Lecture 2 - Image Fundamentals

This lecture will cover:

- Image acquisition
- Sampling and Quantization
- Pixels
- Image operation
- Color space

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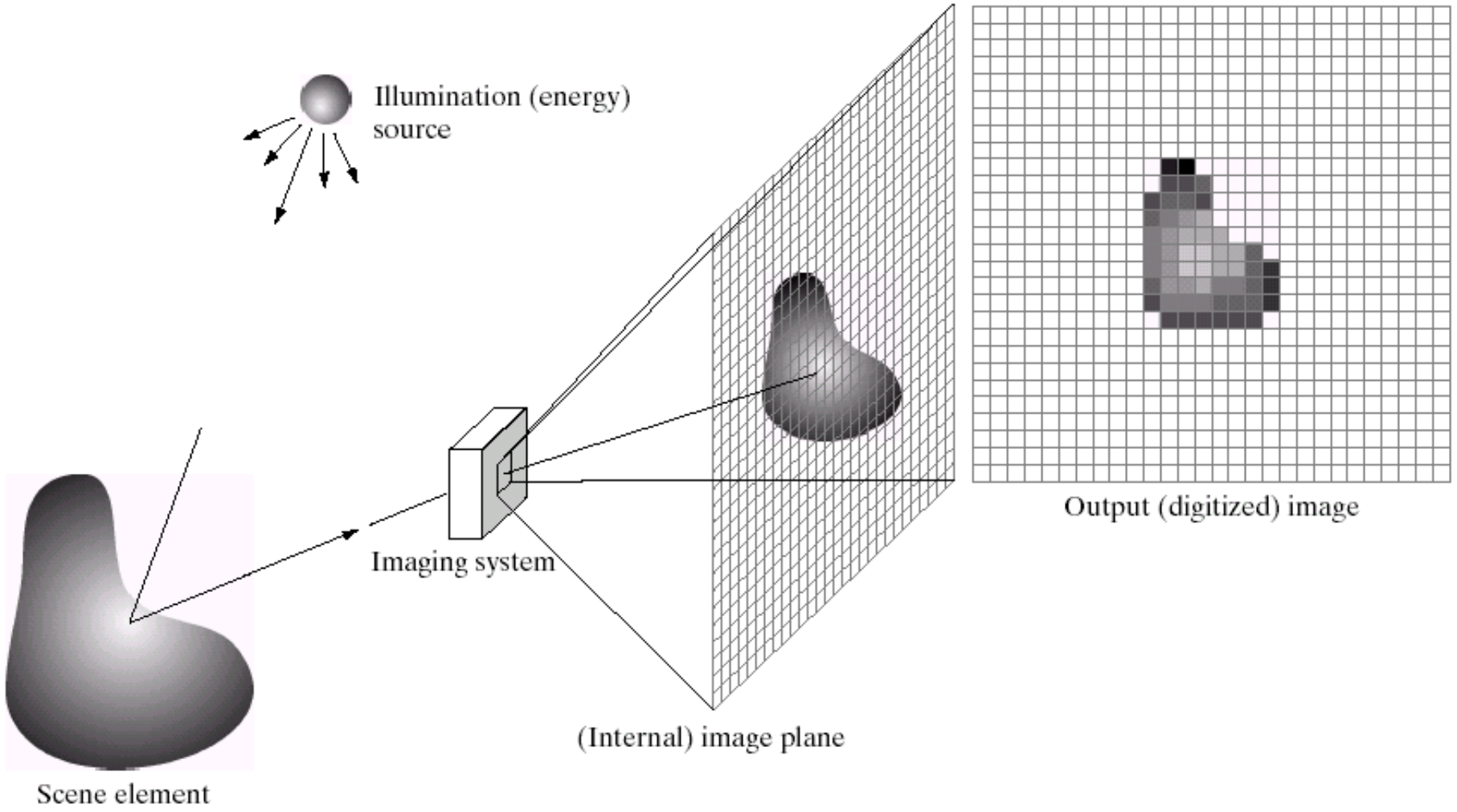
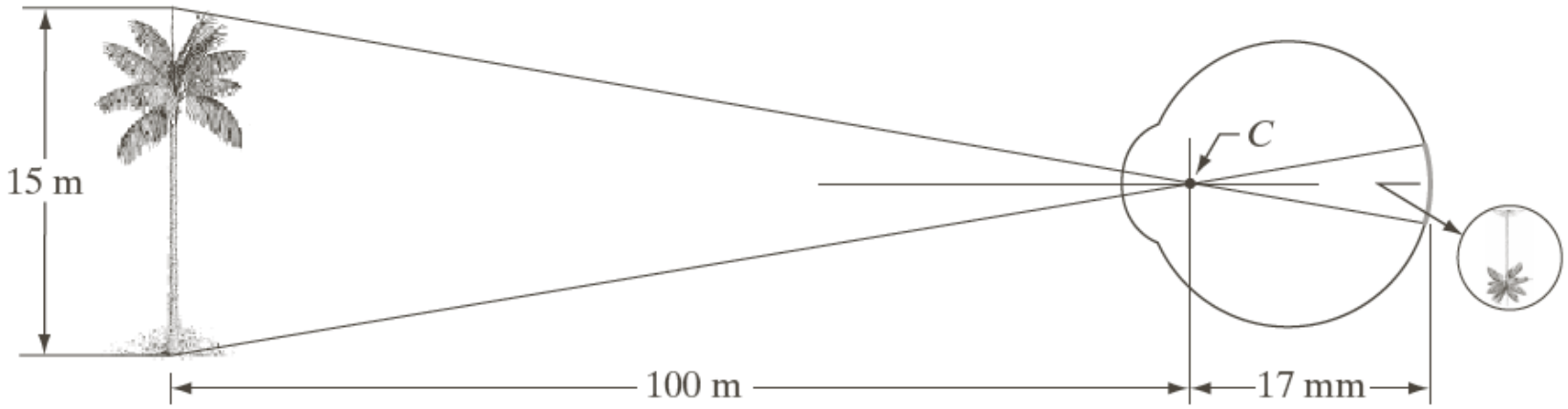
Image Acquisition System

