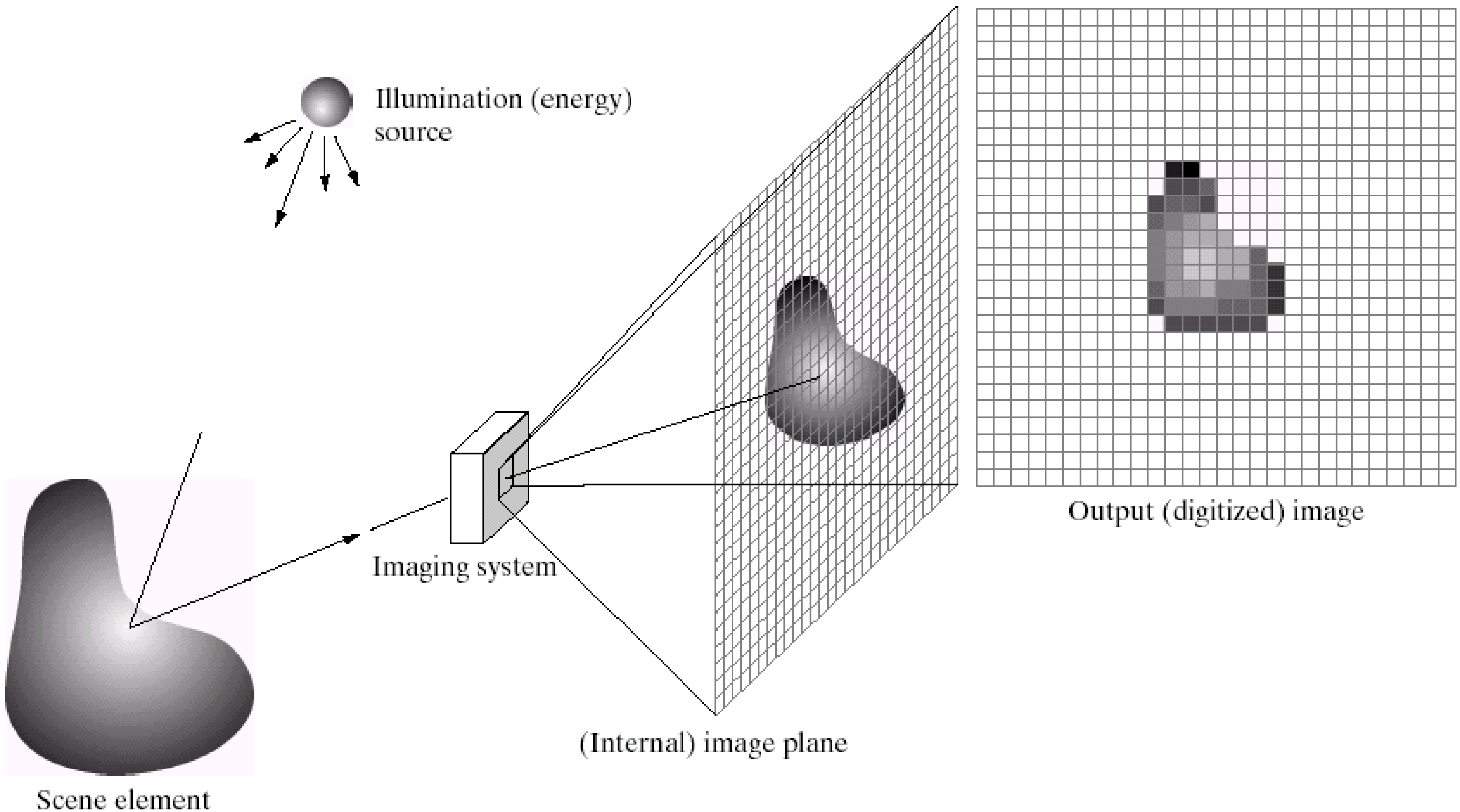
Digital Image Acquisition Process



(Images from Rafael C. Gonzalez and Richard E. Wood, Digital Image Processing, 2nd Edition.

A Simple Image Formation Model

Mathematical representation

- Two dimensional function $f(x,y)$, where f is the gray level of a pixel at location x and y.

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

- The values of the function f at different locations are proportional to the energy radiated from the imaged object.

