Imaging and digital image fundamentals

History related to digital imaging

Coded images transferred by submarine cables:

London to NY

5 to 15 gray levels

Advent of computers 40s:

1) memory 2) conditional branching

Transistors: 1948

Programming languages, COBOL, FORTRAN: 50s and 60s

IC: 1958

OS: 60s

Microprocessor: 70s

LSI: 70s

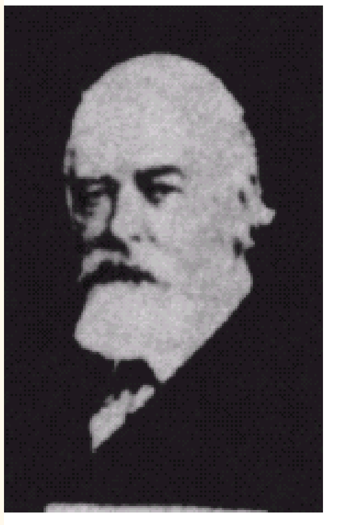
Image processing: 60s (NASA JPL Ranger 7, Moon)

Late 60s and 70s: Medical CT

Early digital images

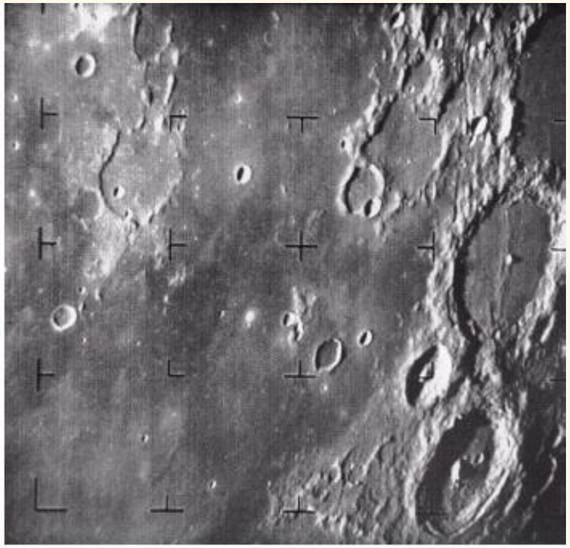
Early Bartlane systems: 5 distinct gray levels

1921



1922

1929



Use of computers JPL, 1964

Imaging

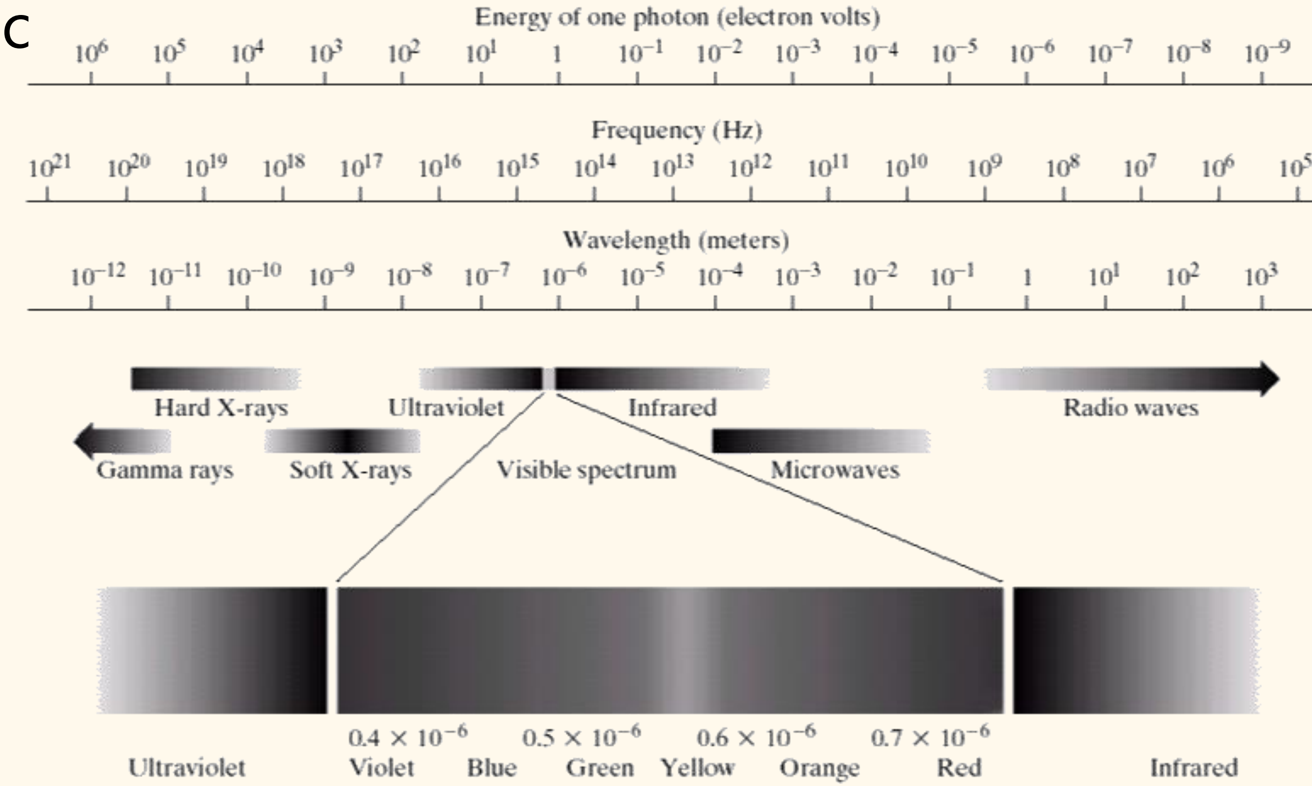
Imaging systems:

- Almost all of the EM spectrum
- Sound
- Electron
- Computer-generated images

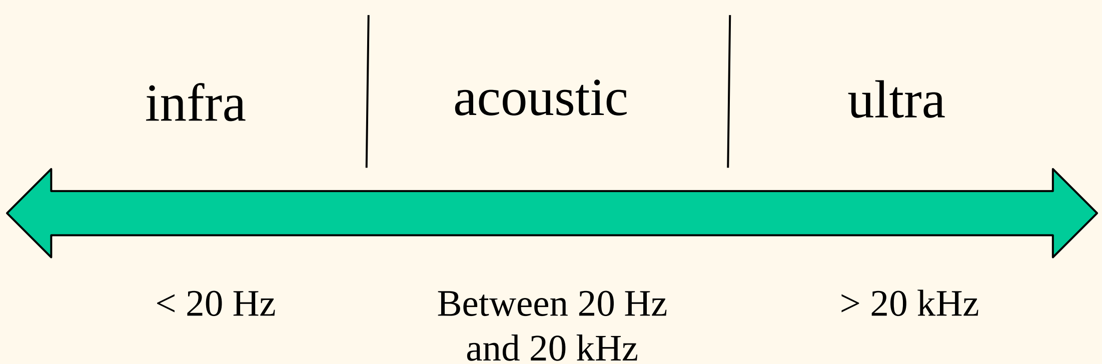
Human vision: visual band of the electromagnetic (EM) spectrum.

Imaging

1. Electromagnetic



2. Sound



3. Electron
4. Computer-generated images

Gamma ray

Nuclear medicine and astronomical:

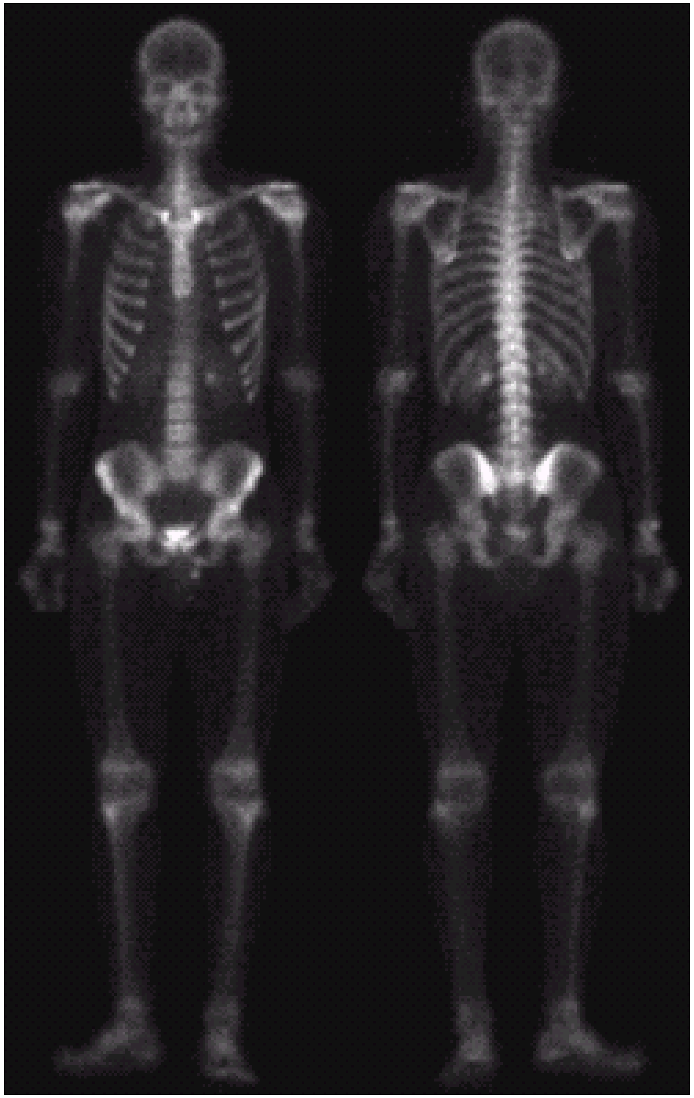
Nuclear: Inject radioactive isotope that emits gamma rays