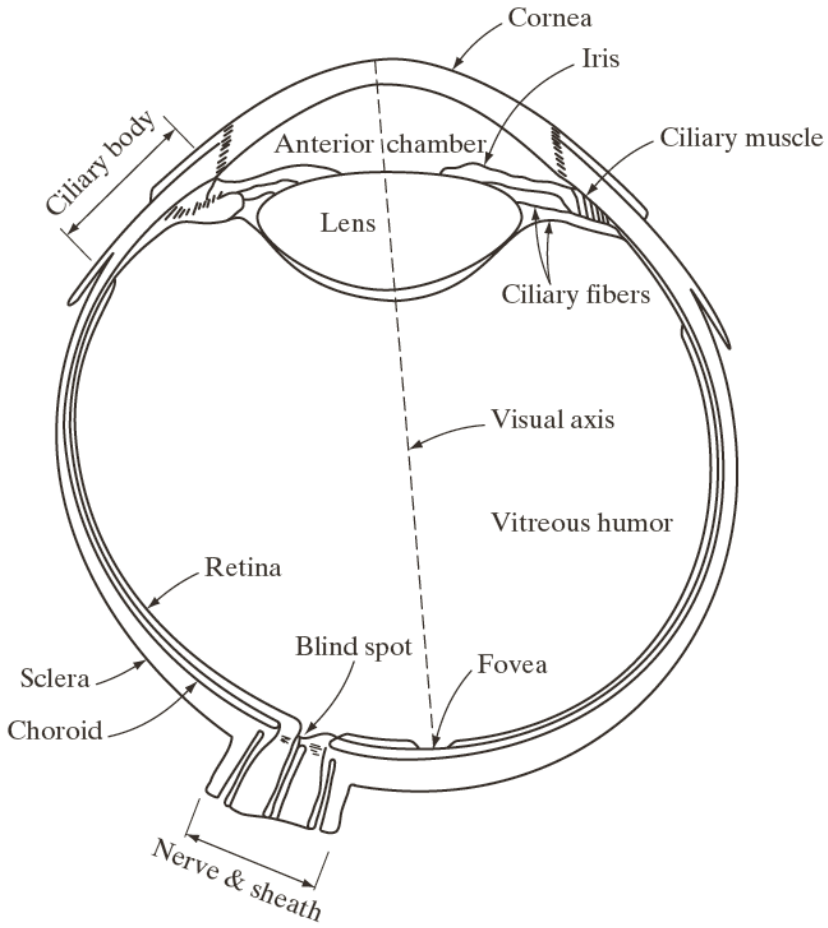


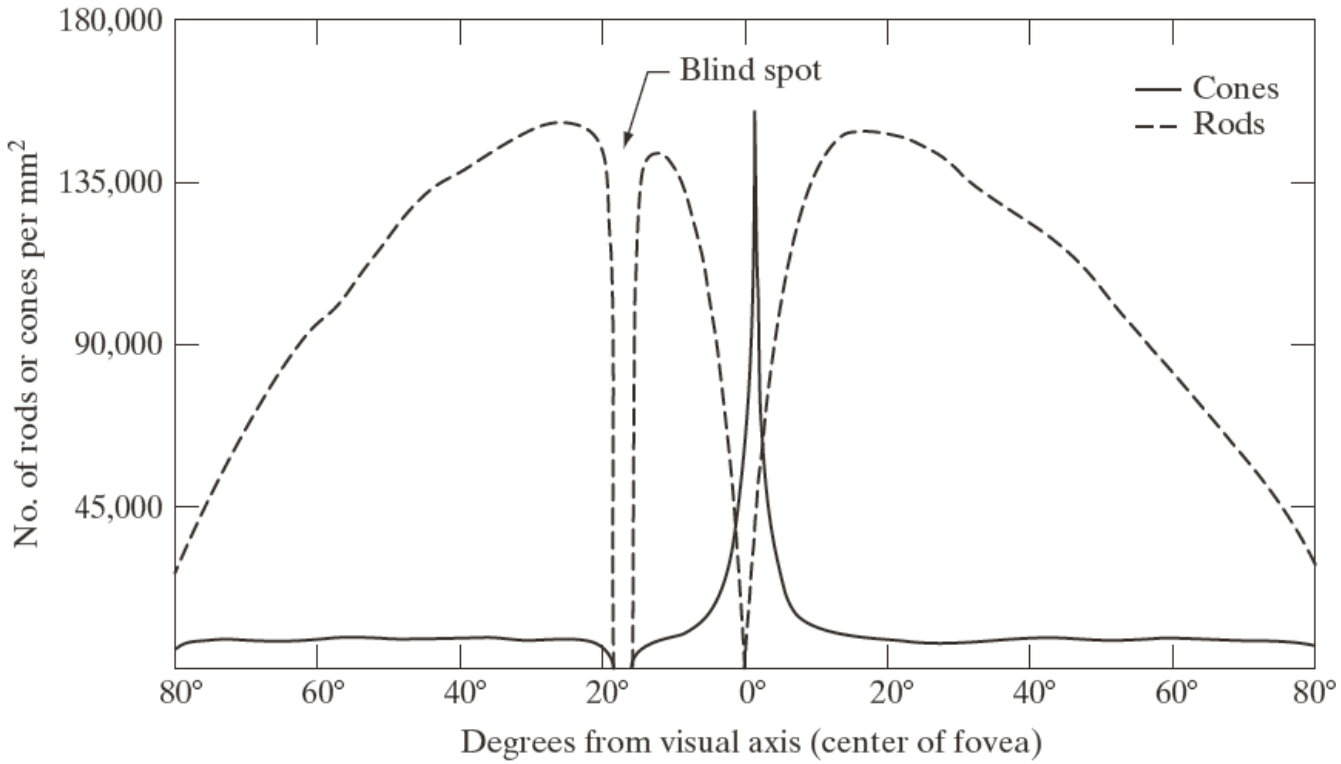
Graphical representation of human eye

- Objects captured as focused images on the image plane at retinas
- Perspective projection based on pinhole model geometry,
- Image size depends on distance of object
- In practice, optical devices with lens



Human Visual Perception





Characteristics of Human Visual System

- Brightness adaption
- Simultaneous contrast
- Mach band effect
- Optical illusion

