Contents

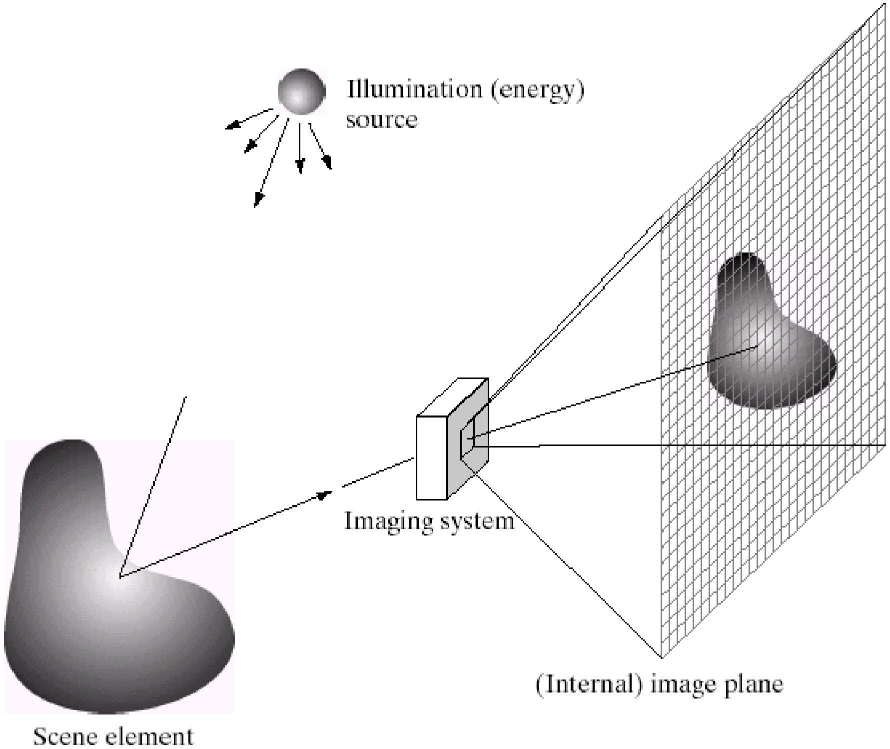
This lecture will cover:

- Image acquisition, formation and sensing
- Sampling, quantisation
- Image representation
- Spatial, Intensity and temporal resolution

Image Acquisition

Images taken from Gonzalez & Woods, Digital Image Processing (2002)

Images are typically generated by *illuminating* a *scene* and absorbing the energy reflected by the objects in that scene



- Typical notions of illumination and scene can be way off:
  - X-rays of a skeleton
  - Ultrasound of an unborn baby
  - Electro-microscopic images of molecules

Image Formation

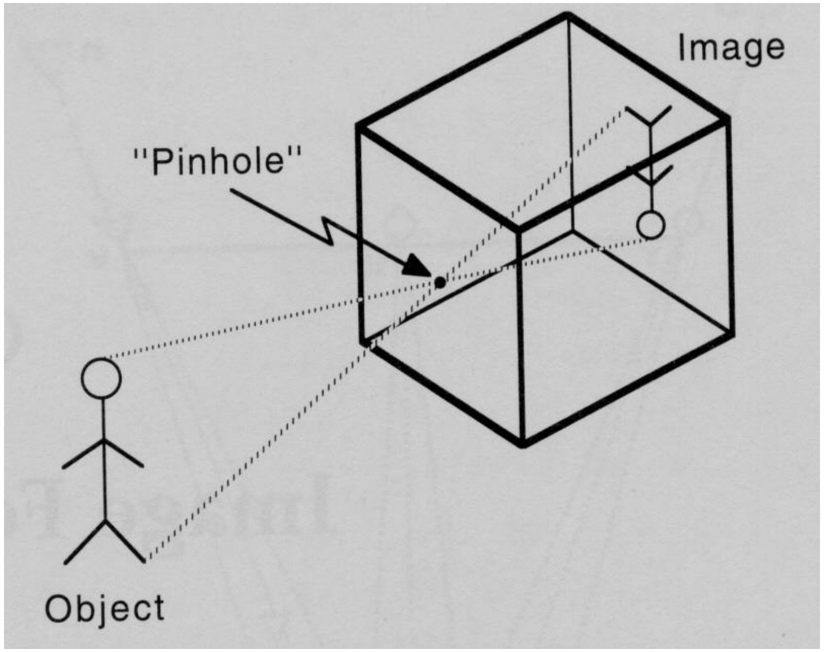
There are two parts to the image formation process:

- The **geometry of image formation**, which determines where in the image plane the projection of a point in the scene will be located.
- The **physics of light**, which determines the brightness of a point in the image plane as a function of illumination and surface properties.

Pinhole camera

This is the simplest device to form an image of a 3D scene on a 2D surface.

Straight rays of light pass through a “pinhole” and form an inverted image of the object on the image plane.

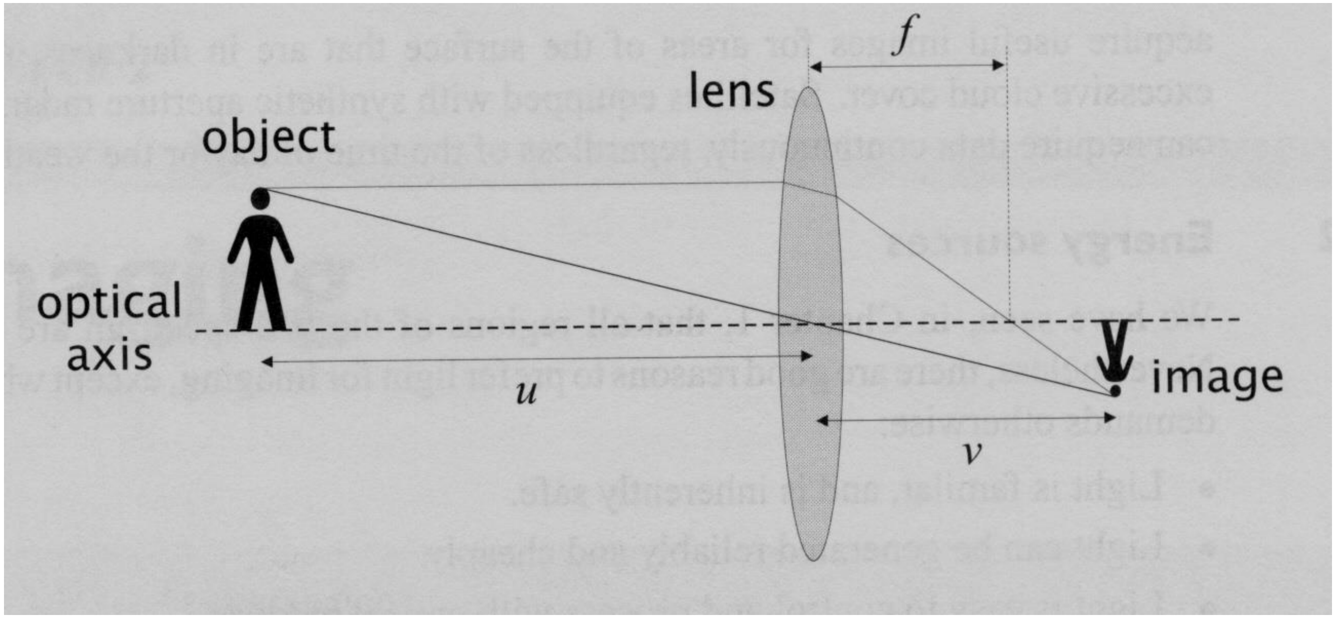


$$x = \frac{fX}{Z}$$

$$y = \frac{fY}{Z}$$

Camera optics

- In practice, the aperture must be larger to admit more light.
- Lenses are placed to in the aperture to **focus** the bundle of rays from each scene point onto the corresponding point in the image plane