Then the gamma rays are detected

PET: Inject radioactive isotope that emits positron (positive electron)

$$p + e \longrightarrow 2 \text{ gamma ray}$$

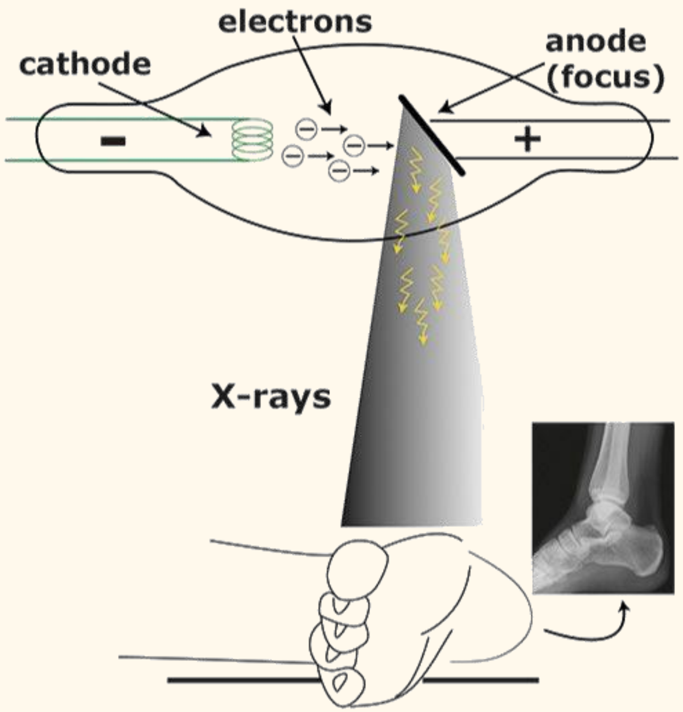
Gamma ray



Bone scan

PET image

X-ray

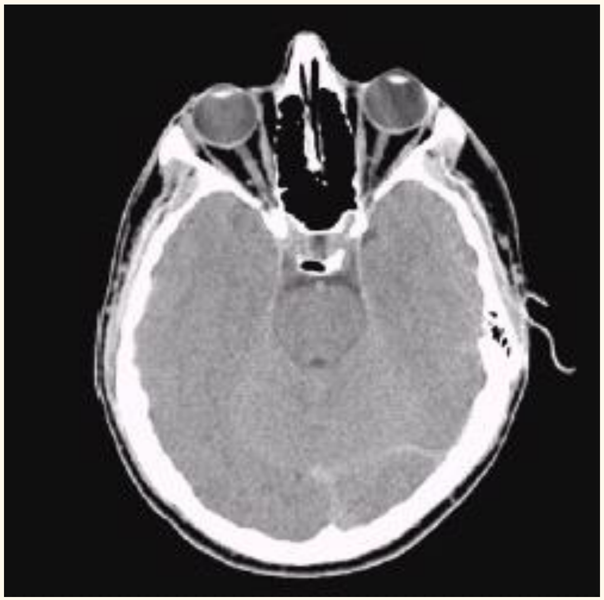


- Energy (penetrating power) is controlled by the voltage applied across the anode and by the current applied to the filament in the cathode.
- When electron strikes a nucleus, energy is released in X-ray form

X-ray

Chest x-ray

Aortic angiogram



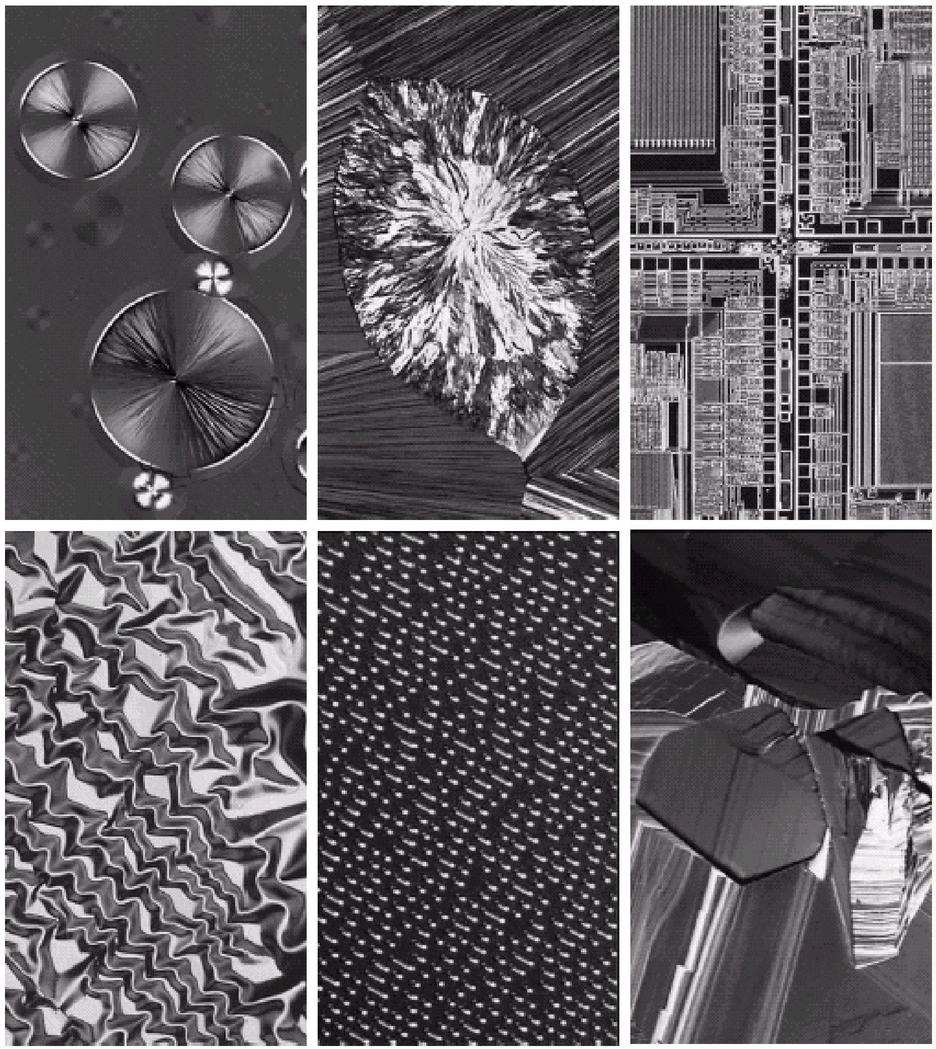
Head CT

UV

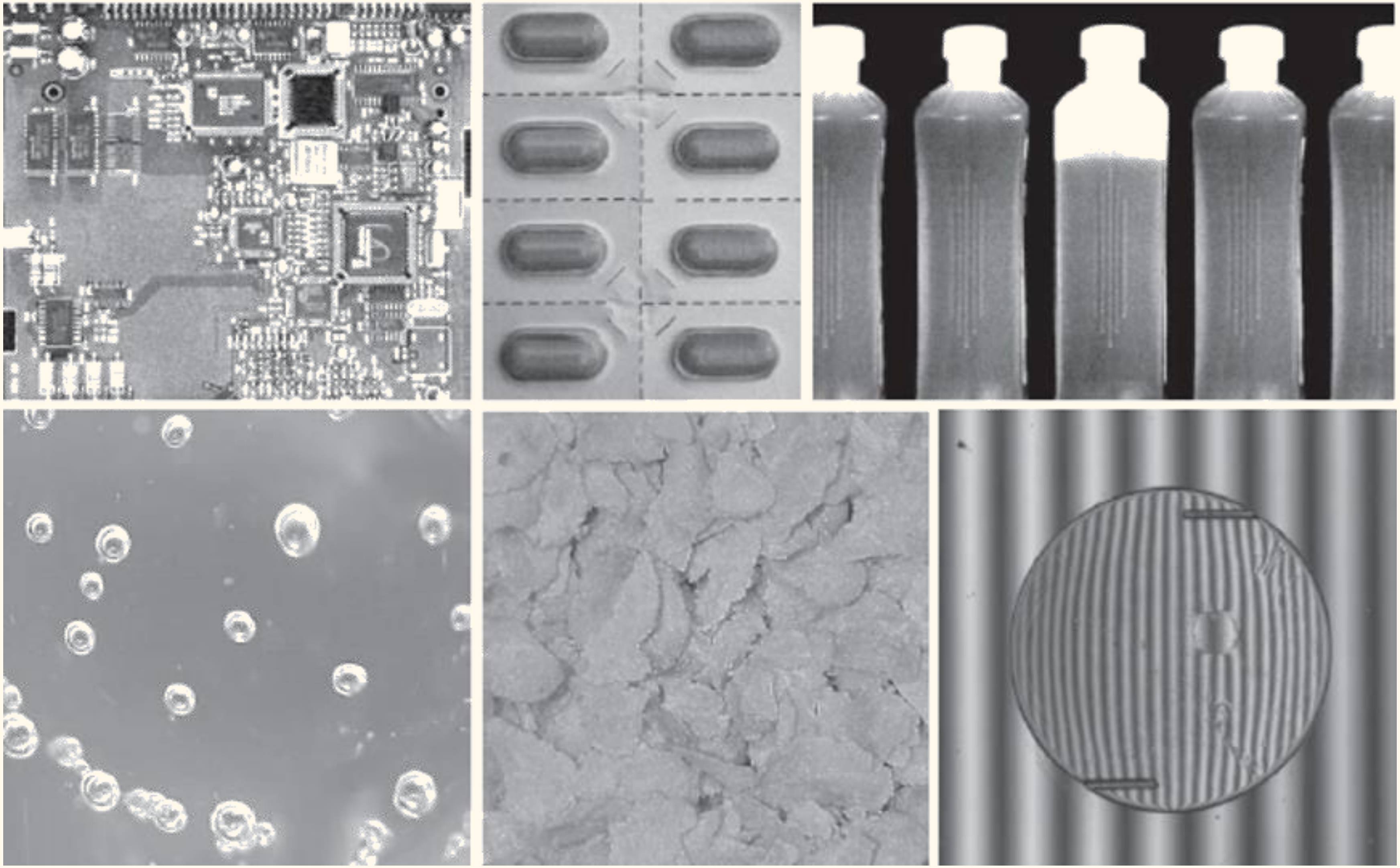
Applications:
Lithography, industrial, microscopy, biological, astronomy, microscopy: fluorescence microscopy