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- **Brightness adaption**
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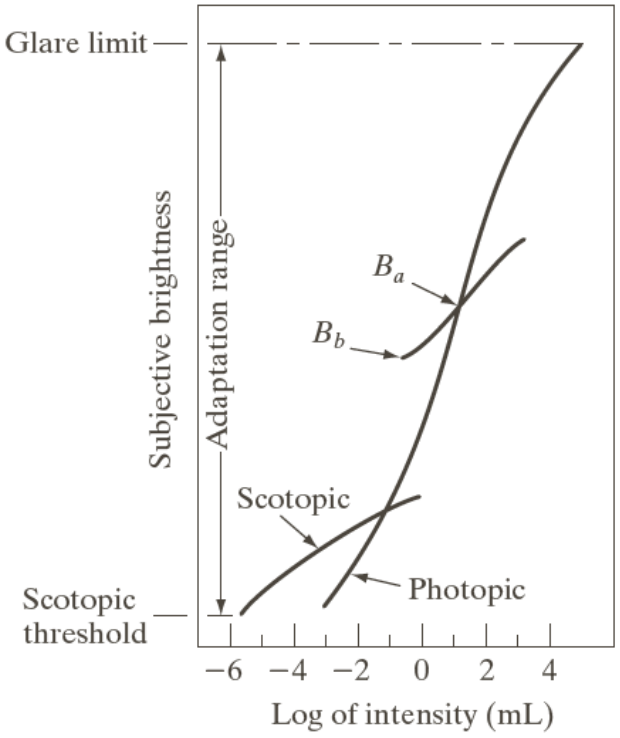
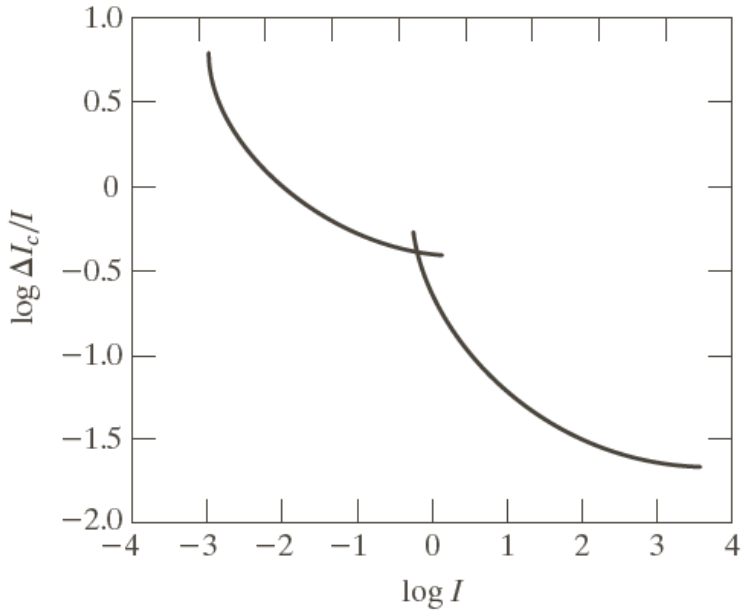


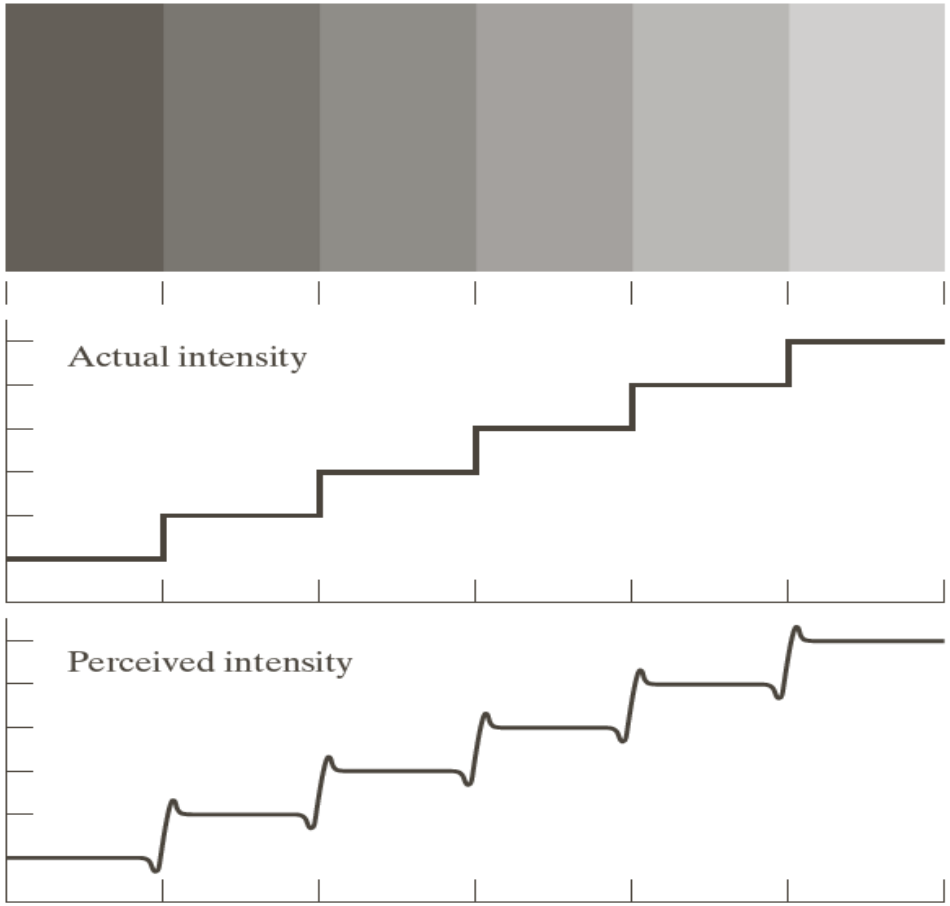
Range of subjective brightness sensations showing a particular adaption level



Typical Weber ratio as a function of intensity

Characteristics of Human Visual System

- Brightness adaption
- Simultaneous contrast
- **Mach band effect**
- Optical illusion