A Simple Photometric Model

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

$f(x, y)$: intensity at the point (x, y)

$i(x, y)$: illumination at the point (x, y)

(the amount of source illumination incident on the scene)

$r(x, y)$: reflectance/transmissivity at the point (x, y)

(the amount of illumination reflected/transmitted by the object)

where $0 < i(x, y) < \infty$ and $0 < r(x, y) < 1$

Digital Image

- Function $f : A \rightarrow B,$ where A: domain, B: range

  Continuous – A, B: continuous

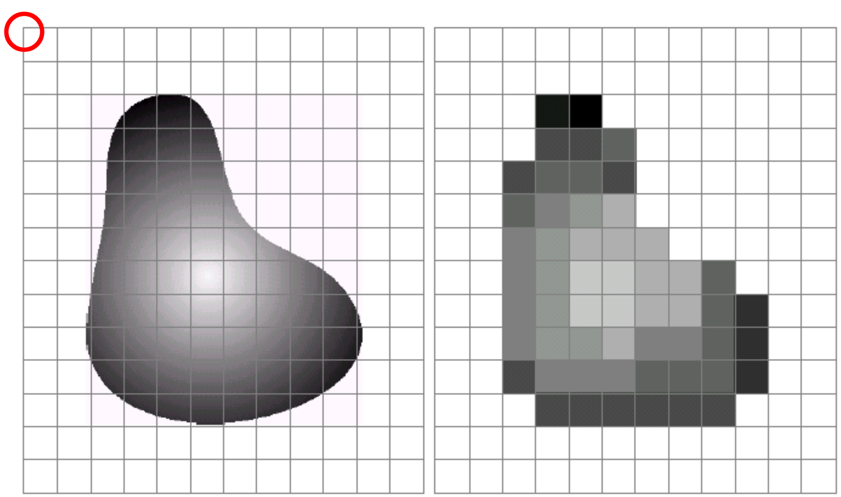
  Discrete – A: discrete, B: continuous

  Digital – A, B: discrete

- Scene $g(x,y,z)$: a 3-D continuous function

  Digital image $f(x,y)$: a 2-D digital function

Origin



Pixel: picture element

Digital Image (cont…)

Pixel values typically represent gray levels, colours, heights, opacities etc

Remember *digitization* implies that a digital image is an *approximation* of a real scene

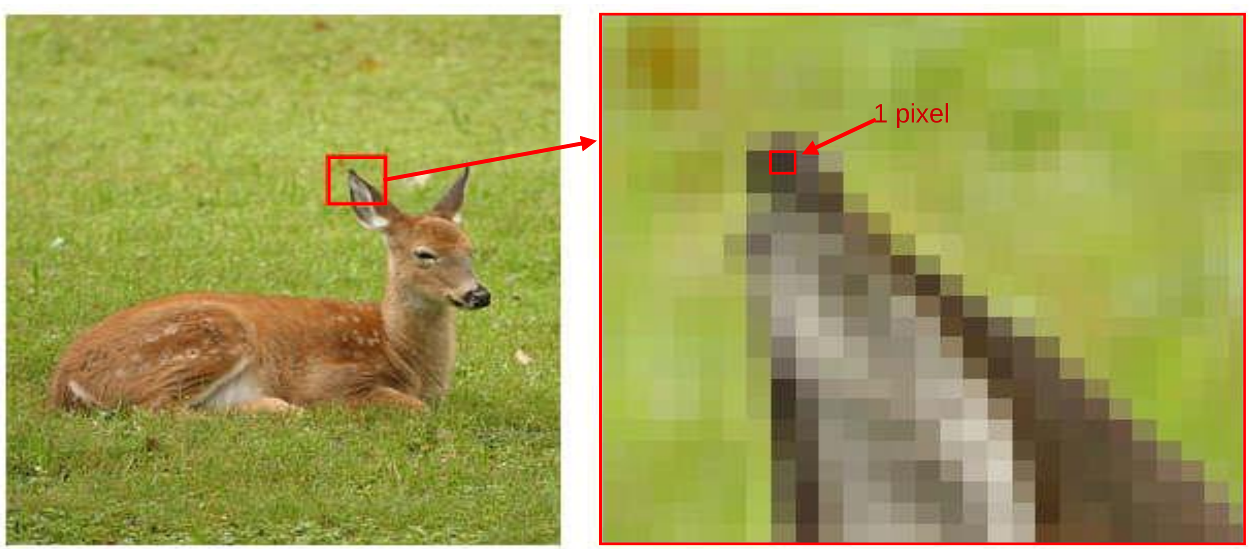


Image types

Common image formats include:

- 1 sample per point (B&W or Grayscale)
- 3 samples per point (Red, Green, and Blue)
- 4 samples per point (Red, Green, Blue, and “Alpha”, a.k.a. Opacity)

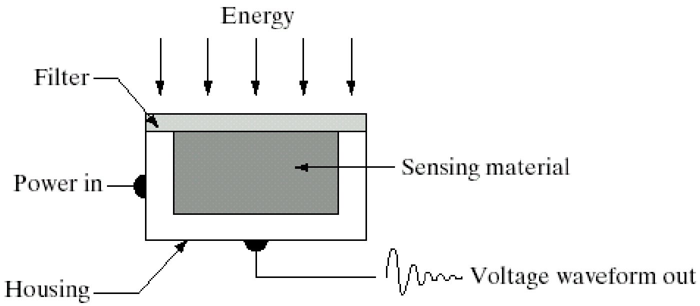


For most of this course we will focus on grey-scale images

Digital cameras

A digital camera replaces film with a sensor array.

- Each cell in the array is light-sensitive diode that converts photons to electrons

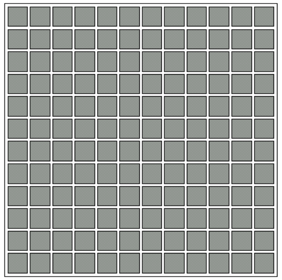


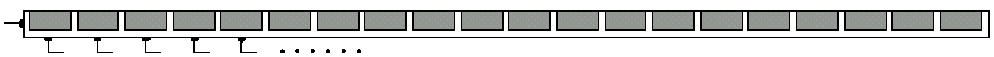
- Two common types
  - Charge Coupled Device (CCD)
  - Complementary metal oxide semiconductor (CMOS)

Image Sensing

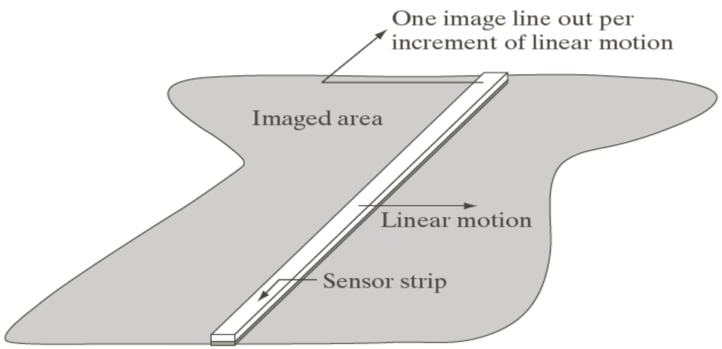
Sensors can be arranged in fixed 2D array or a line strip or a ring

