     |
|----|-----|
| 30 | 85  |
| 45 | 105 |

2 x 2

5 x 5

???

|    |  |  |     |  |
|----|--|--|-----|--|
|    |  |  |     |  |
| 30 |  |  | 85  |  |
|    |  |  |     |  |
|    |  |  |     |  |
| 45 |  |  | 105 |  |
|    |  |  |     |  |

# Image Interpolation

## Nearest Neighbor Example

$$I(R \times C) = \begin{bmatrix} (1,1) & (1,2) & (1,3) & (1,4) \\ (2,1) & (2,2) & (2,3) & (2,4) \\ (3,1) & (3,2) & (3,3) & (3,4) \\ (4,1) & (4,2) & (4,3) & (4,4) \end{bmatrix}$$

$$R=r \text{ \& } C=c$$

$$S_r = \frac{R}{r} = 0.5 \quad S_c = \frac{C}{c} = 0.5$$

$$J(\hat{R} \times \hat{C}) = \begin{bmatrix} (1,1) & (1,2) & (1,3) & (1,4) & (1,5) & (1,6) & (1,7) & (1,8) \\ (2,1) & (2,2) & (2,3) & (2,4) & (2,5) & (2,6) & (2,7) & (2,8) \\ (3,1) & (3,2) & (3,3) & (3,4) & (3,5) & (3,6) & (3,7) & (3,8) \\ (4,1) & (4,2) & (4,3) & (4,4) & (4,5) & (4,6) & (4,7) & (4,8) \\ (5,1) & (5,2) & (5,3) & (5,4) & (5,5) & (5,6) & (5,7) & (5,8) \\ (6,1) & (6,2) & (6,3) & (6,4) & (6,5) & (6,6) & (6,7) & (6,8) \\ (7,1) & (7,2) & (7,3) & (7,4) & (7,5) & (7,6) & (7,7) & (7,8) \\ (8,1) & (8,2) & (8,3) & (8,4) & (8,5) & (8,6) & (8,7) & (8,8) \end{bmatrix}$$

$$[(r_f, c_f)] = [(S_r * \hat{r}, S_c * \hat{c})] = \begin{bmatrix} (0.5, 0.5) & (0.5, 1) & (0.5, 1.5) & (0.5, 2) & (0.5, 2.5) & (0.5, 3) & (0.5, 3.5) & (0.5, 4) \\ (1, 0.5) & (1, 1) & (1, 1.5) & (1, 2) & (1, 2.5) & (1, 3) & (1, 3.5) & (1, 4) \\ (1.5, 0.5) & (1.5, 1) & (1.5, 1.5) & (1.5, 2) & (1.5, 2.5) & (1.5, 3) & (1.5, 3.5) & (1.5, 4) \\ (2, 0.5) & (2, 1) & (2, 1.5) & (2, 2) & (2, 2.5) & (2, 3) & (2, 3.5) & (2, 4) \\ (2.5, 0.5) & (2.5, 1) & (2.5, 1.5) & (2.5, 2) & (2.5, 2.5) & (2.5, 3) & (2.5, 3.5) & (2.5, 4) \\ (3, 0.5) & (3, 1) & (3, 1.5) & (3, 2) & (3, 2.5) & (3, 3) & (3, 3.5) & (3, 4) \\ (3.5, 0.5) & (3.5, 1) & (3.5, 1.5) & (3.5, 2) & (3.5, 2.5) & (3.5, 3) & (3.5, 3.5) & (3.5, 4) \\ (4, 0.5) & (4, 1) & (4, 1.5) & (4, 2) & (4, 2.5) & (4, 3) & (4, 3.5) & (4, 4) \end{bmatrix}$$

$$[(\bar{r}, \bar{c})] = [\text{Round}[(r_f, c_f)]] = \begin{bmatrix} (1, 1) & (1, 1) & (1, 2) & (1, 2) & (1, 3) & (1, 3) & (1, 4) & (1, 4) \\ (1, 1) & (1, 1) & (1, 2) & (1, 2) & (1, 3) & (1, 3) & (1, 4) & (1, 4) \\ (2, 1) & (2, 1) & (2, 2) & (2, 2) & (2, 3) & (2, 3) & (2, 4) & (2, 4) \\ (2, 1) & (2, 1) & (2, 2) & (2, 2) & (2, 3) & (2, 3) & (2, 4) & (2, 4) \\ (3, 1) & (3, 1) & (3, 2) & (3, 2) & (3, 3) & (3, 3) & (3, 4) & (3, 4) \\ (3, 1) & (3, 1) & (3, 2) & (3, 2) & (3, 3) & (3, 3) & (3, 4) & (3, 4) \\ (4, 1) & (4, 1) & (4, 2) & (4, 2) & (4, 3) & (4, 3) & (4, 3.5) & (4, 4) \\ (4, 1) & (4, 1) & (4, 2) & (4, 2) & (4, 3) & (4, 3) & (4, 4) & (4, 4) \end{bmatrix}$$

Source:  
ImageProcessingJU



# Thank You