Fluorescence: Mineral fluorspar fluoresces when UV light is directed upon it.
Fluorescence microscopy:
Primary: Natural form
Secondary: After treatment with chemicals

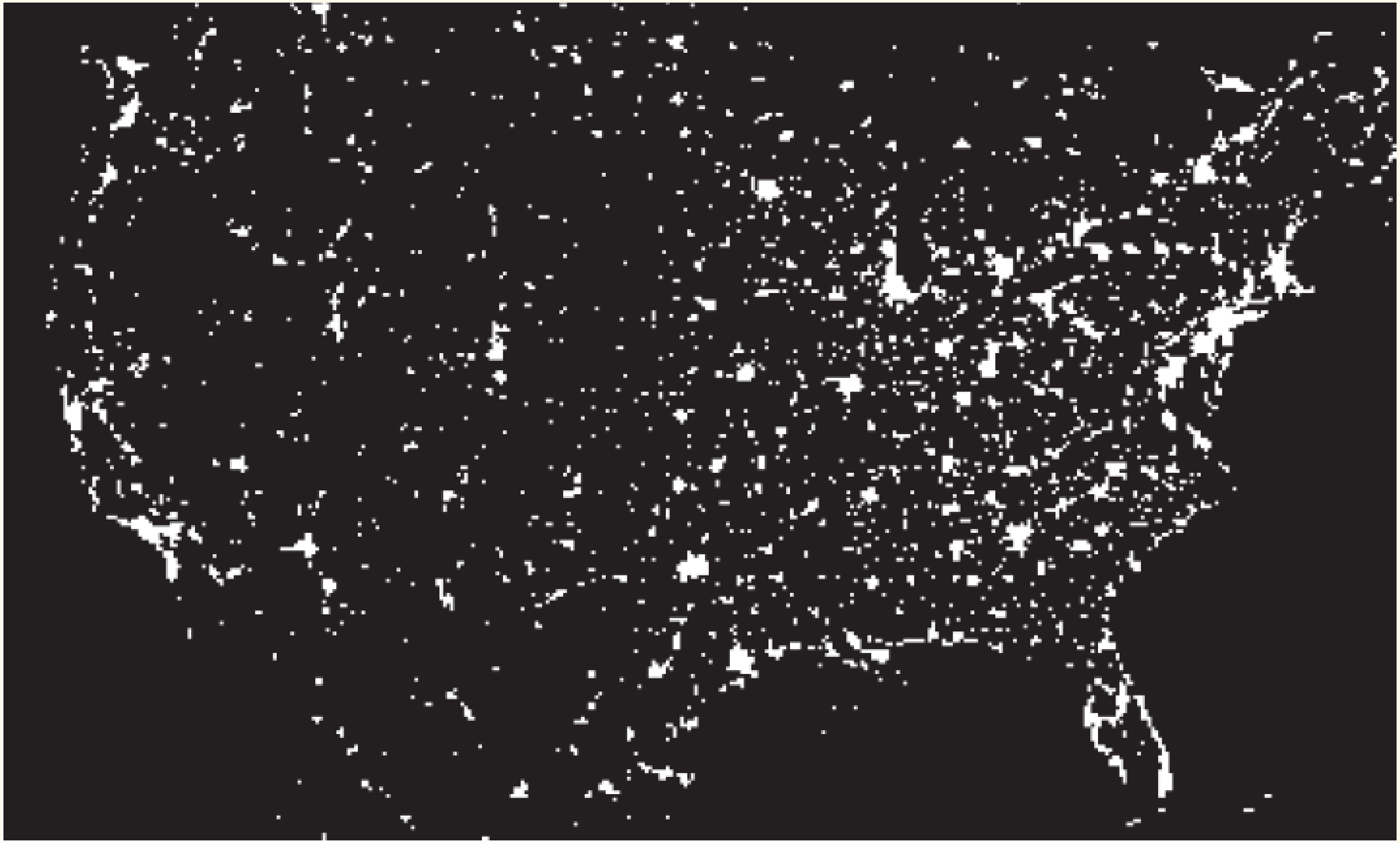
Light microscopy



Visible band

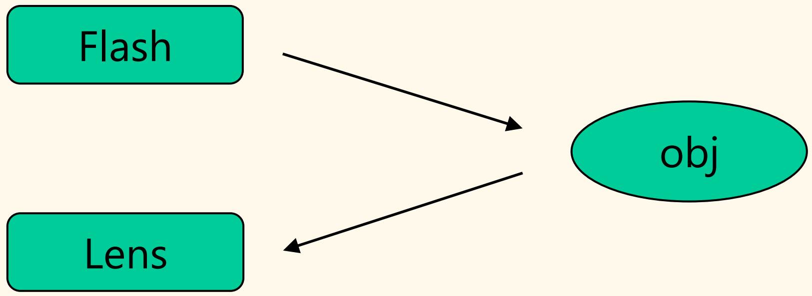


Infrared (IR) imaging

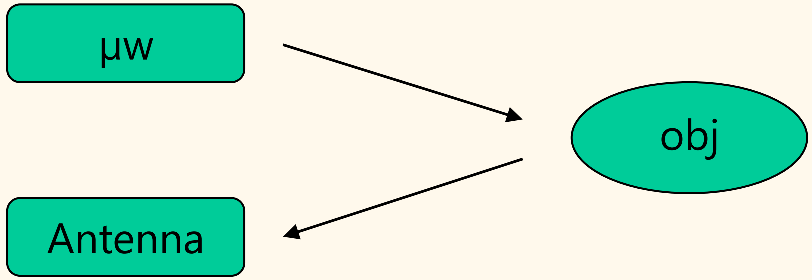


Microwave

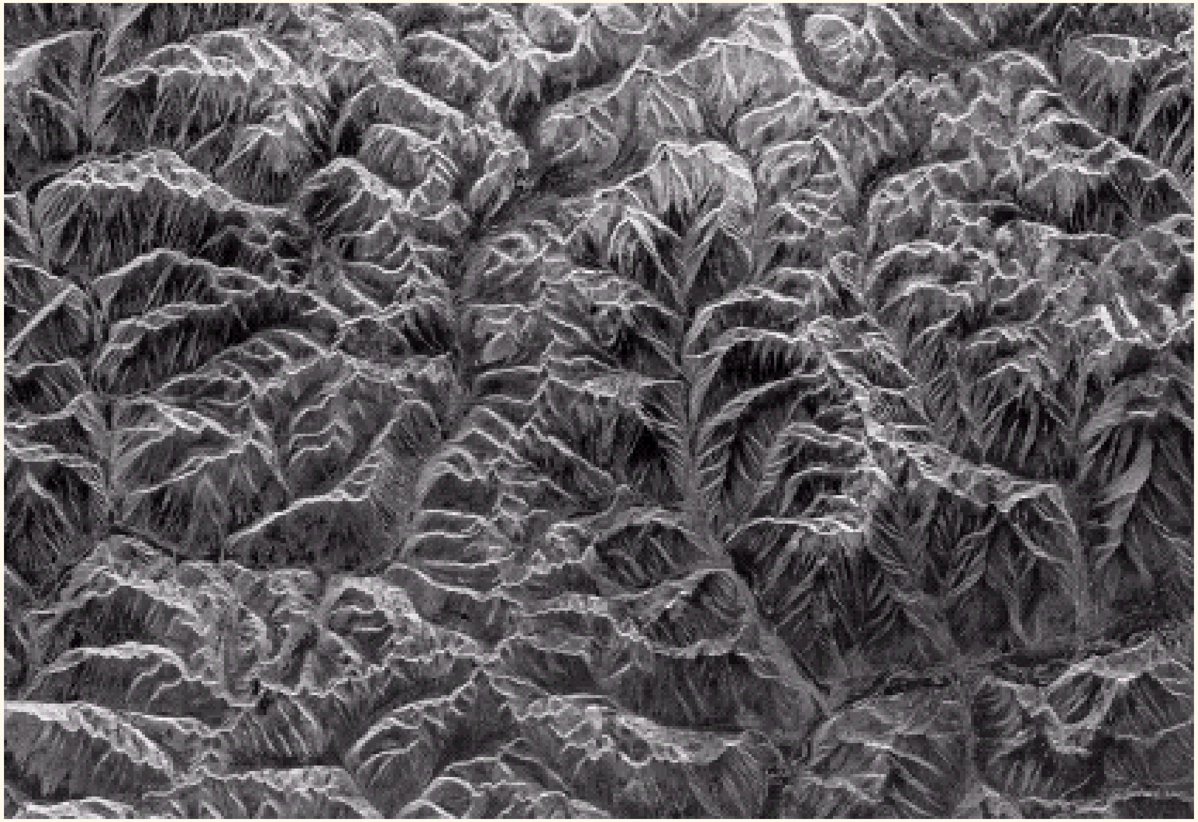
Flash camera:



Radar:



Microwave band



Radar image of Tibet mountains

Radio band

Medical & astronomy:

MRI:

Patient in powerful magnetic field
+ passing radio waves in short
pulses

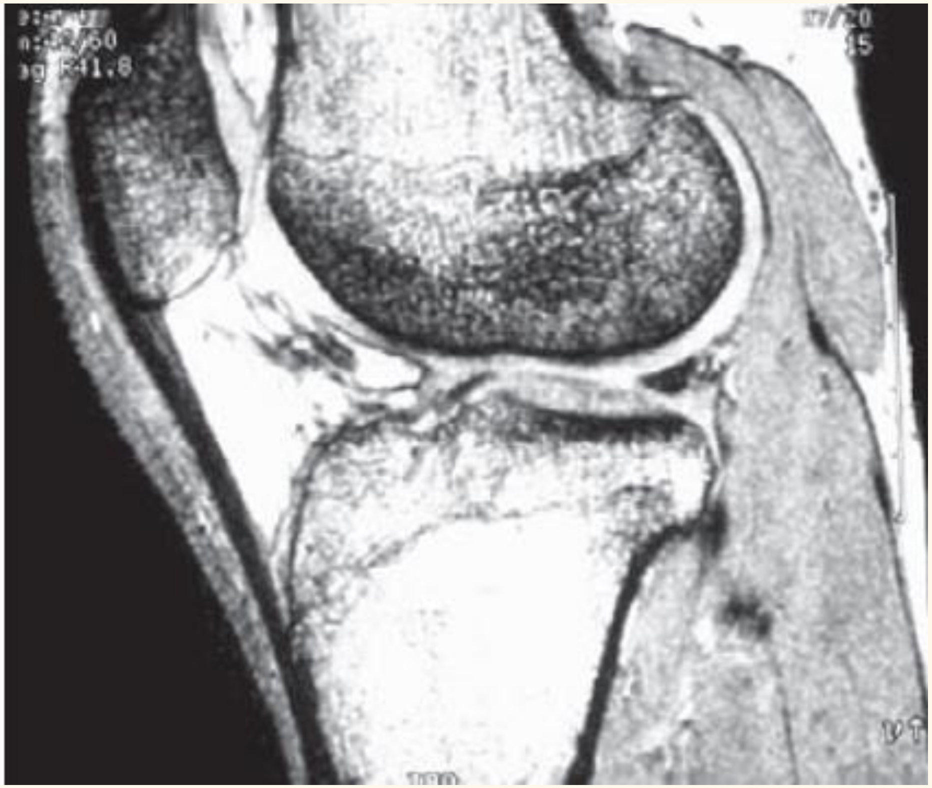
↓

Pulse response from tissue

↓

Location & strength of pulse ⟶ 2D image

Radio band

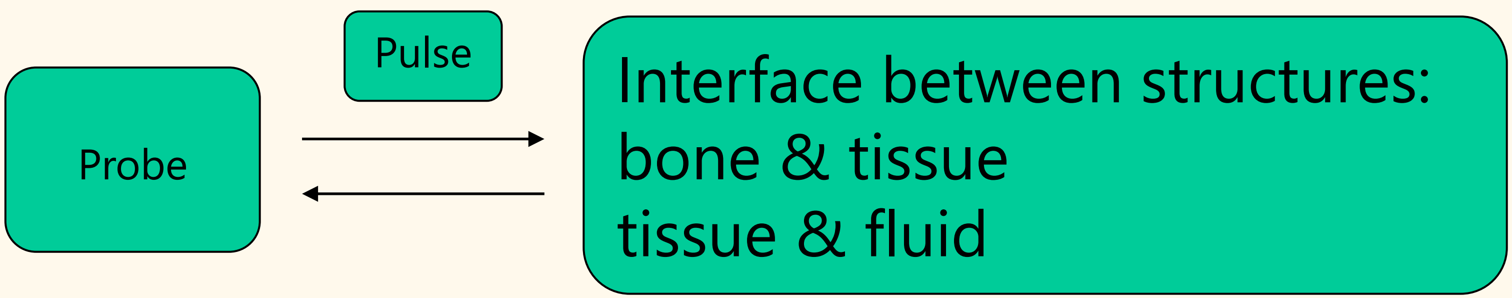


MRI image of knee

MRI image of spine

Sound

Ultrasound: geology oil exploration
Med: 1-5 MHZ



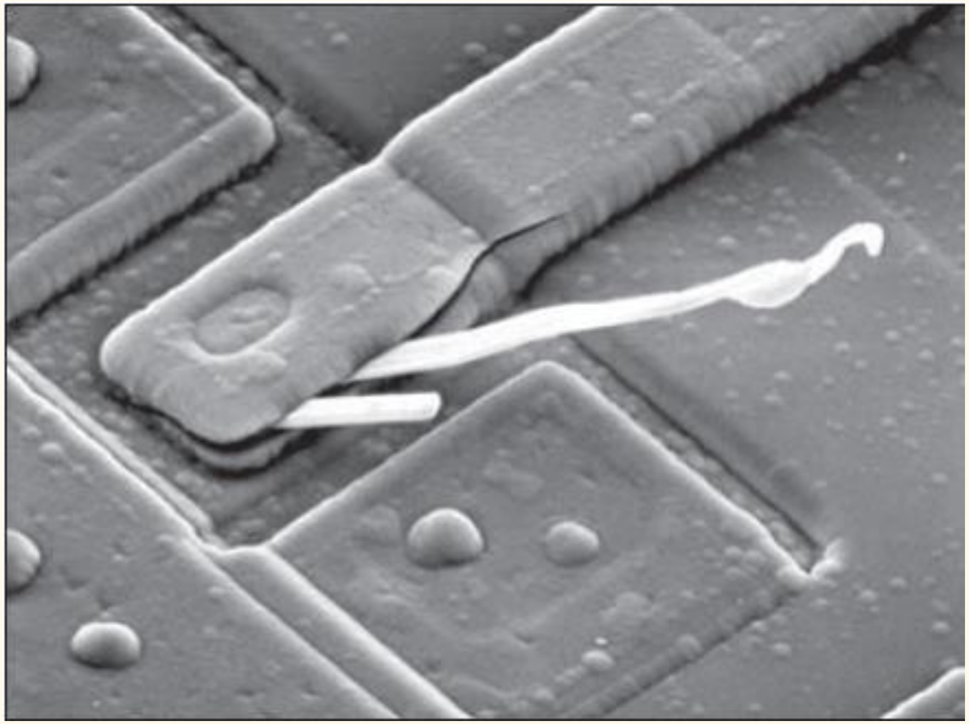
Ultrasound imaging

Fetus images

Scanning electron microscope (SEM)

Similar to light microscopy

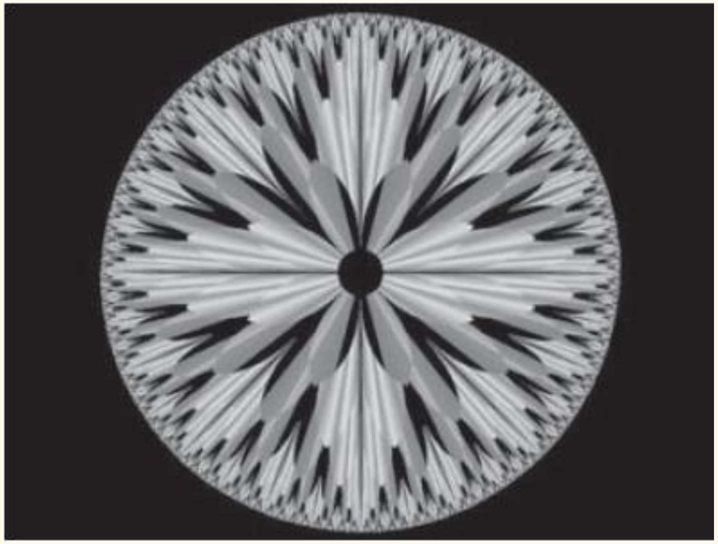
Focused beam & electron instead of light