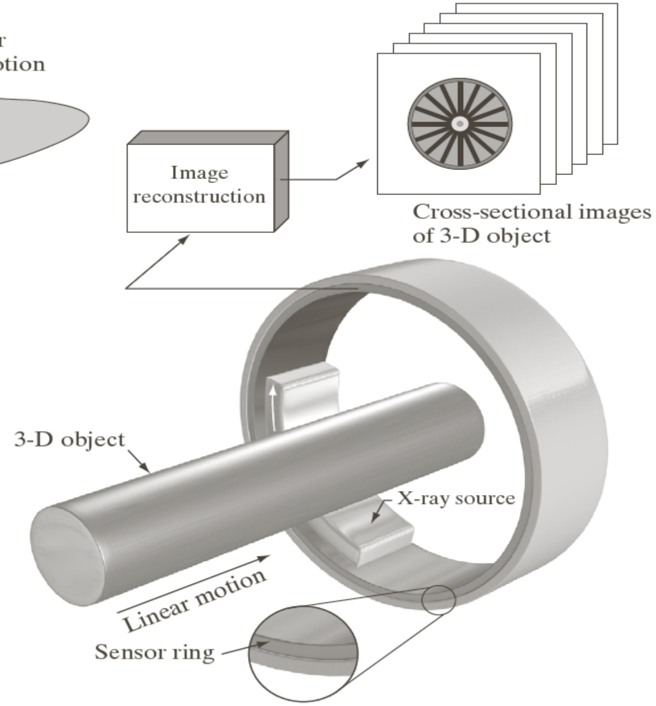
Array of Image Sensors





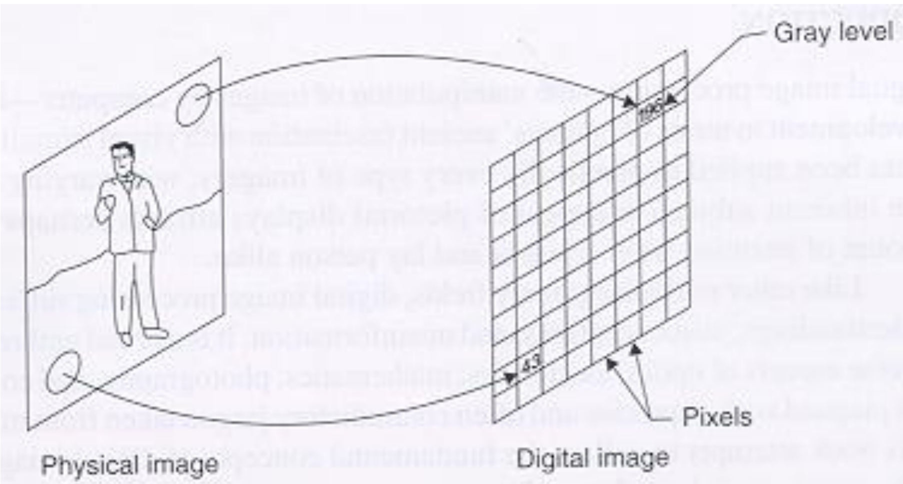
Line of Image Sensors

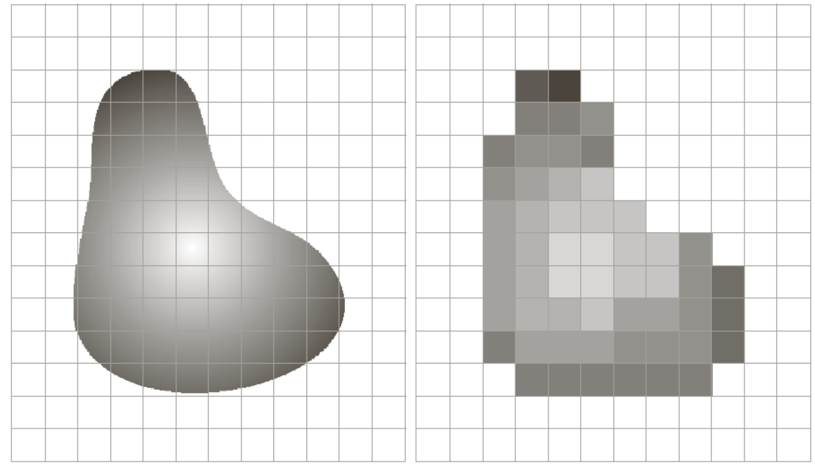




Images taken from Gonzalez & Woods, Digital Image Processing (2002)

Image Sampling And Quantisation





Sampling: measure the value of an image at a finite number of points.

Quantization: represent measured value (i.e., voltage) at the sampled point by a finite set of integer values.

Image Sampling And Quantisation

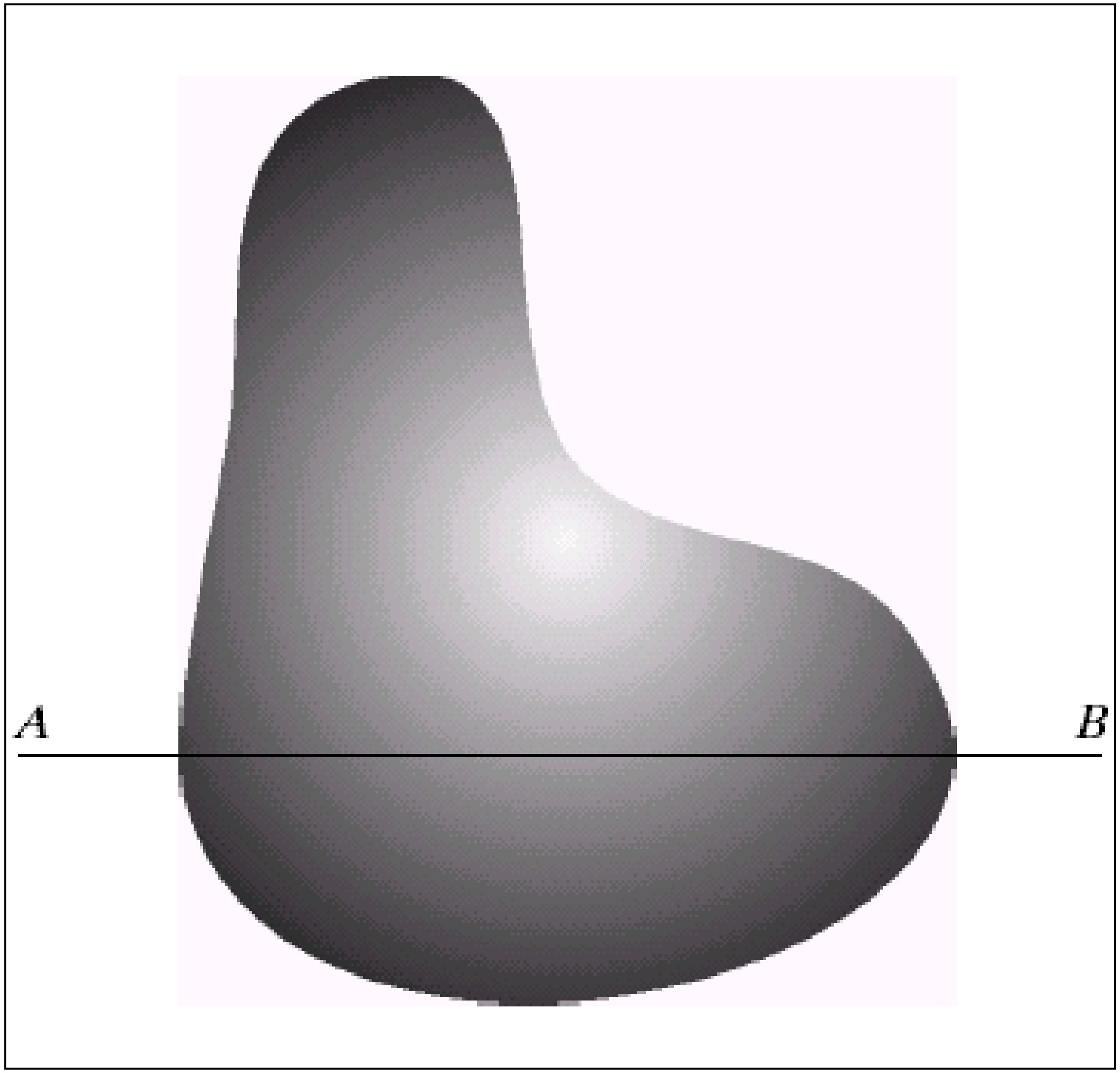
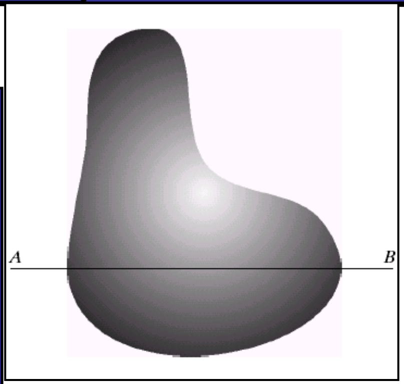