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

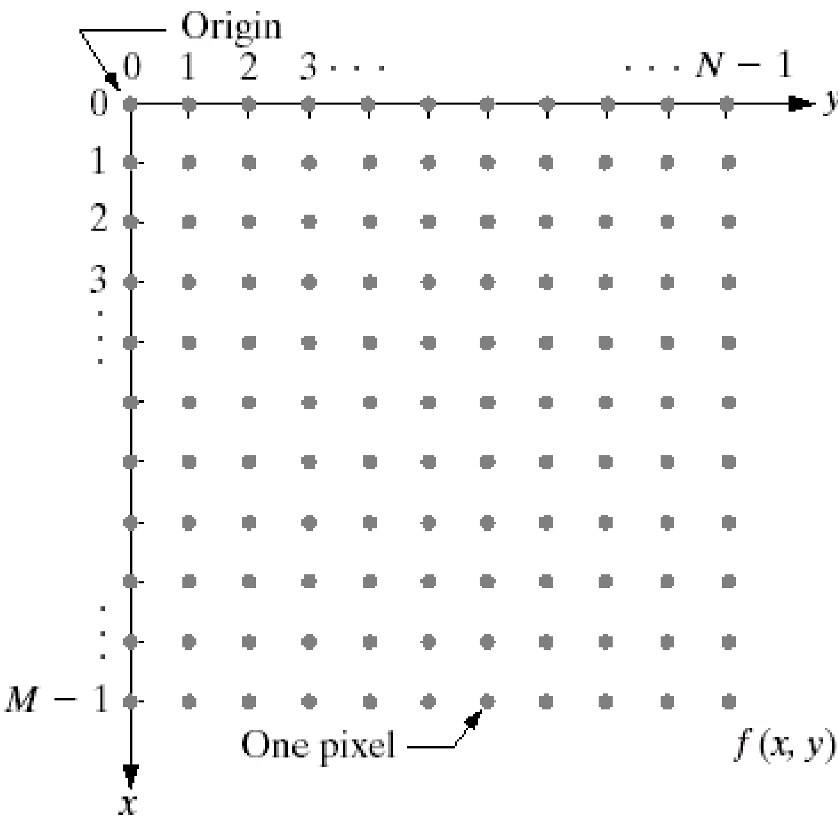
$$0 < i(x,y) < \infty$$

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

A Simple Image Formation Model

$i(x,y)$	: Sun on clear day	90,000 lm/m2
	: Sun on cloudy day	10,000 lm/m2
	: Full moon	0.1 lm/m2
	: Commercial office	1,000 lm/m2
$r(x,y)$	:Black Velvet	0.01
	:Stainless Steel	0.65
	:Flat-white Wall Paint	0.80
	:Silver-plated Metal	0.90
	:Snow	0.93

Image Representation



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

$$\mathbf{A} = \begin{bmatrix} a_{0,0} & a_{0,1} & \cdots & a_{0,N-1} \\ a_{1,0} & a_{1,1} & \cdots & a_{1,N-1} \\ \vdots & \vdots & & \vdots \\ a_{M-1,0} & a_{M-1,1} & \cdots & a_{M-1,N-1} \end{bmatrix}$$

Representing Digital Images

The pixel intensity levels (gray scale levels) are in the interval of $[0, L\text{-}1]$.

$$\mathbf{0 \le \mathit{a}_{\mathit{i,j}} \le \mathit{L}\text{-}1 \qquad \text{where} \qquad \mathit{L} = 2^{\mathit{k}}}$$

The dynamic range of an image is the range of values spanned by the gray scale.

The number, b, of bits required to store a digitized image of size M by N is

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

Image Sampling and Quantization

- A digital sensor can only measure a limited number of **samples** at a **discrete** set of energy levels
- *Quantisation* is the process of converting a continuous **analogue** signal into a digital representation of this signal