Perceived intensity is not a simple function of actual intensity

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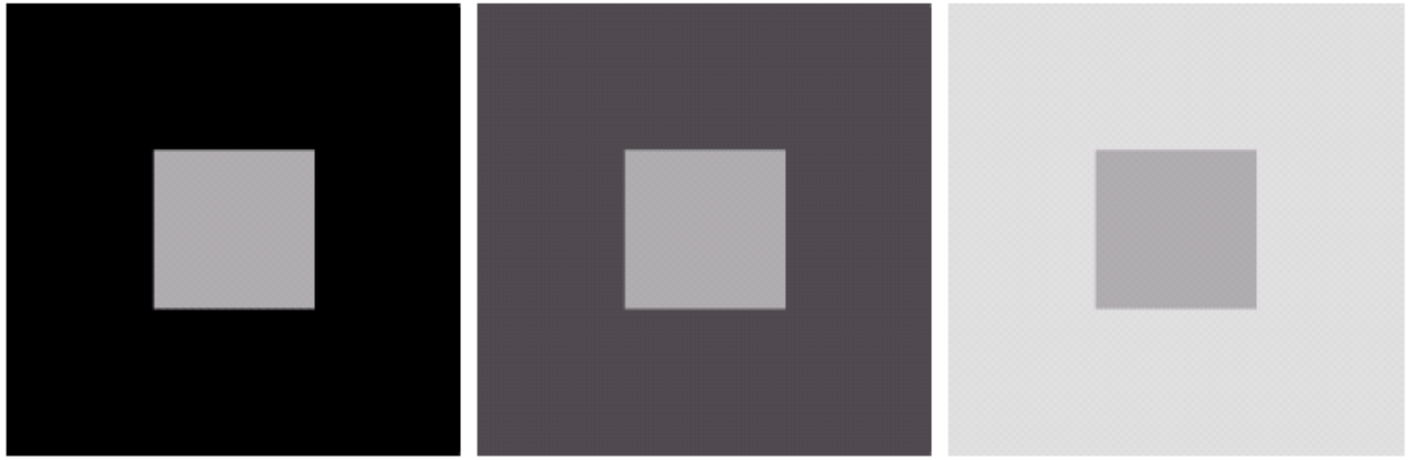

All the inner squares have the same intensity,
but they appear progressively darker as the background becomes lighter

Characteristics of Human Visual System

- Brightness adaption
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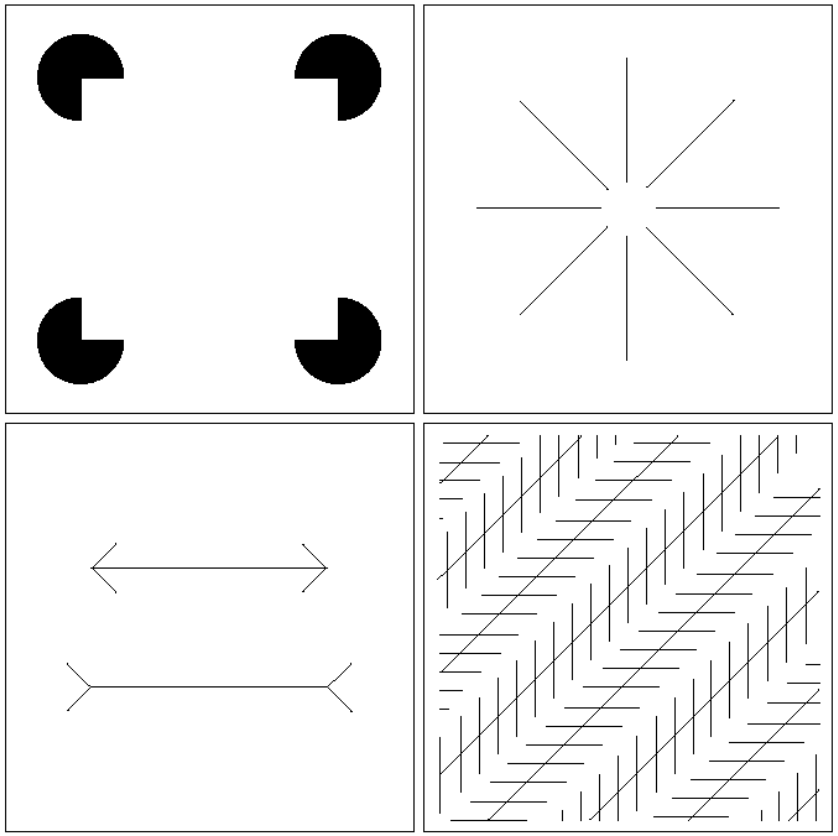
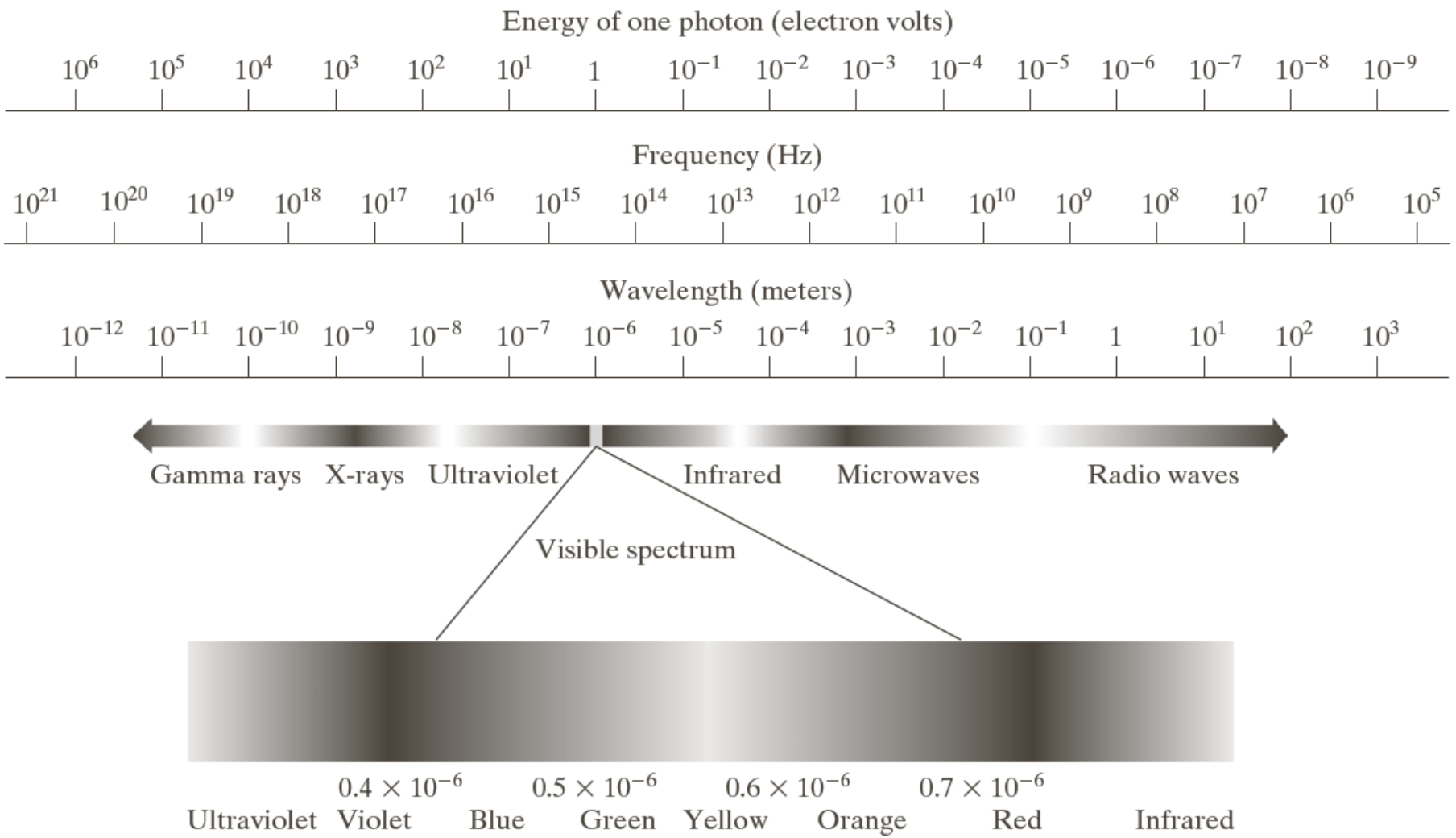
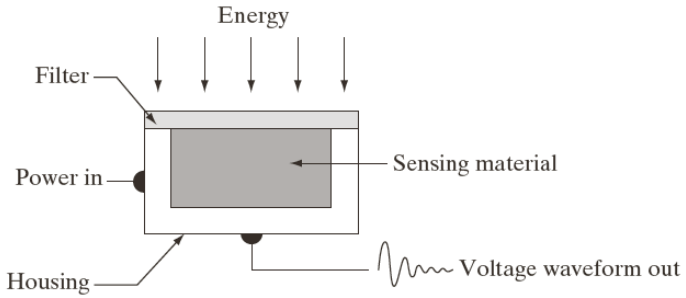
- **Optical illusion**