Image Sampling And Quantisation



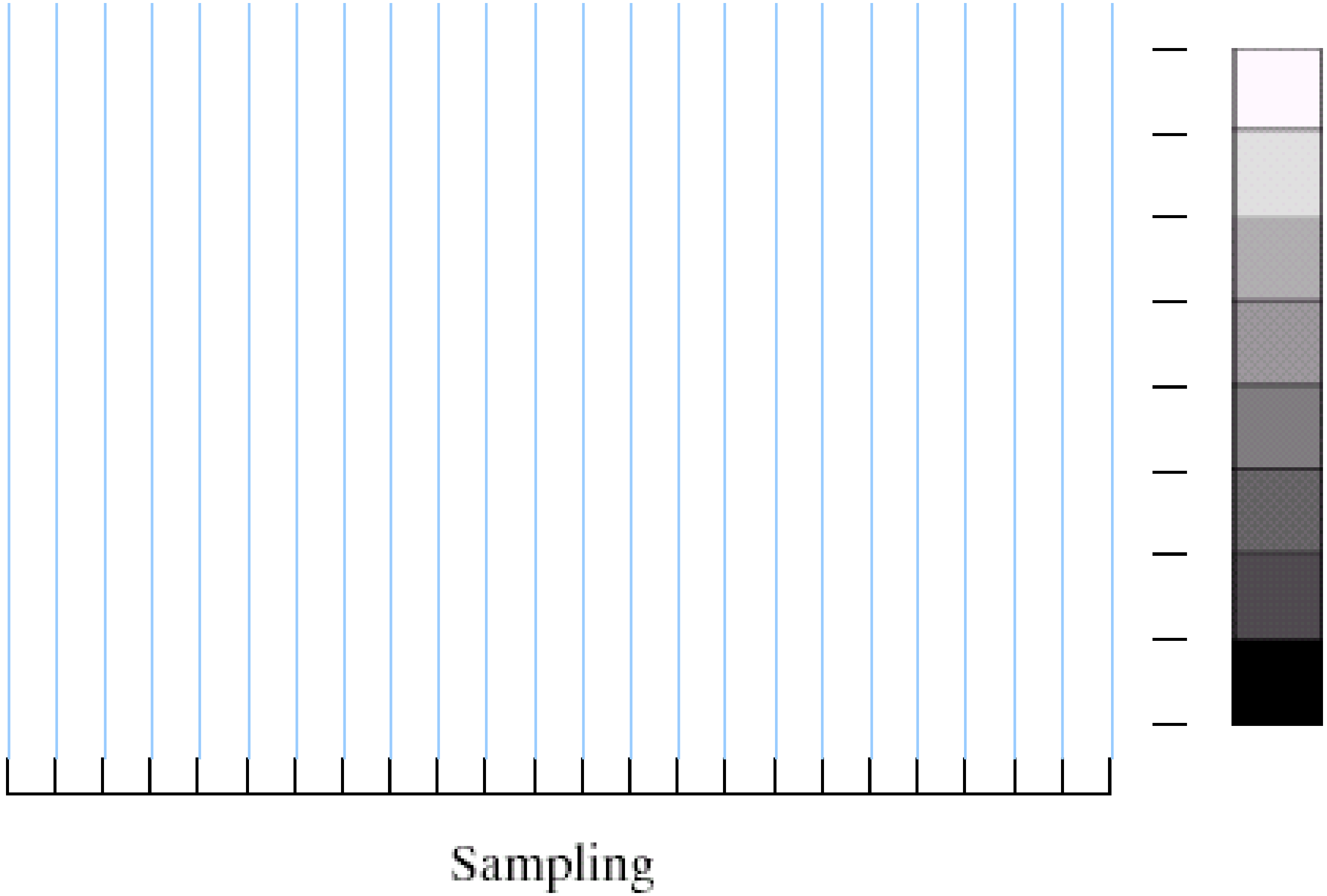
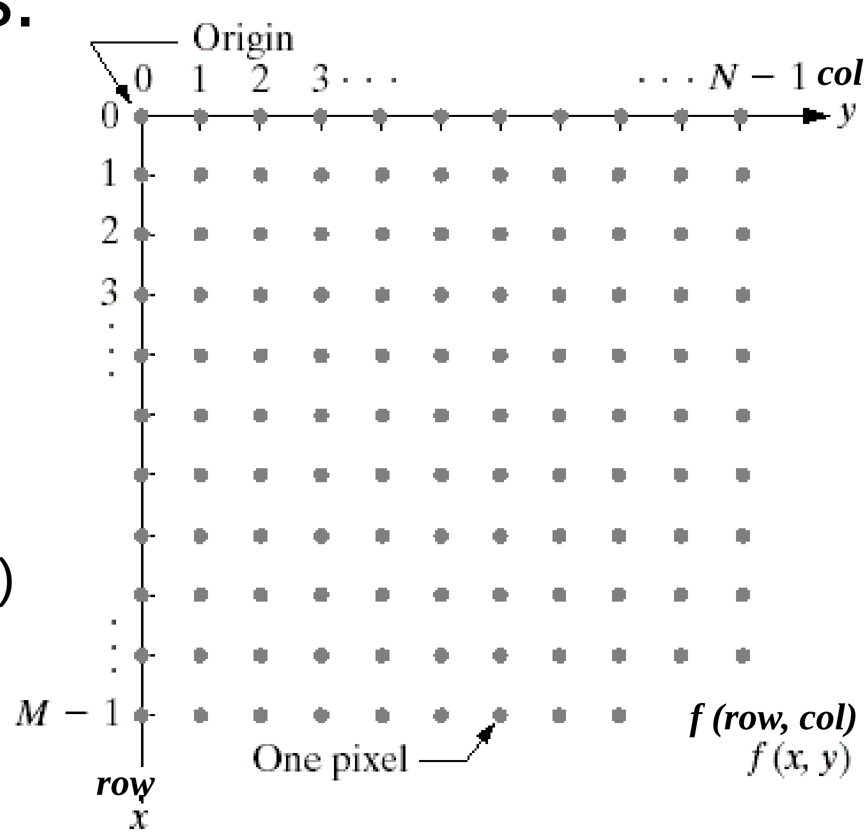