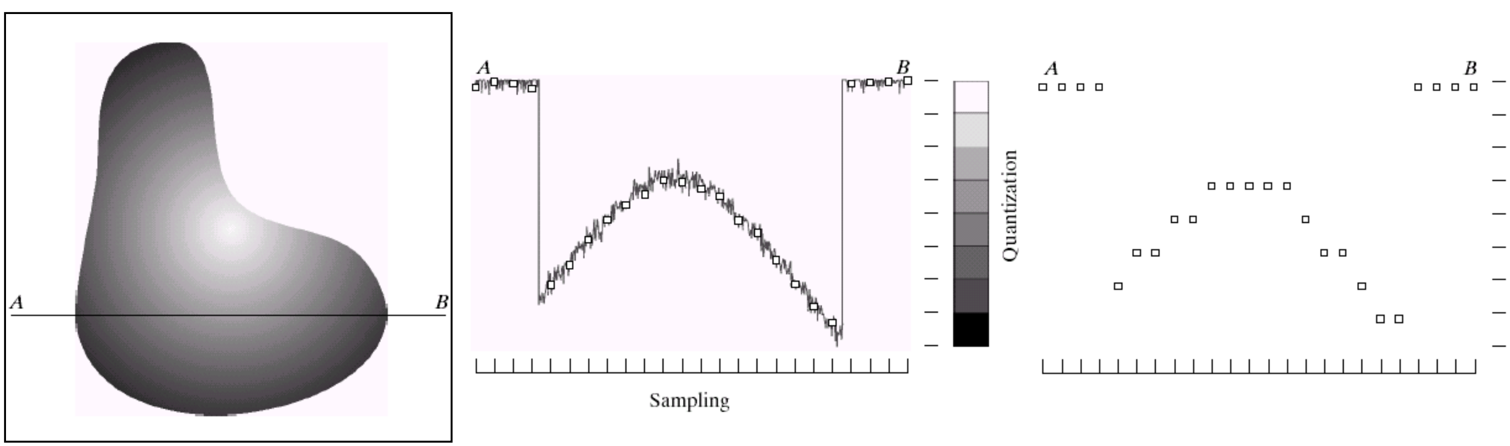


Image Sampling and Quantization

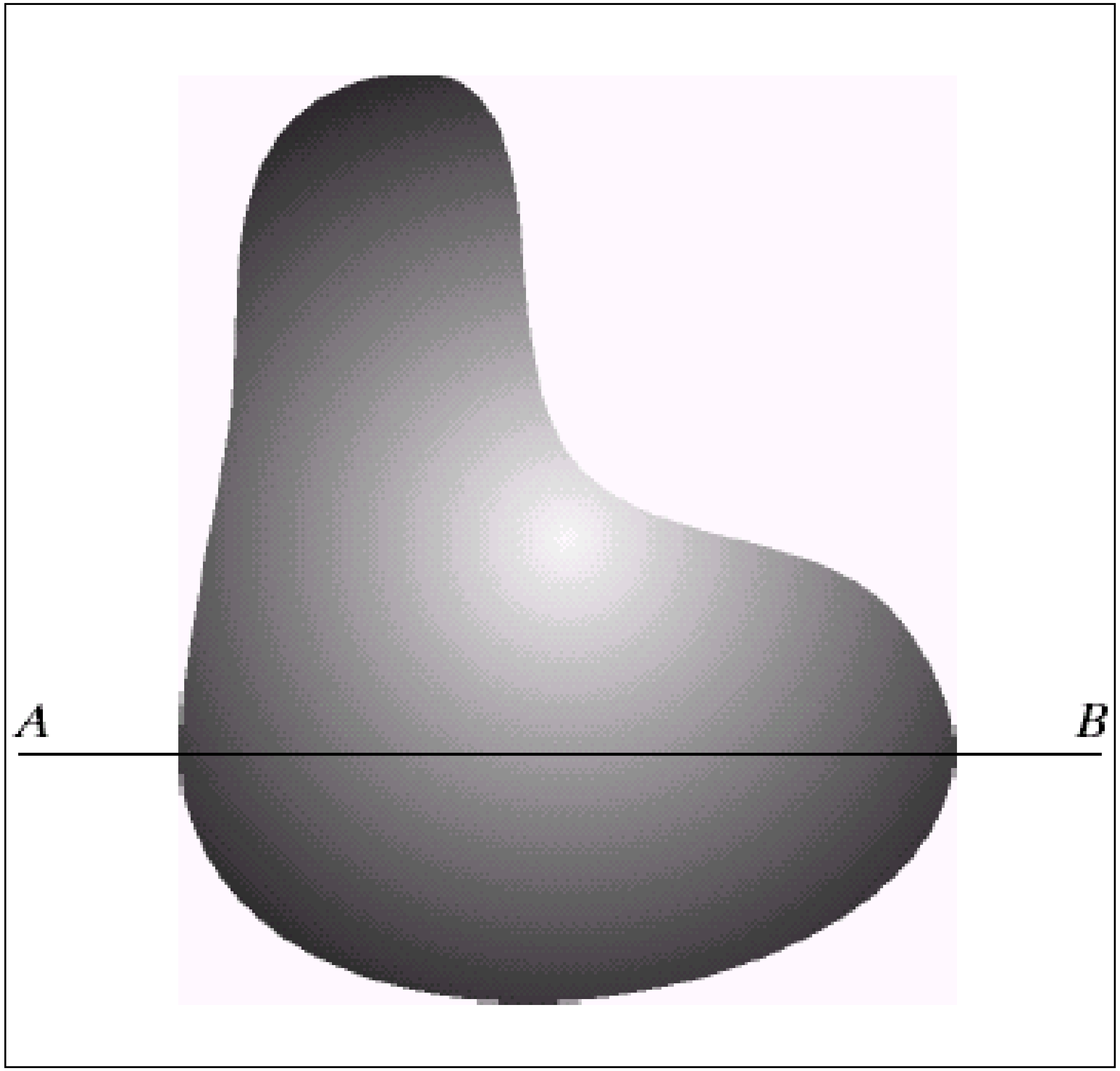