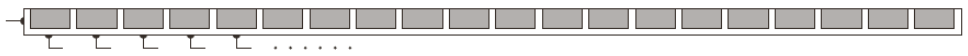


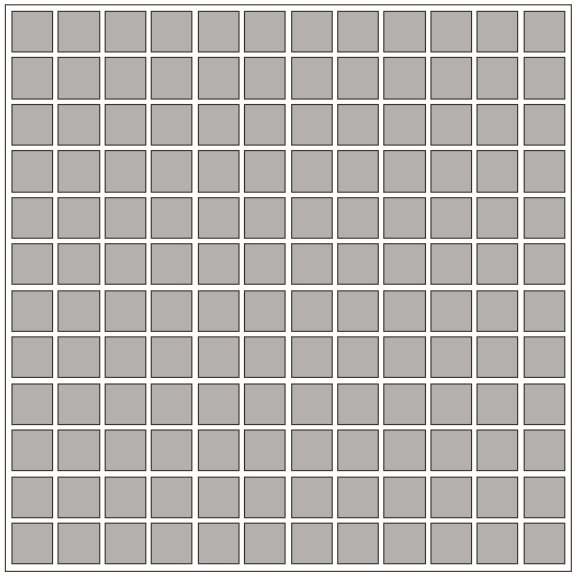
Imaging Source



Imaging Sensors







Transform energy to voltage:

- **Single Sensor**
  - Photodiode
  - Piezoelectric element
- **Sensor Strips**
  - CAT
  - Airborne imaging
  - Ultrasound array transducer
- **Sensor Array**
  - CCD – digital camera
- **Color Images**

Use a Bayer's mosaic pattern of R/G/B filters to reduce cost, then use demosaicing to construct full resolution color images.