Image Representation

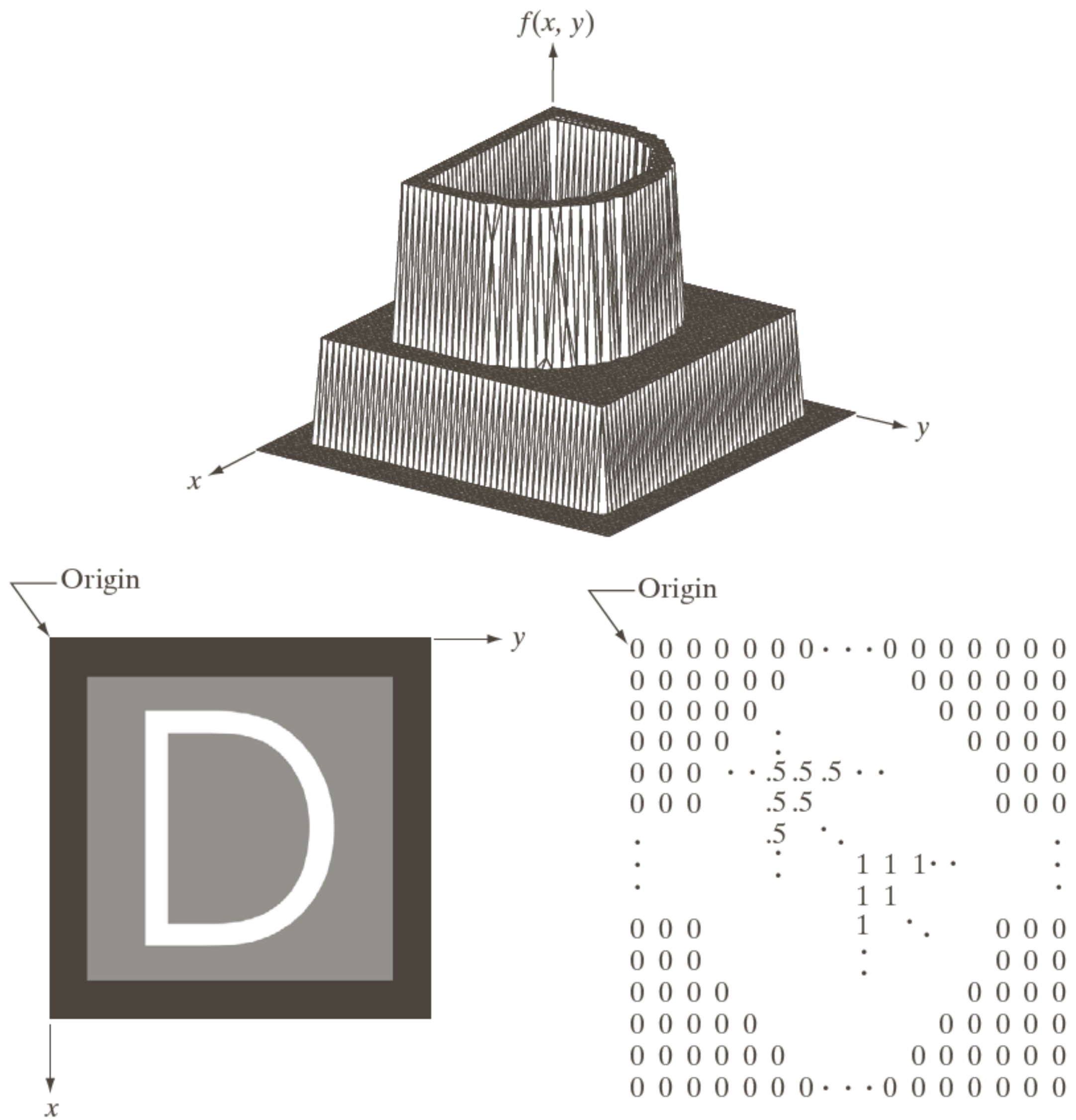
A digital image can easily be represented as matrices composed of M rows and N columns of pixel values.

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



Pixel values are most often grey levels in the range 0-255(black-white)

Image Representation



Images taken from Gonzalez & Woods, Digital Image Processing (2002)