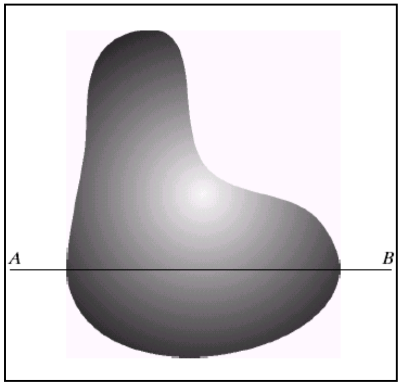
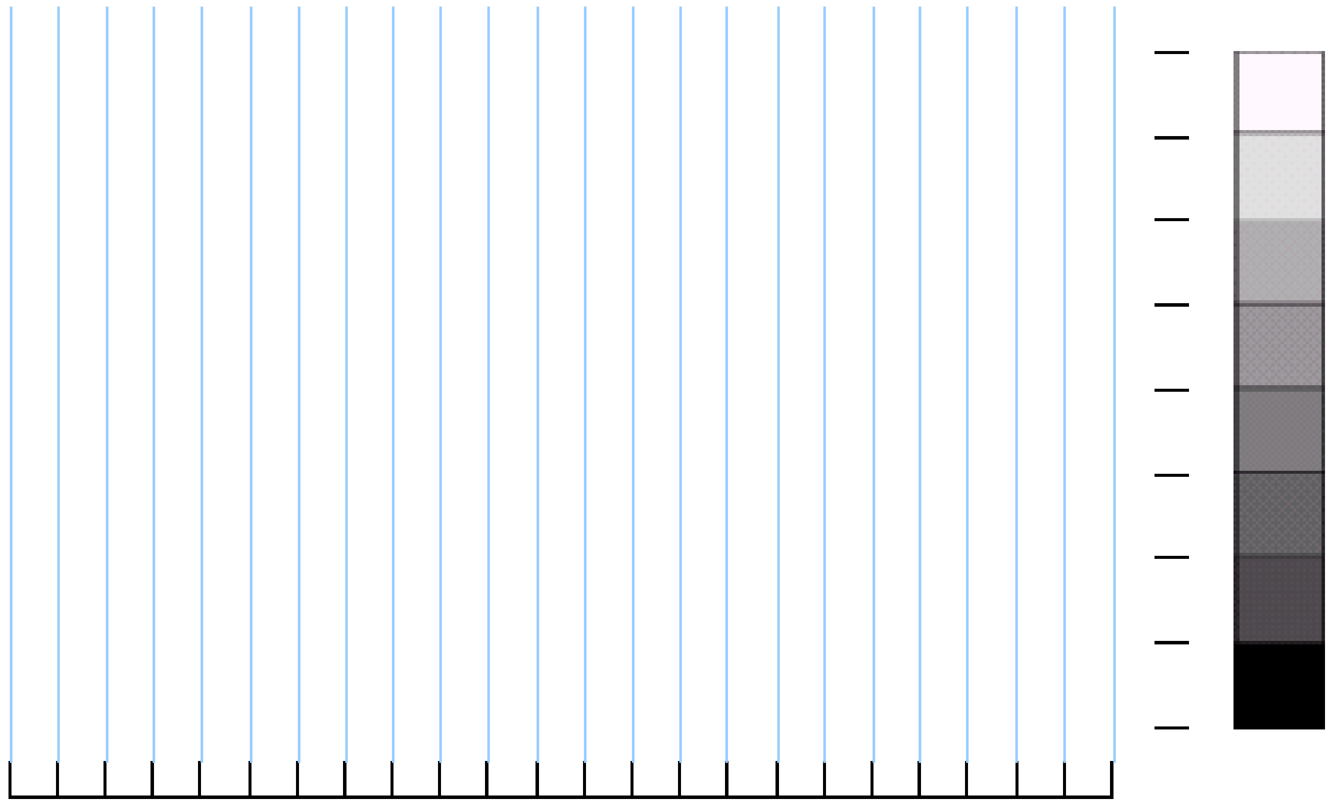