Damaged IC

Synthetic images

Fractal



Computer model

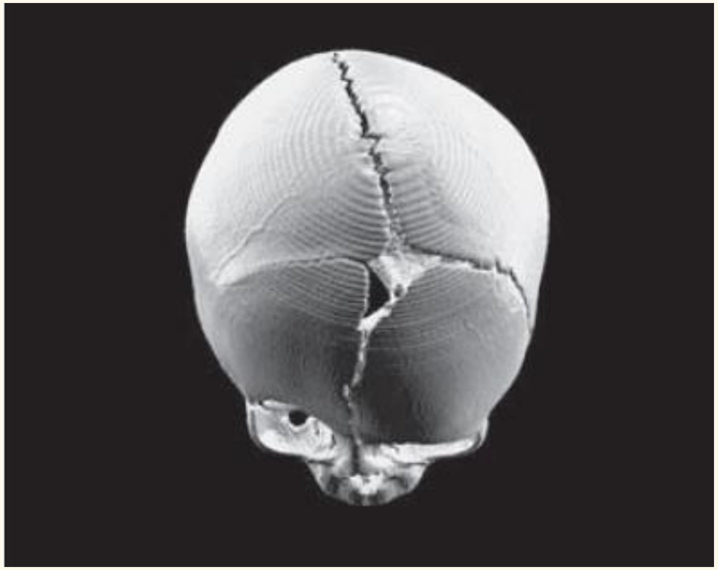


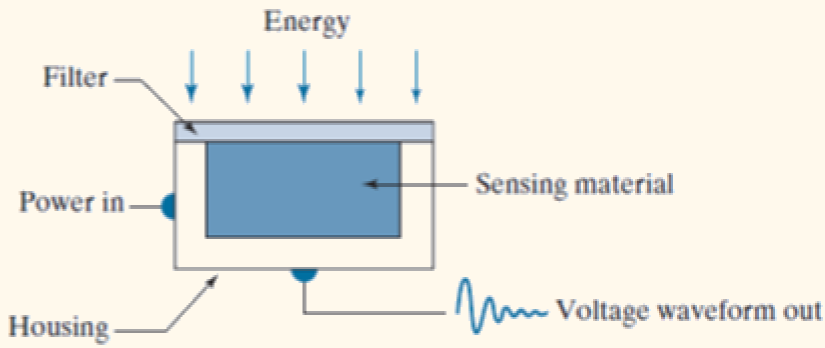
Image acquisition

1) Illumination source
2) Reflection or transmission by the elements of a scene

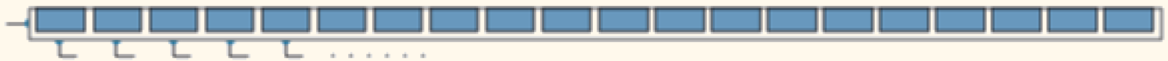
Example:
- Light reflected from an object
- X-ray passing through a patient

Image acquisition

Single sensor



Line sensor



Array sensor

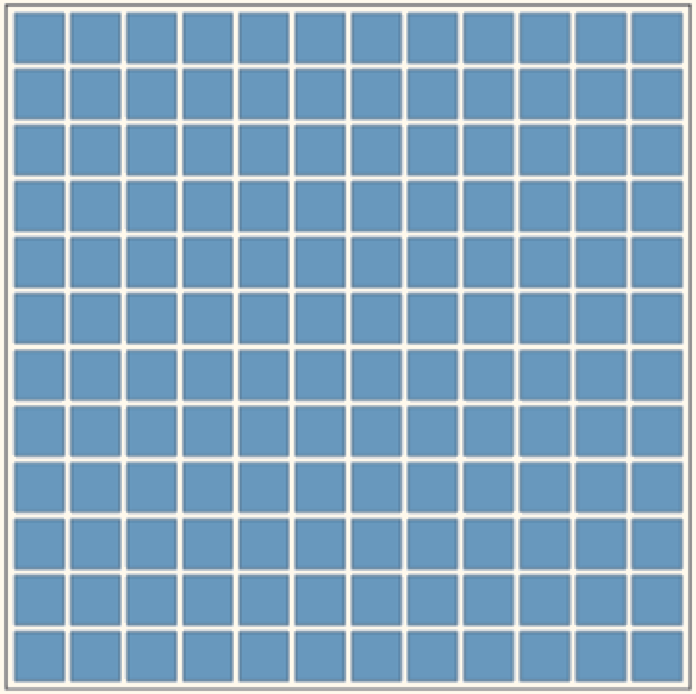
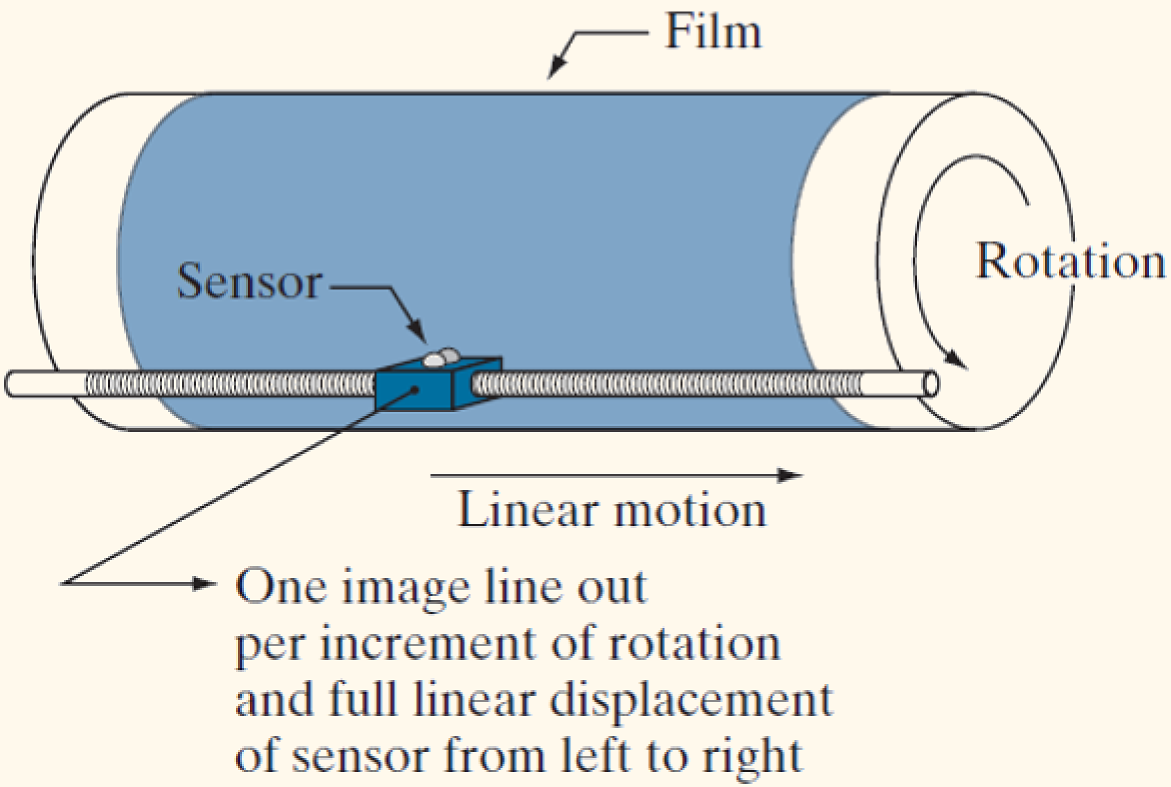