Image Representation

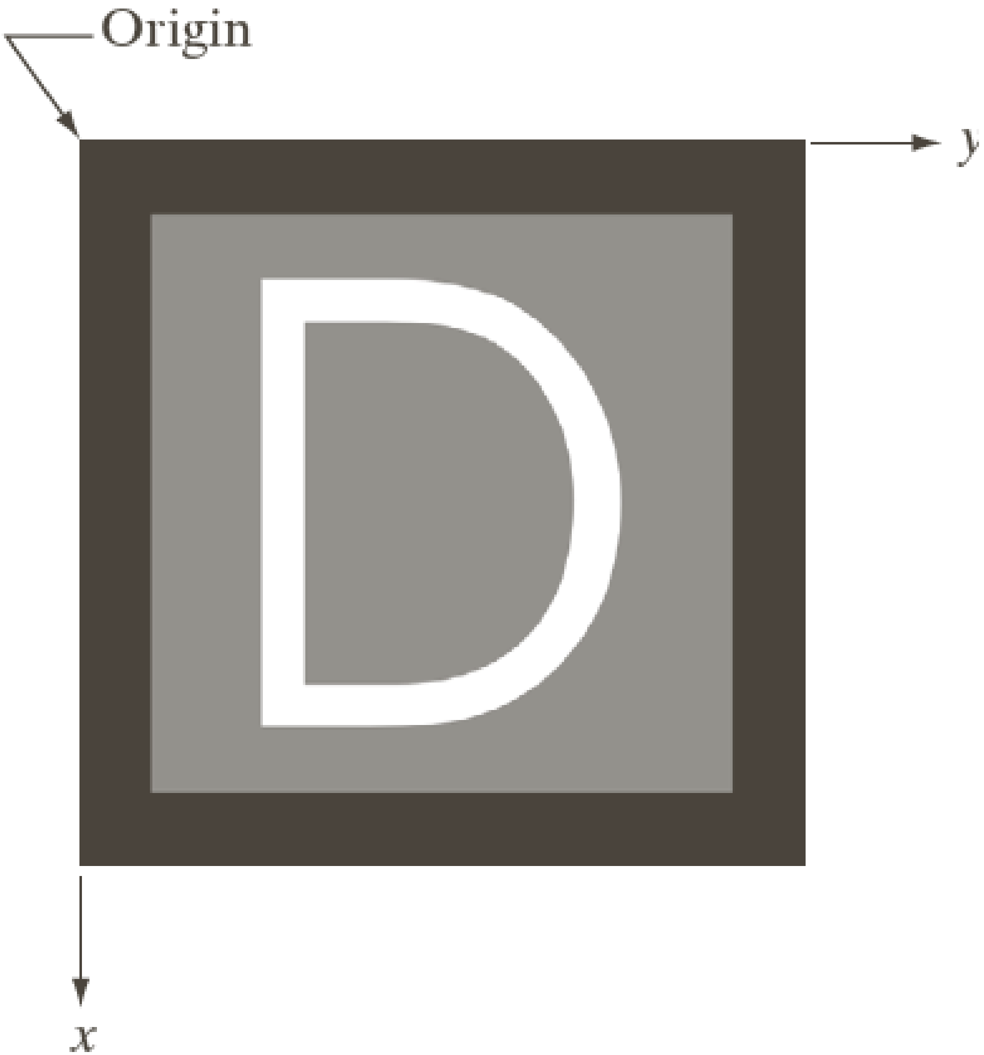


Image Representation

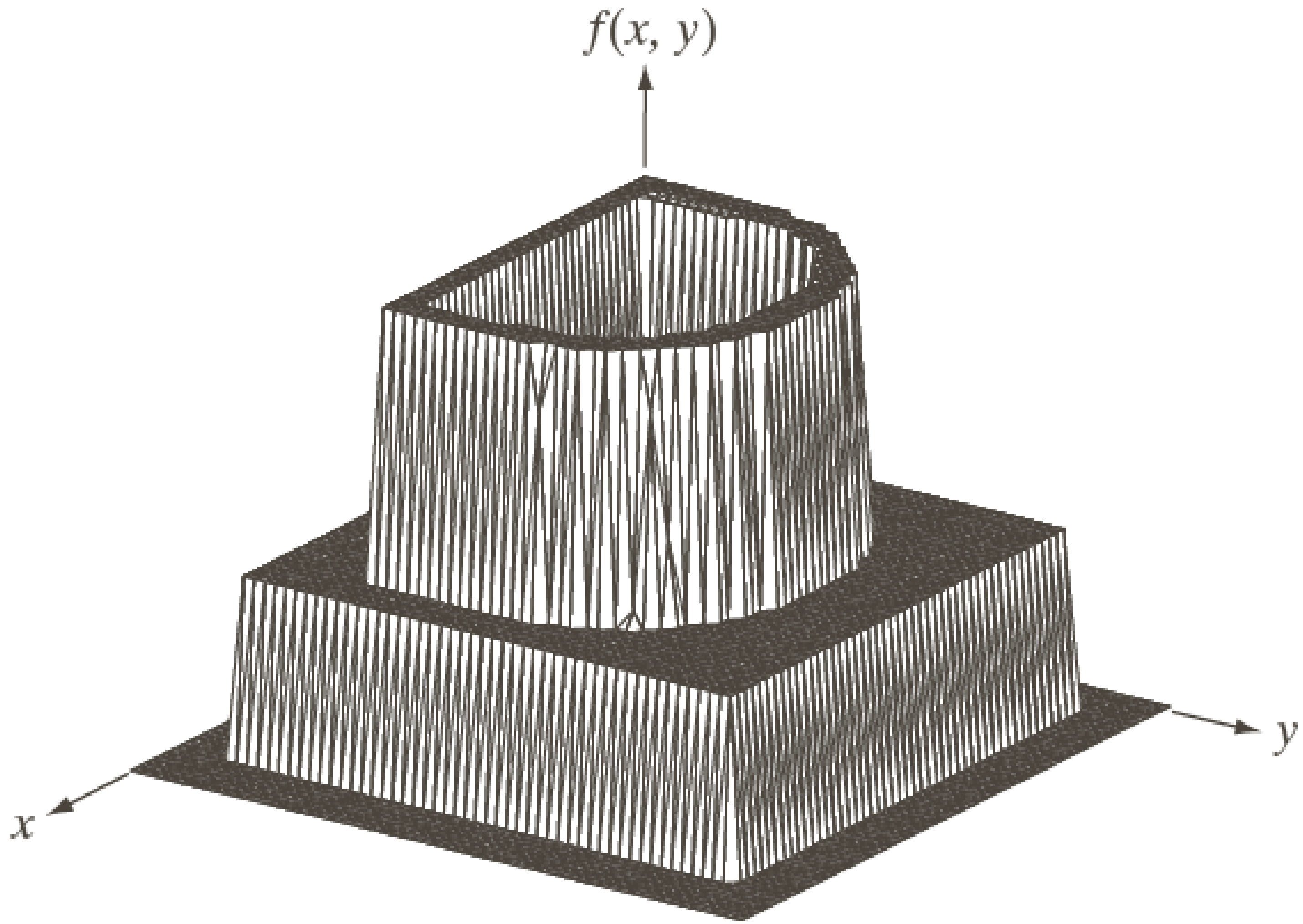
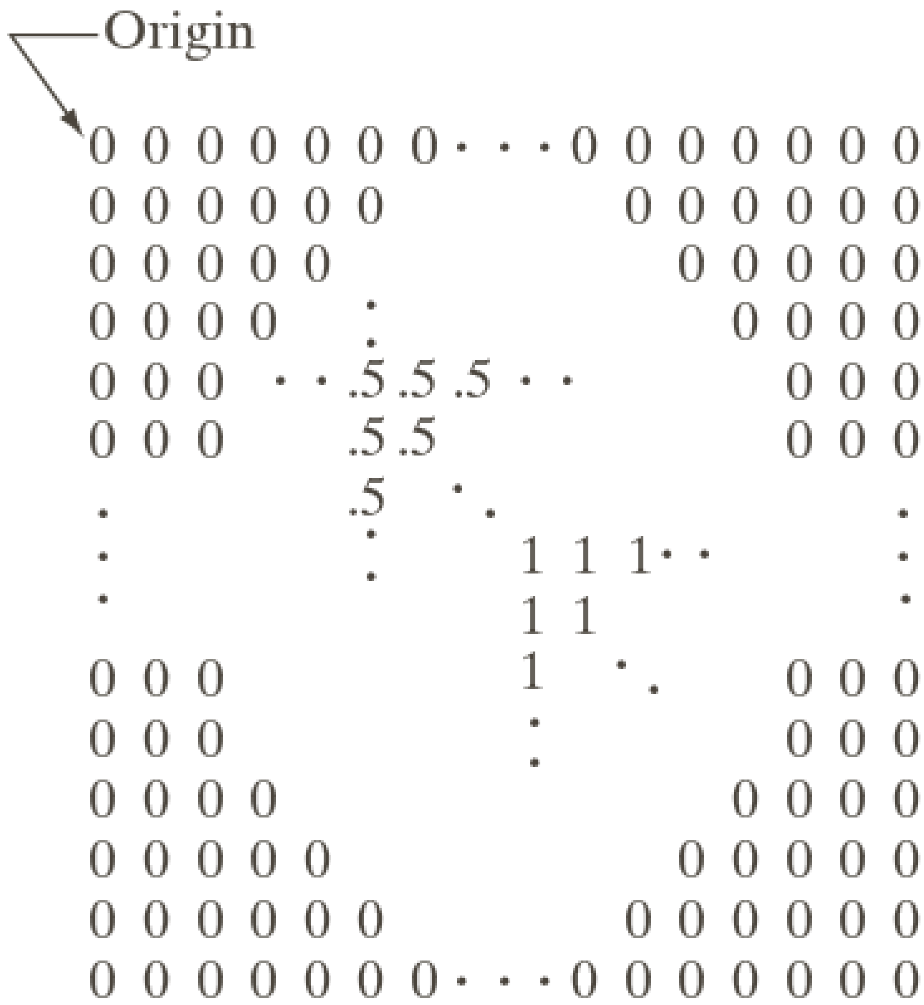


Image Representation



Images taken from Gonzalez & Woods, Digital Image Processing (2002)