Image Sampling and Quantization

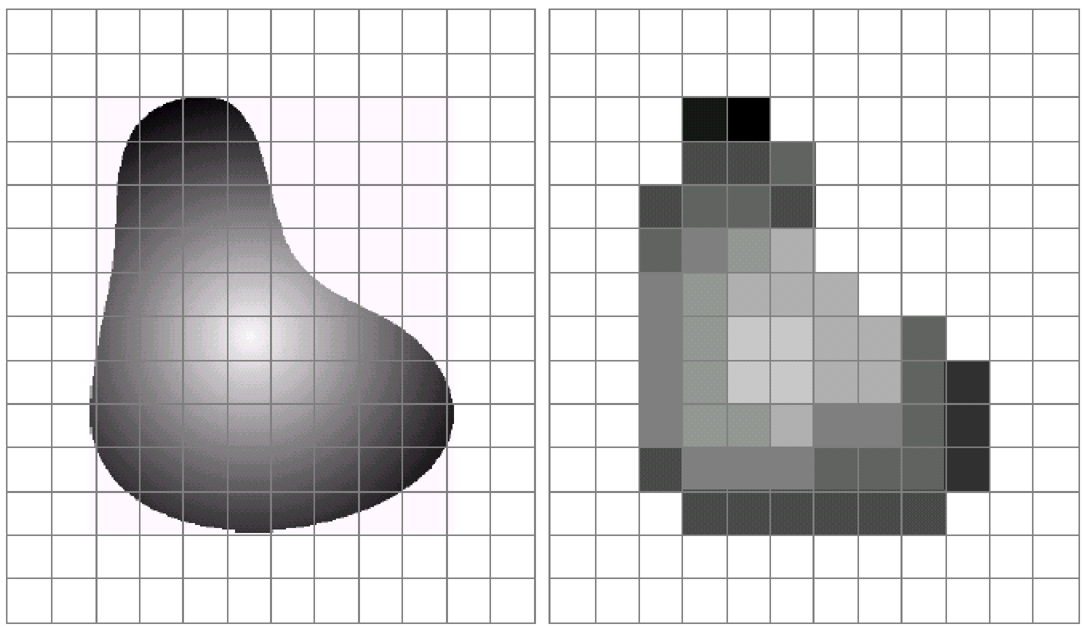




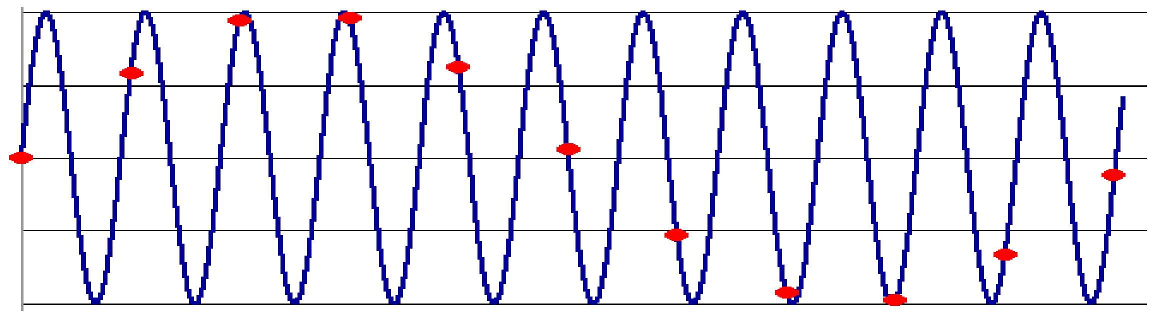
Sampling

Image Sampling and Quantization

- Remember that a digital image is always only an **approximation** of a real world scene