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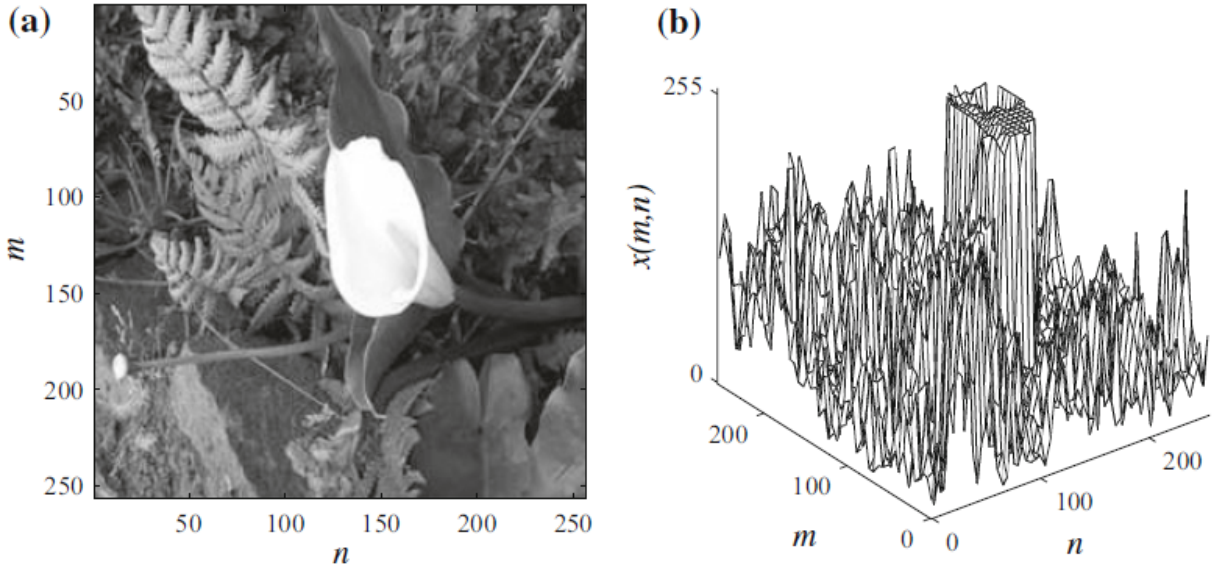
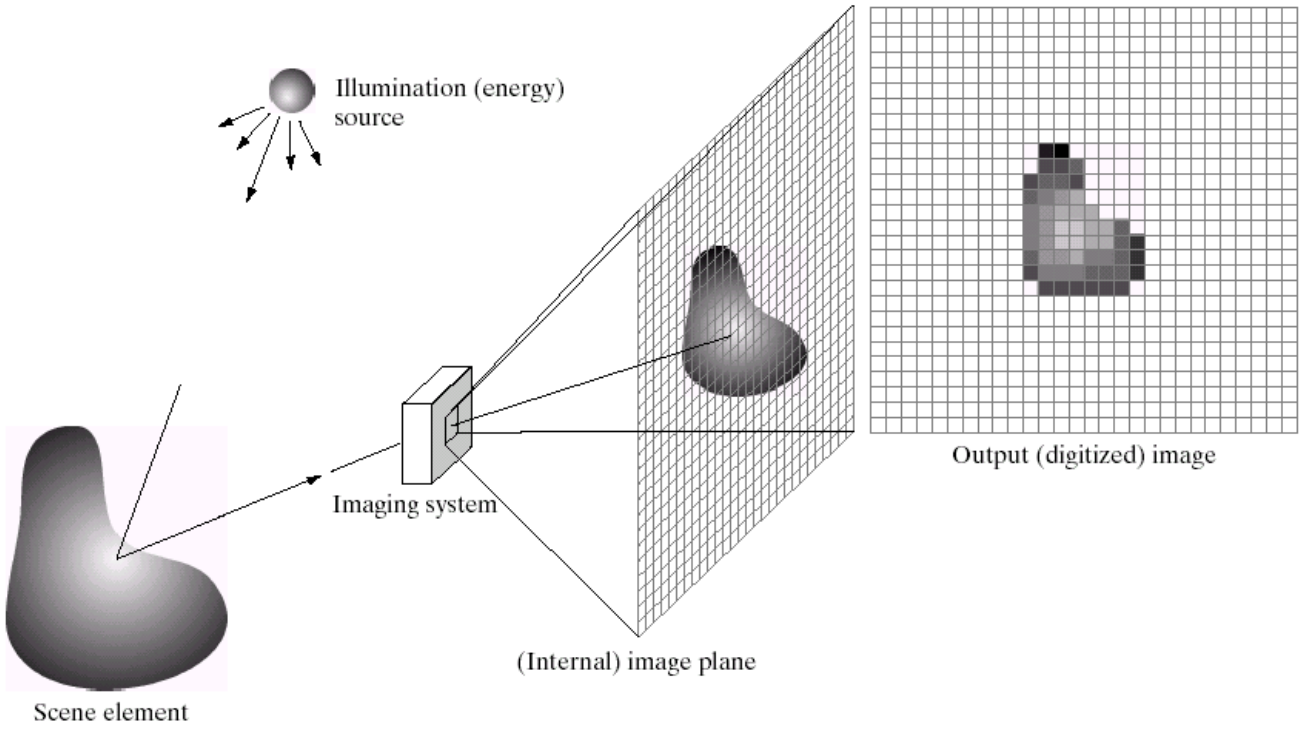
Digital image

- **A visual representation in form of a function *f*(*x*,*y*), where**
  - *f* is related to the intensity or brightness (color) at point
  - (*x*, *y*) are spatial coordinates
  - *x*, *y*, and the amplitude of *f* are finite and discrete quantities