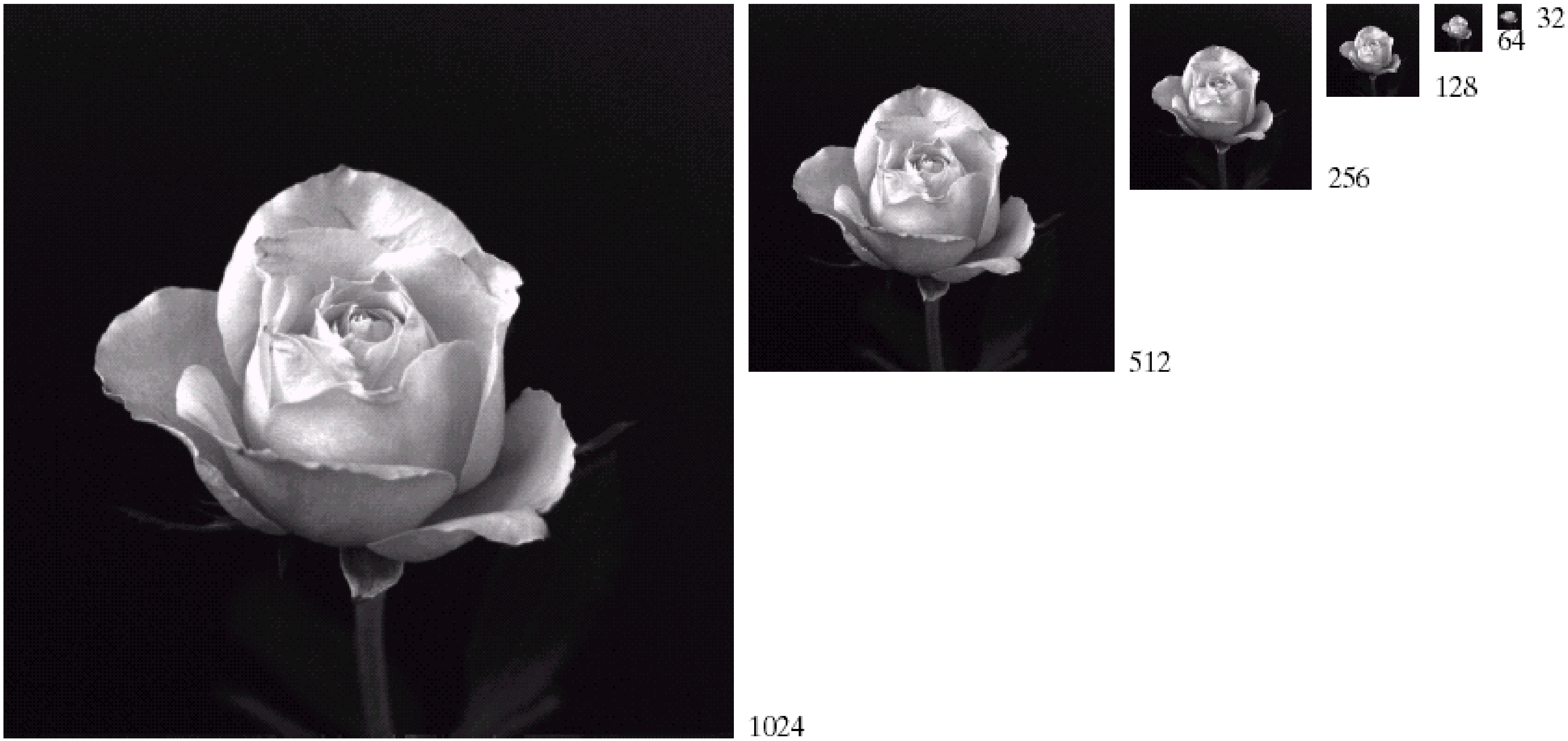
Spatial Resolution

The spatial resolution of an image is determined by how sampling was carried out

Spatial resolution simply refers to the smallest discernable detail in an image

Spatial Resolution (cont…)

Images taken from Gonzalez & Woods, Digital Image Processing (2002)



Spatial Resolution (cont…)

Spatial Resolution (cont…)

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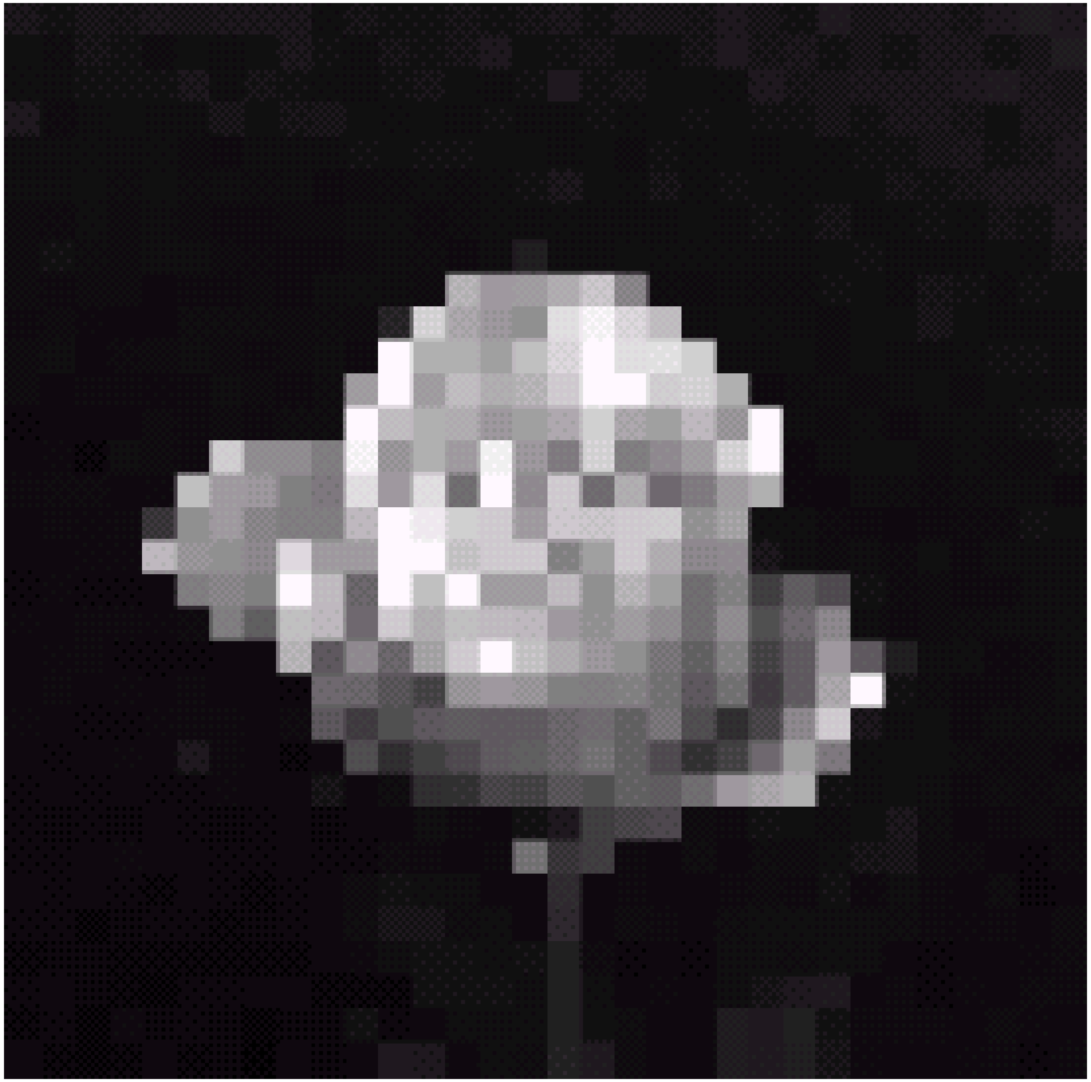
Images taken from Gonzalez & Woods, Digital Image Processing (2002)

Spatial Resolution (cont…)



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 discernable 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

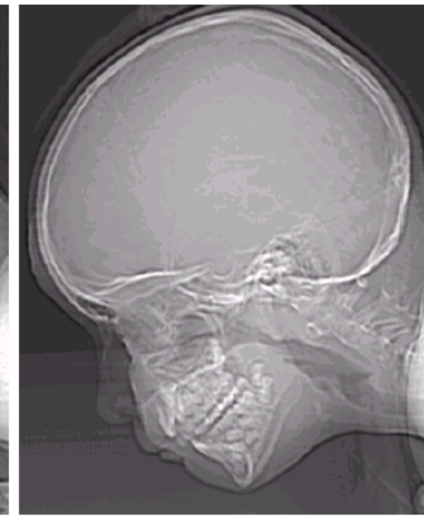
Intensity Level Resolution (cont…)

256 grey levels (8 bits per pixel)