Sampling and the Nyquist rate



- **Aliasing** can arise when you sample a continuous signal or image
  - occurs when your sampling rate is not high enough to capture the amount of detail in your image
  - Can give you the wrong signal/image—an *alias*
  - formally, the image contains structure at different scales
    - called “frequencies” in the Fourier domain
  - the sampling rate must be high enough to capture the highest frequency in the image

- To avoid aliasing:
  - sampling rate > 2 * max frequency in the image
  - This minimum sampling rate is called the **Nyquist rate**

Effect of Spatial Resolution

(Images from Rafael C. Gonzalez and Richard E. Wood, Digital Image Processing, 2nd Edition.

Effect of Spatial Resolution

1024 X 1024

Effect of Spatial Resolution

512 X 512

Effect of Spatial Resolution

256 X 256

Effect of Spatial Resolution

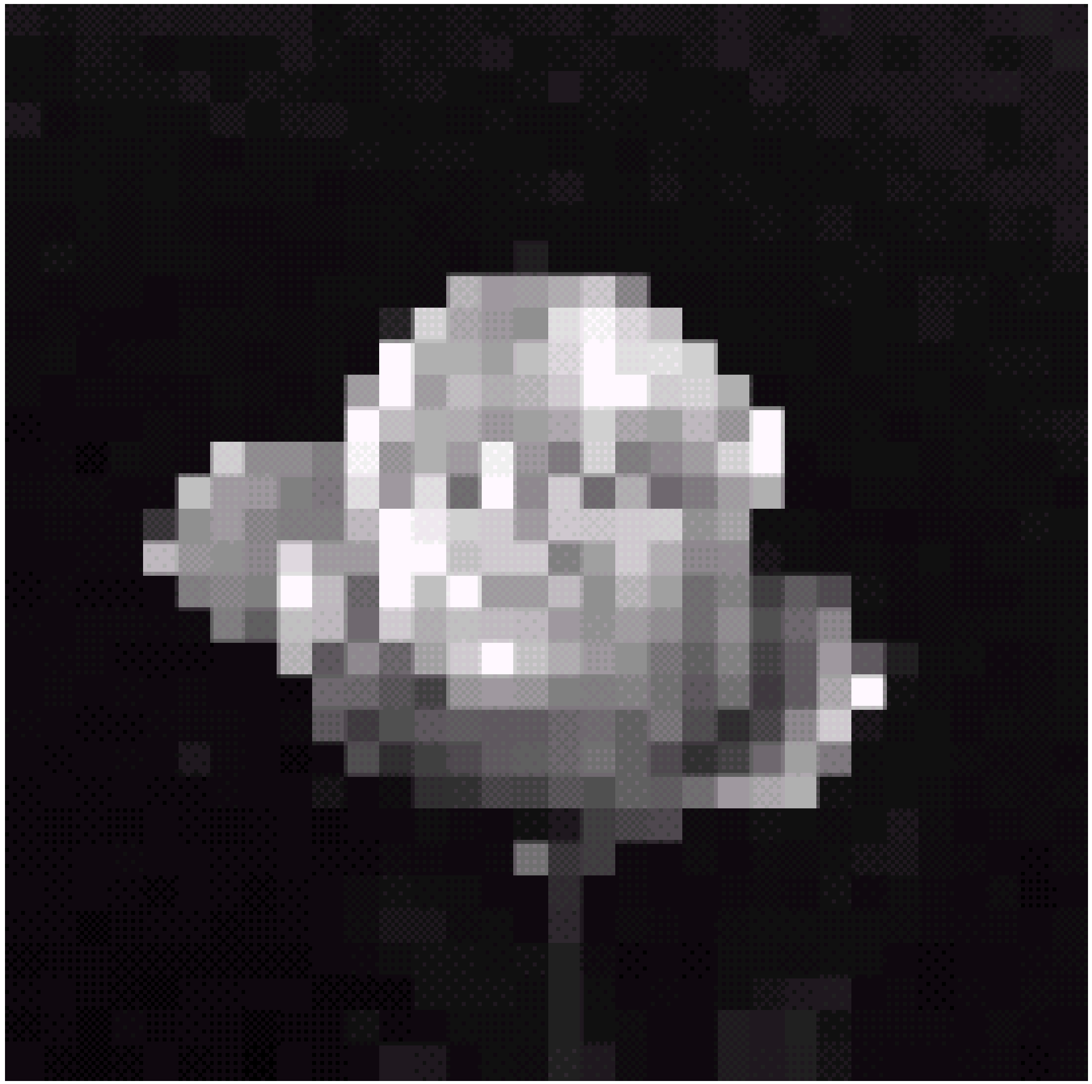
128 X 128

Effect of Spatial Resolution