Image acquisition



2D image by a single sensor

Image acquisition

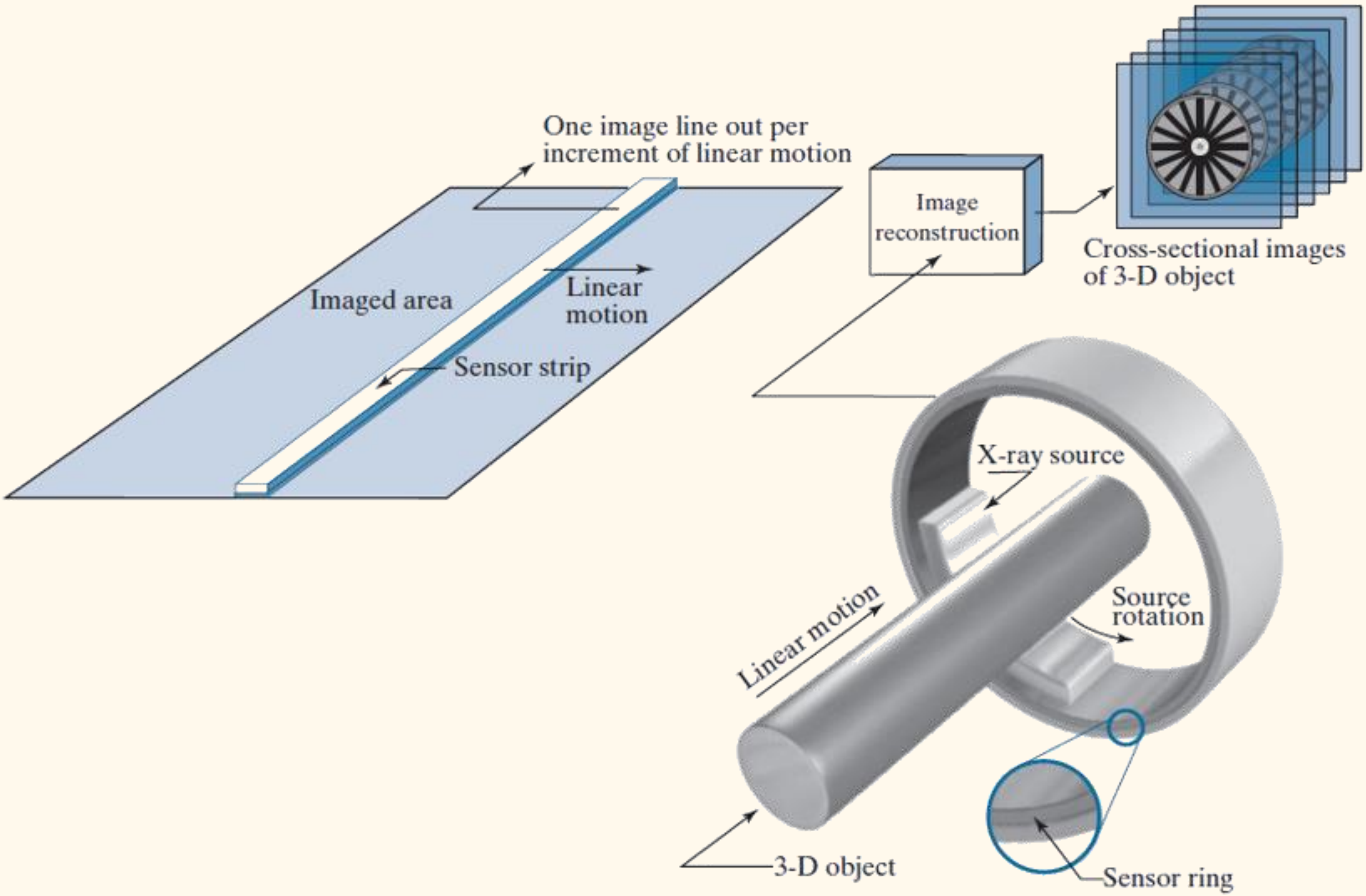
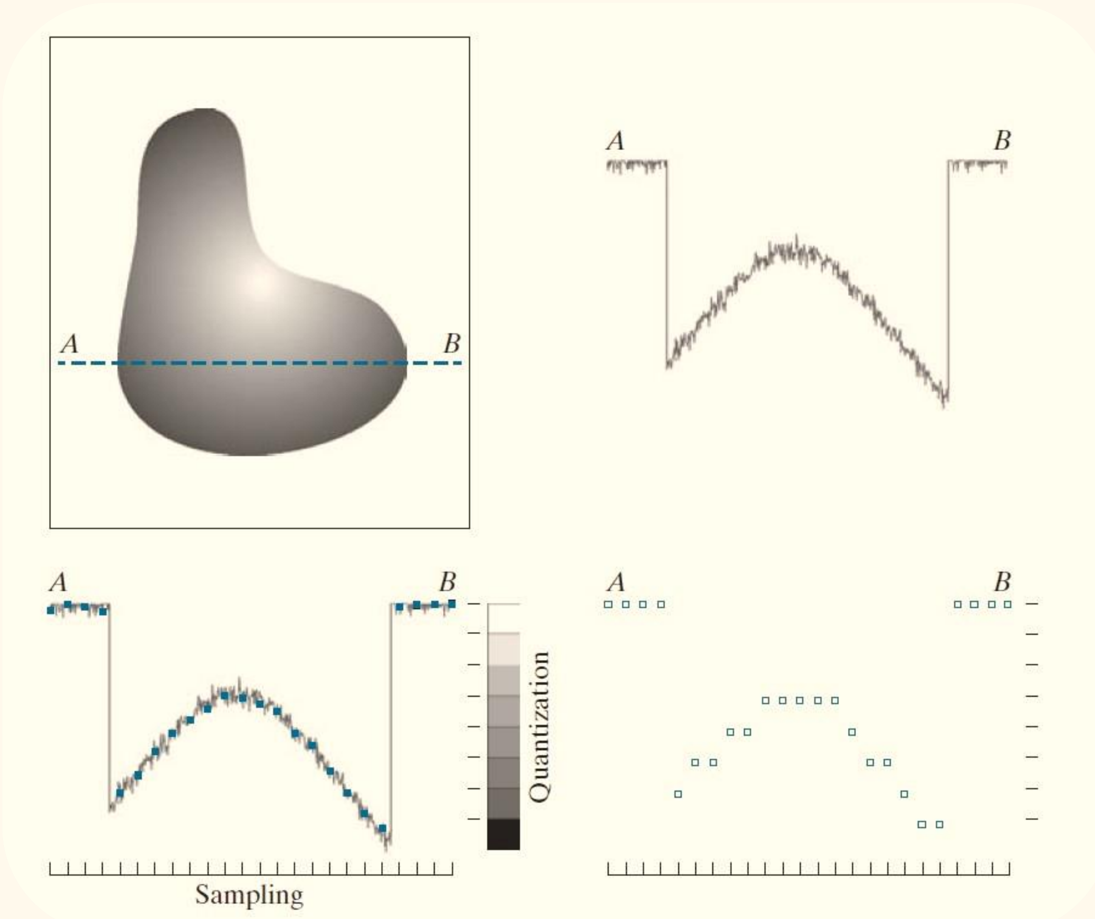