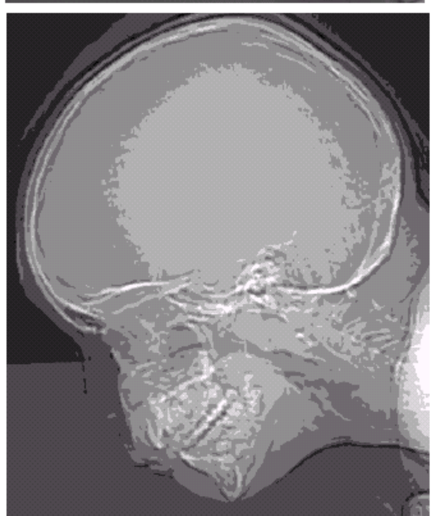
128 grey levels (7 bpp)

64 grey levels (6 bpp)

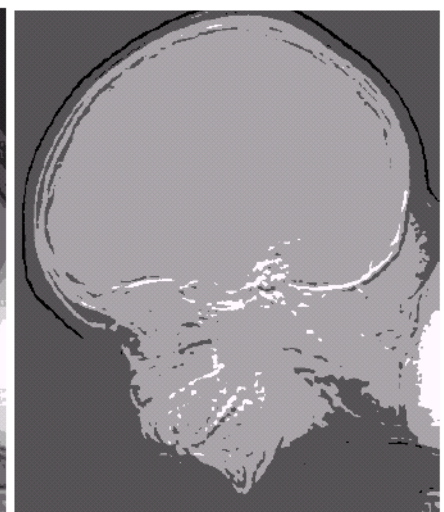
32 grey levels (5 bpp)



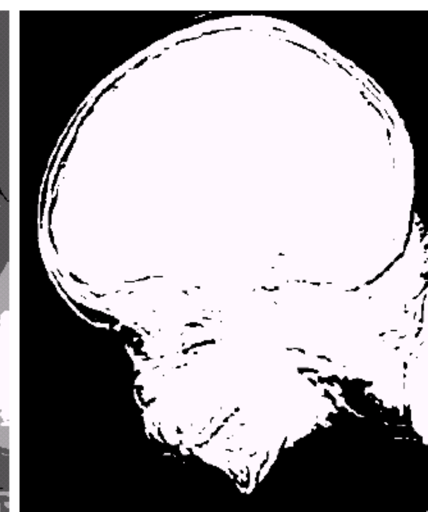
16 grey levels (4 bpp)



8 grey levels (3 bpp)



4 grey levels (2 bpp)



2 grey levels (1 bpp)

Images taken from Gonzalez & Woods, Digital Image Processing (2002)

Intensity Level Resolution (cont…)

Intensity Level Resolution (cont…)

Intensity Level Resolution (cont…)

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Intensity Level Resolution (cont…)

Intensity Level Resolution (cont…)

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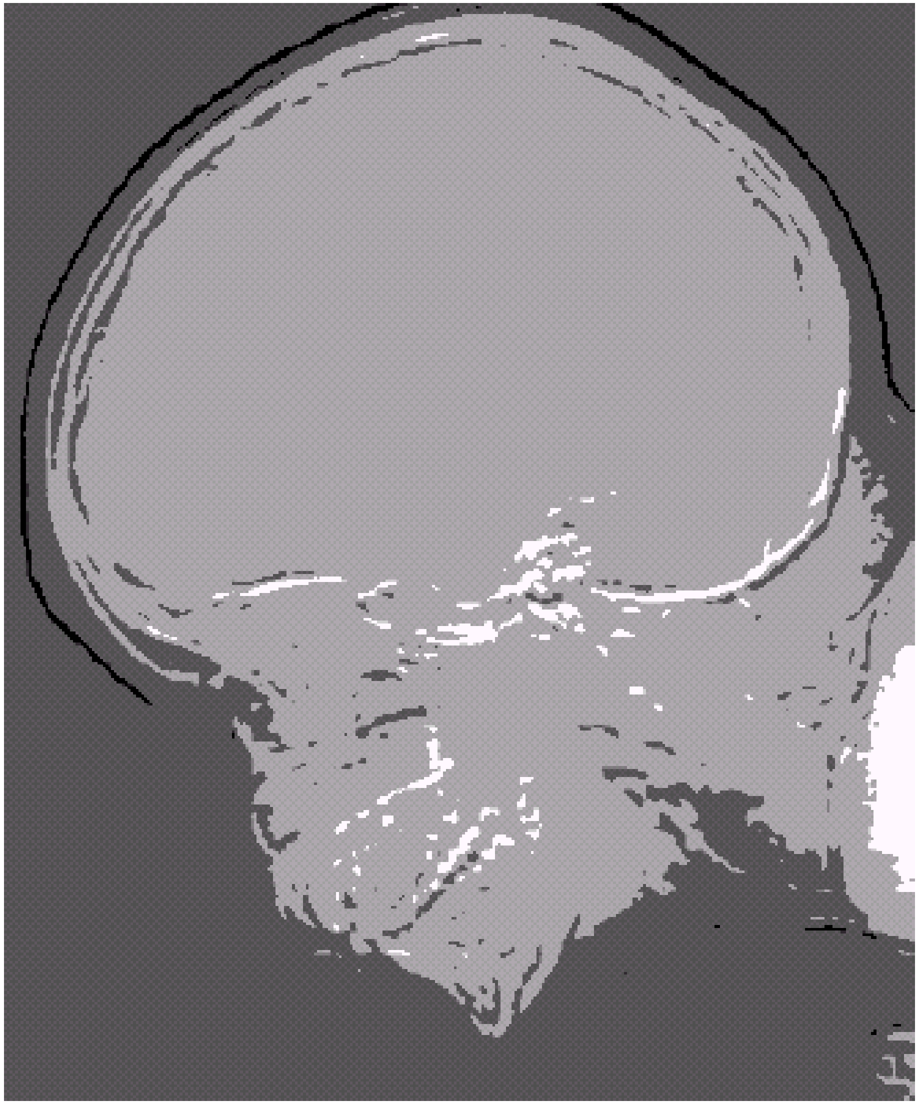


Intensity Level Resolution (cont…)

Resolution: How Much Is Enough?

The big question with resolution is always *how much is enough*?

- This all depends on what is in the image and what you would like to do with it
- Key questions include
  - Does the image look aesthetically pleasing?
  - Can you see what you need to see within the image?

Resolution: How Much Is Enough? (cont…)

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

Intensity Level Resolution (cont…)

Low Detail

Medium Detail

High Detail

Intensity Level Resolution (cont…)

Intensity Level Resolution (cont…)

Intensity Level Resolution (cont…)

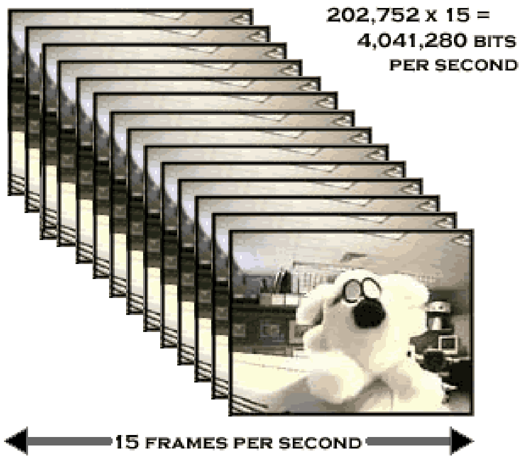
Temporal Resolution

A Digital video can be thought of as a sequence of digital image. A video playback device creates the illusion of full motion by displaying a rapid sequence of changing images on a display device.

Temporal resolution

Frame Rate

- animation is an illusion caused by the rapid display of still images.
- television and movies play at 25-30 fps but acceptable playback can be achieved with 12-15 fps.



Summary

We have looked at:

- Image acquisition, formation and sensing
- What is a Digital Image?
- Sampling, quantisation
- Image representation
- Spatial, Intensity, temporal resolution

Next time we start to look basic terminologies, relationship between pixels and common image operations