64 X 64

Effect of Spatial Resolution

32 X 32



Intensity Level Resolution

- *Intensity level resolution* refers to the number of intensity levels used to represent the image
  - The more intensity levels used, the finer the level of detail discernible in an image
  - Intensity level resolution is usually given in terms of the number of bits used to store each intensity level

Number of Bits	Number of Intensity Levels	Examples
1	2	0, 1
2	4	00, 01, 10, 11
4	16	0000, 0101, 1111
8	256	00110011, 01010101
16	65,536	1010101010101010

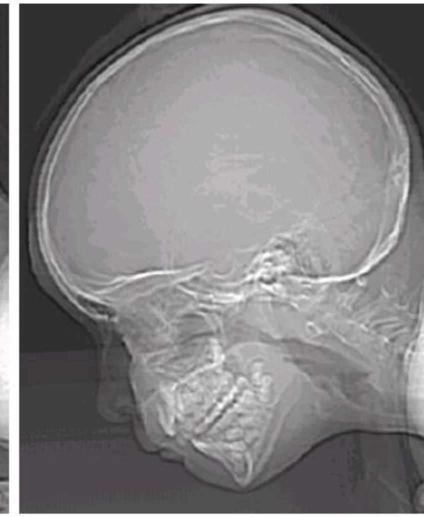
Intensity Level Resolution

256 grey levels (8 bits per pixel)

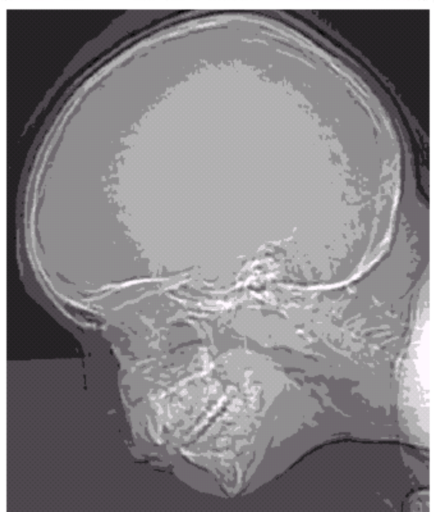
128 grey levels (7 bpp)

64 grey levels (6 bpp)

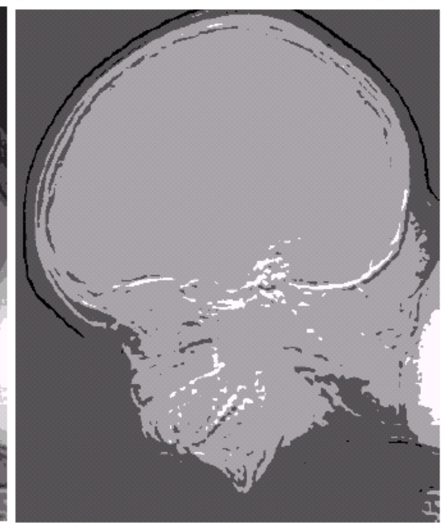
32 grey levels (5 bpp)



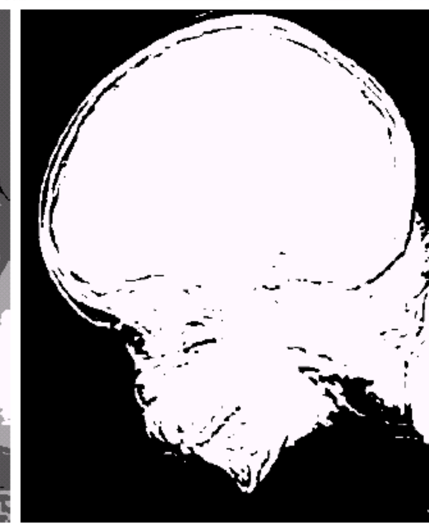
16 grey levels (4 bpp)



8 grey levels (3 bpp)



4 grey levels (2 bpp)



2 grey levels (1 bpp)