Image acquisition by a sensor strip

Image acquisition

Continuous image

Scan line AB



Sampling

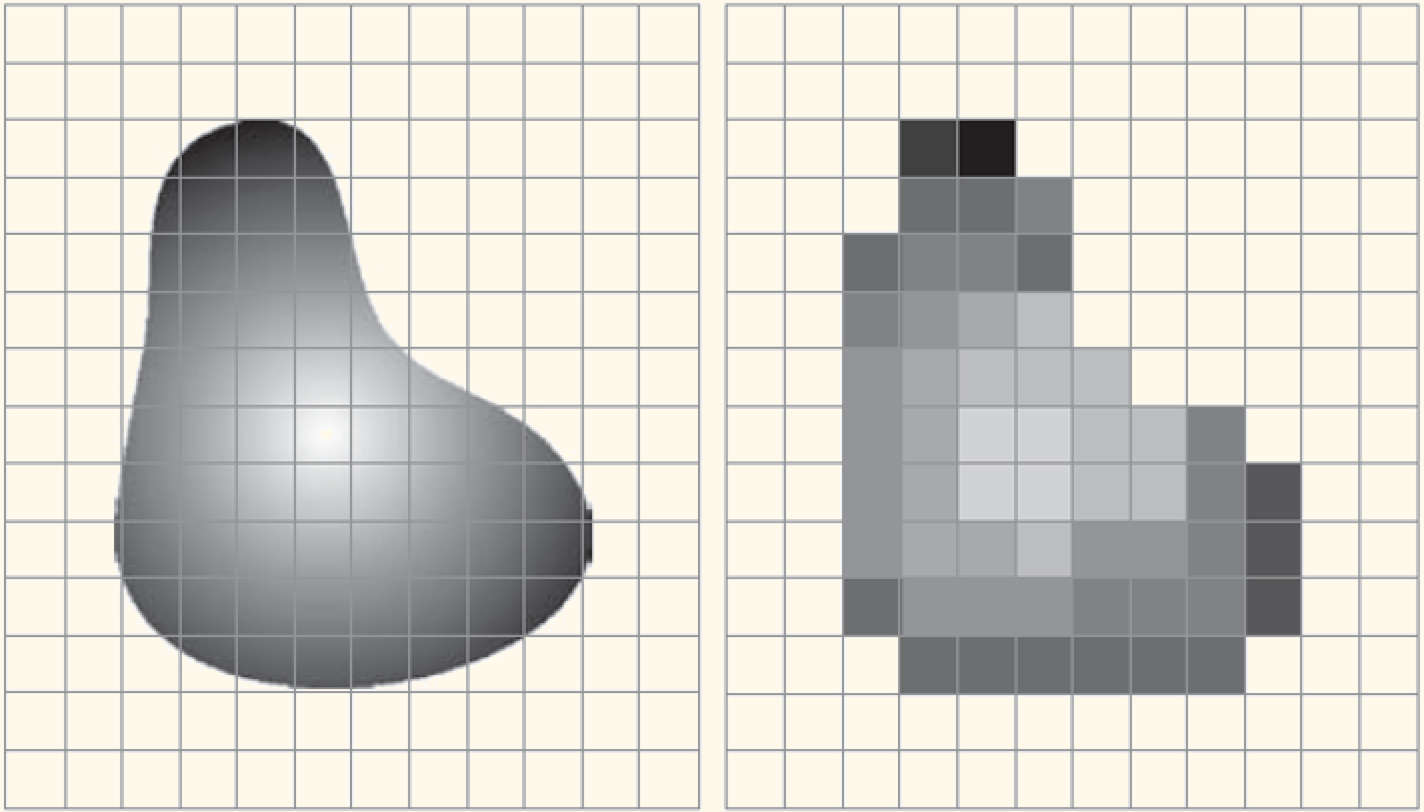
در جهت x و y

Quantization

محور Z

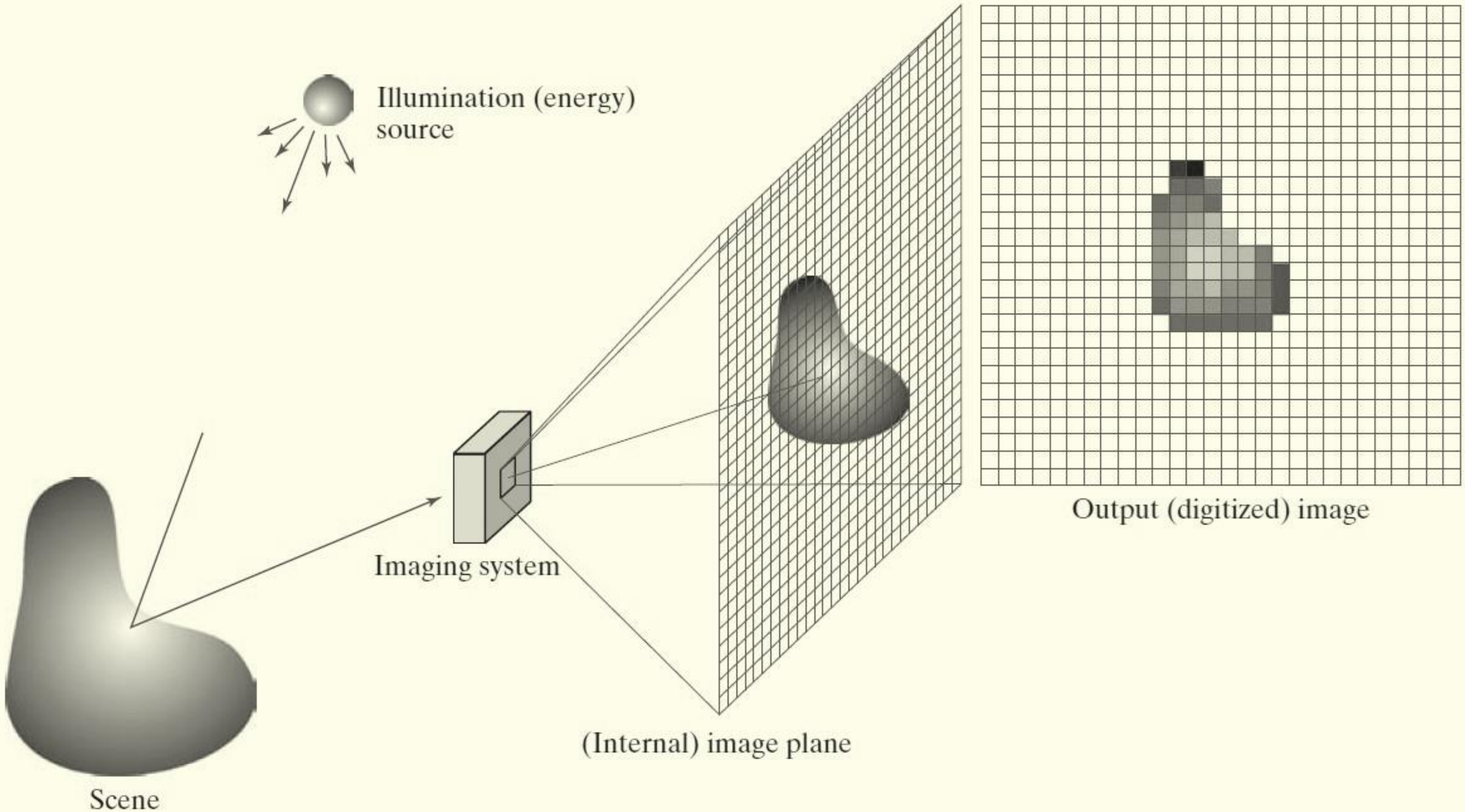
Generating a digital image

Digital image



Sampling: Digitizing the coordinate values
Quantization: Digitizing the amplitude value

Image acquisition



Digital image acquisition

Representing a digital image

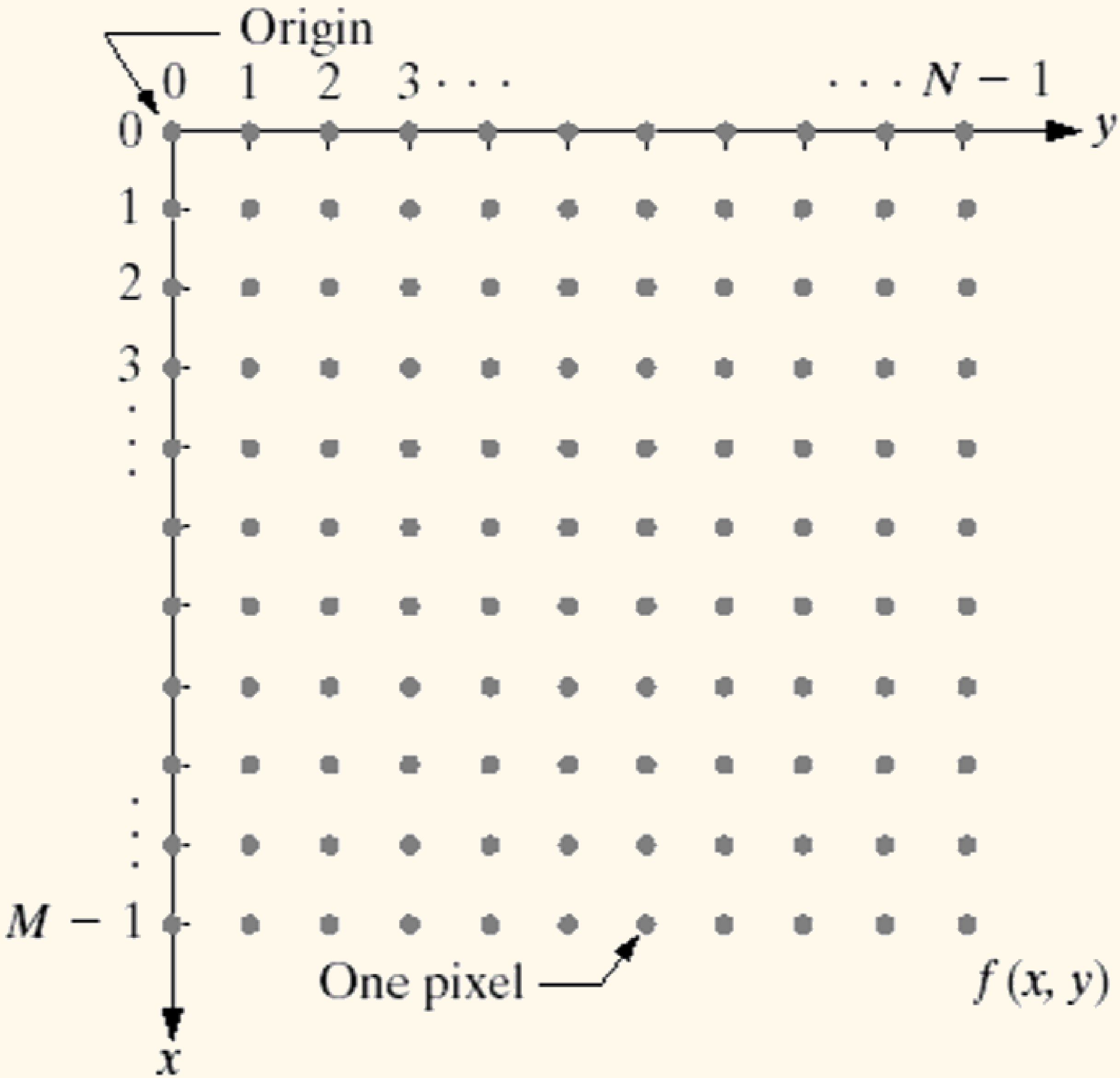


Image storage

Number of gray levels:

$L=2^k$ where k: number of bits

Number of bits required to store a digitized image:

Image storage

Number of gray levels:

$L=2^k$ where k: number of bits

Number of bits required to store a digitized image:

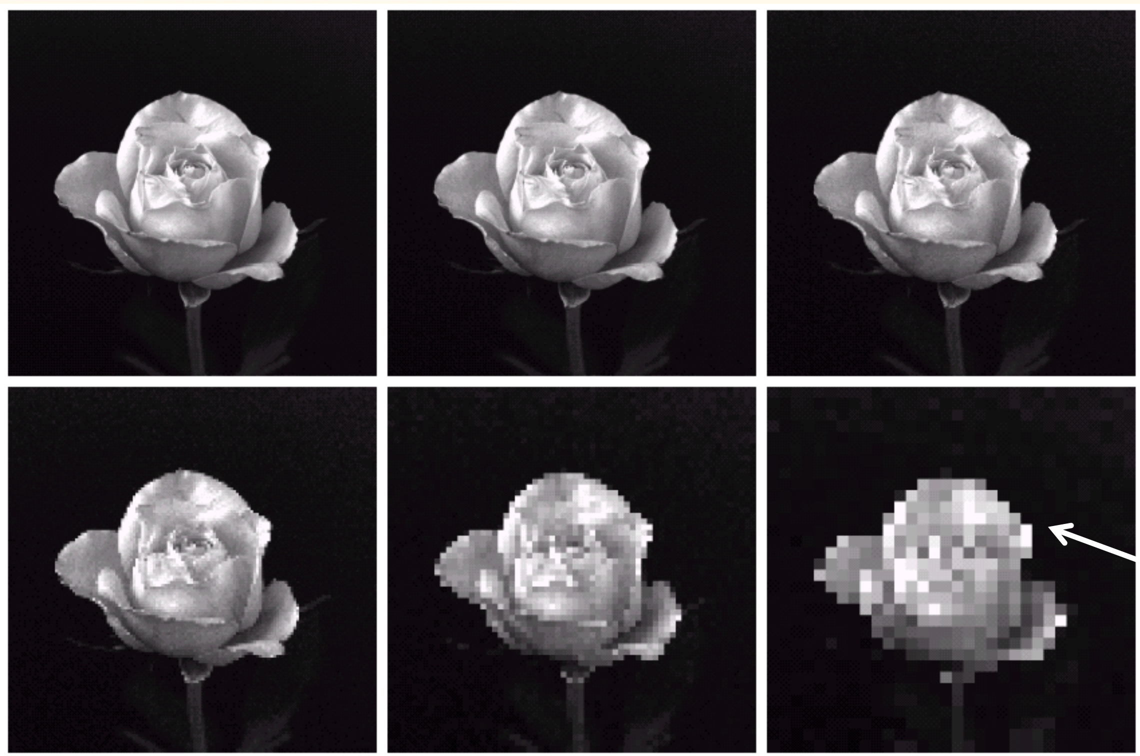
$b=M.N.k$

N/k	1 ($L = 2$)	2 ($L = 4$)	3 ($L = 8$)	4 ($L = 16$)	5 ($L = 32$)	6 ($L = 64$)	7 ($L = 128$)	8 ($L = 256$)
32	1,024	2,048	3,072	4,096	5,120	6,144	7,168	8,192
64	4,096	8,192	12,288	16,384	20,480	24,576	28,672	32,768
128	16,384	32,768	49,152	65,536	81,920	98,304	114,688	131,072
256	65,536	131,072	196,608	262,144	327,680	393,216	458,752	524,288
512	262,144	524,288	786,432	1,048,576	1,310,720	1,572,864	1,835,008	2,097,152
1024	1,048,576	2,097,152	3,145,728	4,194,304	5,242,880	6,291,456	7,340,032	8,388,608
2048	4,194,304	8,388,608	12,582,912	16,777,216	20,971,520	25,165,824	29,369,128	33,554,432
4096	16,777,216	33,554,432	50,331,648	67,108,864	83,886,080	100,663,296	117,440,512	134,217,728
8192	67,108,864	134,217,728	201,326,592	268,435,456	335,544,320	402,653,184	469,762,048	536,870,912

Reducing spatial resolution (x, y)

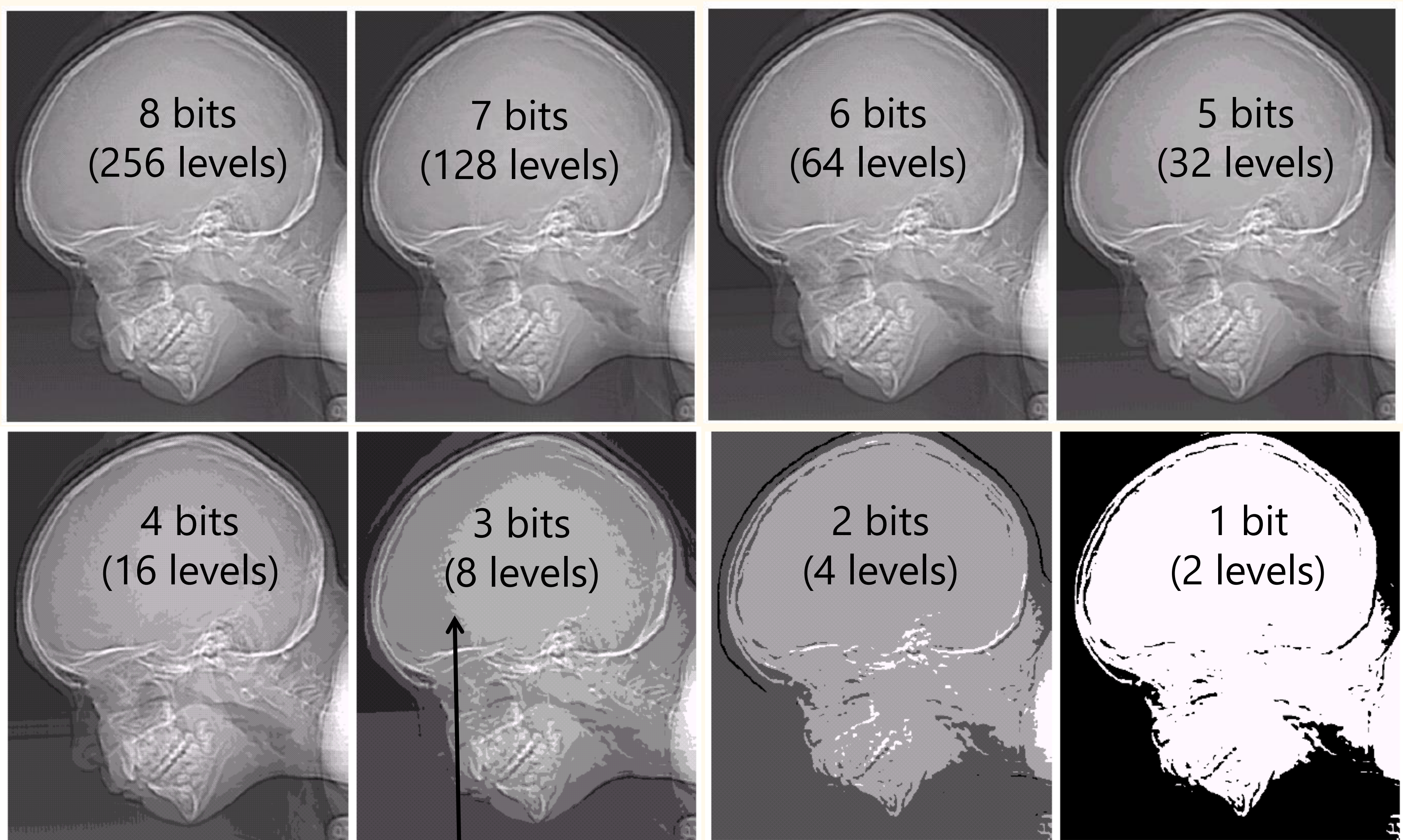
Subsampling

Resampling



Checkerboard pattern

Reducing gray level resolution



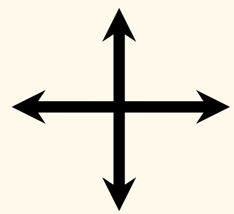
False contour

Binary image

Pixel neighbors

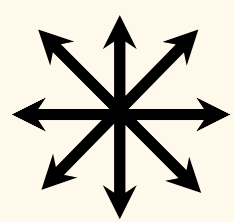
4-neighborhood of pixel p at coordinates (x,y):
set of 4 horizontal and vertical pixel neighbors:

$$(x+1, y), (x-1, y), (x, y+1), (x, y-1)$$



8-neighborhood of pixel p:
4-neighbor hood of pixel p +
set of 4 diagonal pixel neighbors:

$$(x+1, y+1), (x+1, y-1), (x-1, y+1), (x-1, y-1)$$



Distance measures

Distance function (D) or metric

Distance measures

Distance function (D) or metric for pixels *p*, *q*, and *z* with coordinates (*x*,*y*), (*s*,*t*), and (*v*,*w*):

(a) $$D(p,q) \geq 0 \; (D(p,q) = 0 \; if \; p = q),$$

(b) $$D(p,q) = D(q,p), and$$

(c) $$D(p,z) \leq D(p,q) + D(q,z).$$

Distance measures

Euclidean distance between p and q:

City block distance

Chessboard distance

Distance measures

Euclidean distance between *p* and *q*:

$$D_e(p,q) = \left[|x-s|^2 + |y-t|^2\right]^{\frac{1}{2}}$$

City block distance between *p* and *q*:

Chessboard distance between *p* and *q*:

Distance measures

Euclidean distance between *p* and *q*:

$$D_e(p,q) = [|x-s|^2 + |y-t|^2]^{\frac{1}{2}}$$

Circle

City block distance between *p* and *q*:

$$D_4(p,q) = |x-s| + |y-t|$$

Chessboard distance between *p* and *q*:

Distance measures

Euclidean distance between *p* and *q*:

$$D_e(p,q) = [|x-s|^2 + |y-t|^2]^{\frac{1}{2}}$$

Circle

City block distance between *p* and *q*:

$$D_4(p,q) = |x-s| + |y-t|$$

		2		
	2	1	2	
2	1	0	1	2
	2	1	2	
		2		

Chessboard distance between *p* and *q*:

Distance measures

Euclidean distance between *p* and *q*:

$$D_e(p,q) = [|x-s|^2 + |y-t|^2]^{\frac{1}{2}}$$

Circle

City block distance between *p* and *q*:

$$D_4(p,q) = |x-s| + |y-t|$$

		2		
	2	1	2	
2	1	0	1	2
	2	1	2	
		2		

Chessboard distance between *p* and *q*:

$$D_8(p,q) = \max(|x-s|, |y-t|)$$

Distance measures

Euclidean distance between *p* and *q*:

$$D_e(p,q) = [|x-s|^2 + |y-t|^2]^{\frac{1}{2}}$$

Circle

City block distance between *p* and *q*:

$$D_4(p,q) = |x-s| + |y-t|$$

		2		
	2	1	2	
2	1	0	1	2
	2	1	2	
		2		

Chessboard distance between *p* and *q*:

$$D_8(p,q) = \max(|x-s|, |y-t|)$$

2	2	2	2	2
2	1	1	1	2
2	1	0	1	2
2	1	1	1	2
2	2	2	2	2