(a) A 256X256 image with 256 gray levels; (b) its amplitude profile

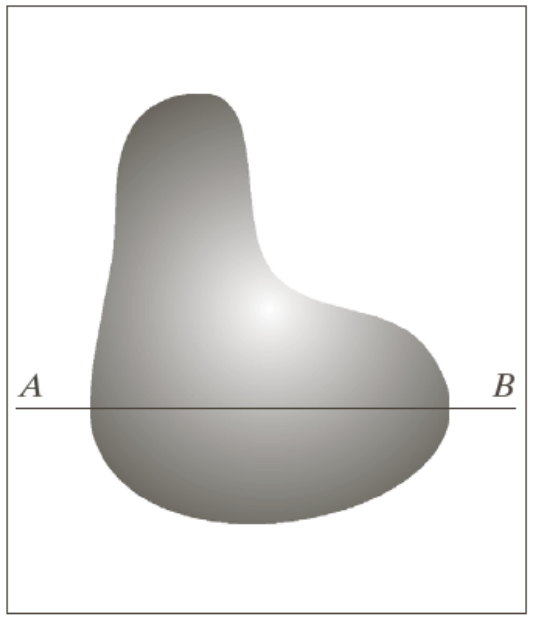
Image Acquisition System

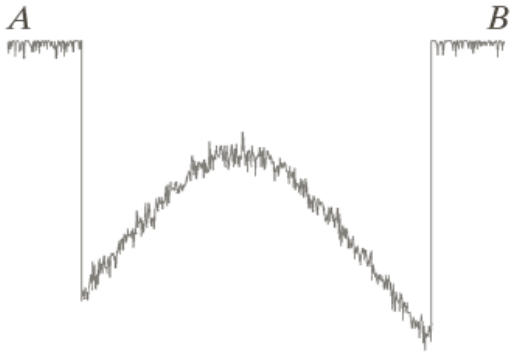


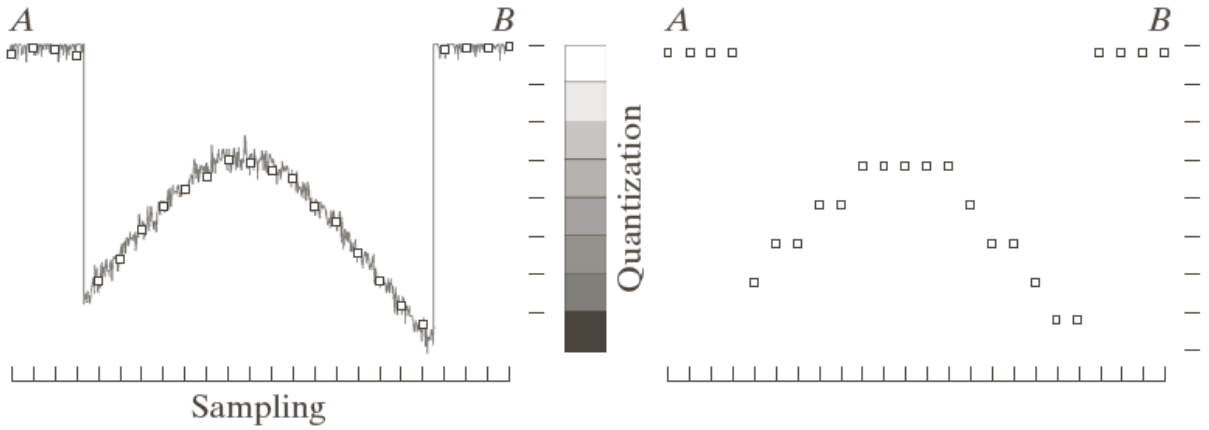
$$f(x,y) = i(x,y)r(x,y) \qquad 0 < i(x,y) < \infty, 0 \le r(x,y) < 1$$

$$L_{min} < f(x_0,y_0) < L_{max} \qquad \text{where } L_{min} \text{ is positive}, L_{max} \text{ is finite}$$

Sampling and Quantization







Sampling : *Digitize the coordinate values*

Quantization: *Digitize the amplitude values*

- Uniform
- Non-uniform

Matrix Representation

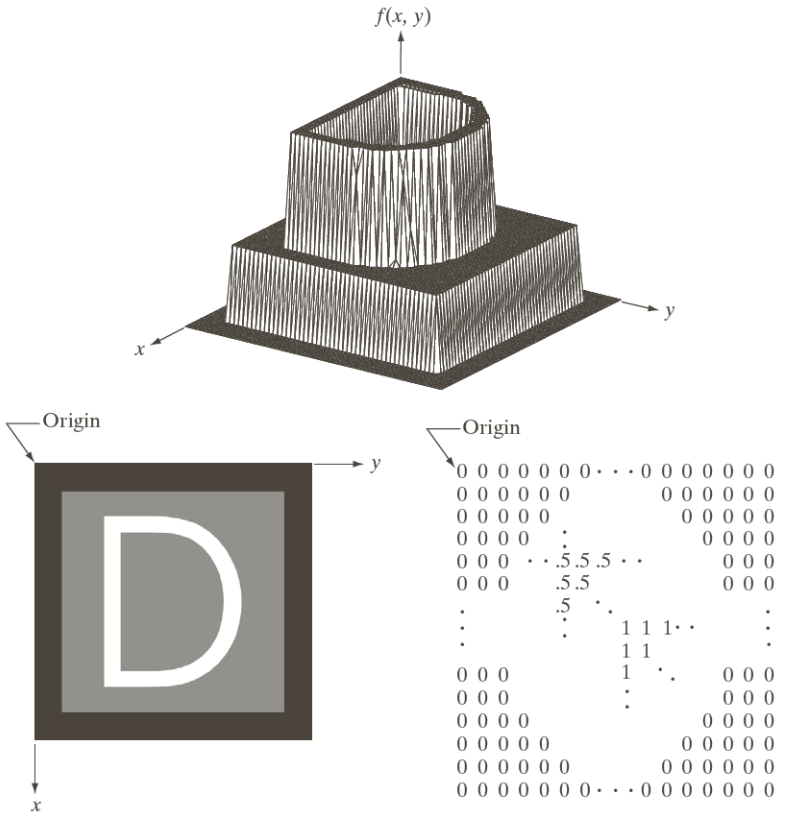
Three basic ways to represent *f*(*x*, *y*)

- Plot of function: *difficult to view and interpret*
- Visual intensity array: *for view*
- numerical array: *for processing and algorithm development*

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

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

Intensity level $L = 2^k$, then $b = M \times N \times k$



Matrix Representation

Number of storage bits for various values of N and k.

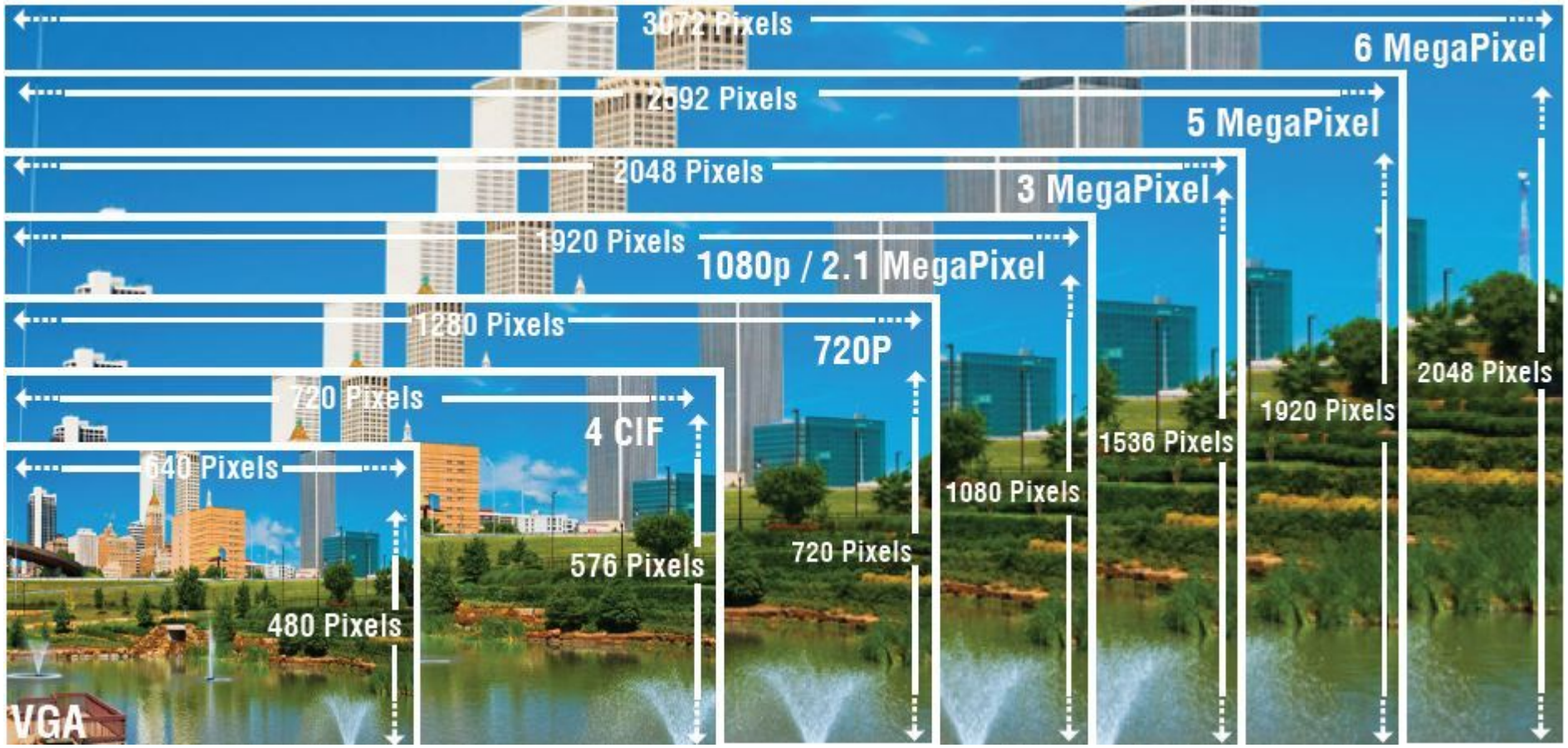
N/k	1 ($L = 2$)	2 ($L = 4$)	3 ($L = 8$)	4 ($L = 16$)	5 ($L = 32$)	6 ($L = 64$)	7 ($L = 128$)	8 ($L = 256$)
32	1,024	2,048	3,072	4,096	5,120	6,144	7,168	8,192
64	4,096	8,192	12,288	16,384	20,480	24,576	28,672	32,768
128	16,384	32,768	49,152	65,536	81,920	98,304	114,688	131,072
256	65,536	131,072	196,608	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

Resolution

Spatial Resolution: smallest discernible detail in an image

Resolution

Spatial resolution – Sampling vs Size



Resolution

Spatial resolution: dpi (Dots Per Inch)

1250 dpi

300 dpi

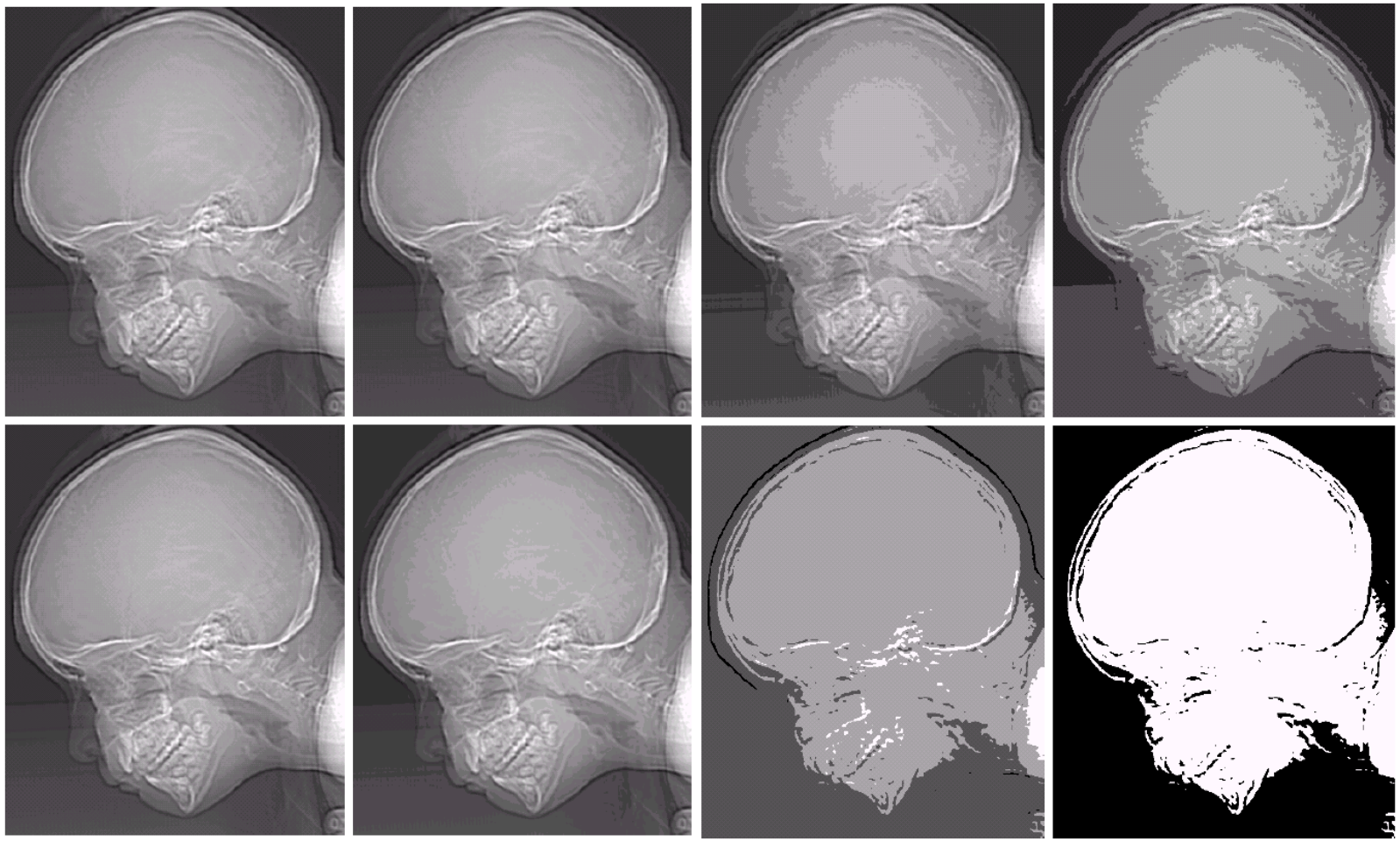
150 dpi

72 dpi

Resolution

Intensity resolution: smallest discernible change in intensity level

8 bit	7 bit
6 bit	5 bit



4 bit	3 bit
2 bit	1 bit

Interpolation

- Use known data to estimate values at unknown lications
- Basic tool for geometric transformation
- A resampling method

Question?

Optical zoom vs **Digital zoom**