Digital Image Processing

Digital Image Fundamentals

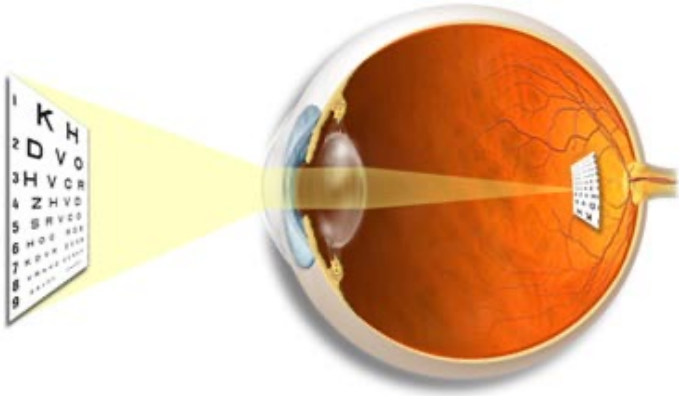
Ming-Sui (Amy) Lee

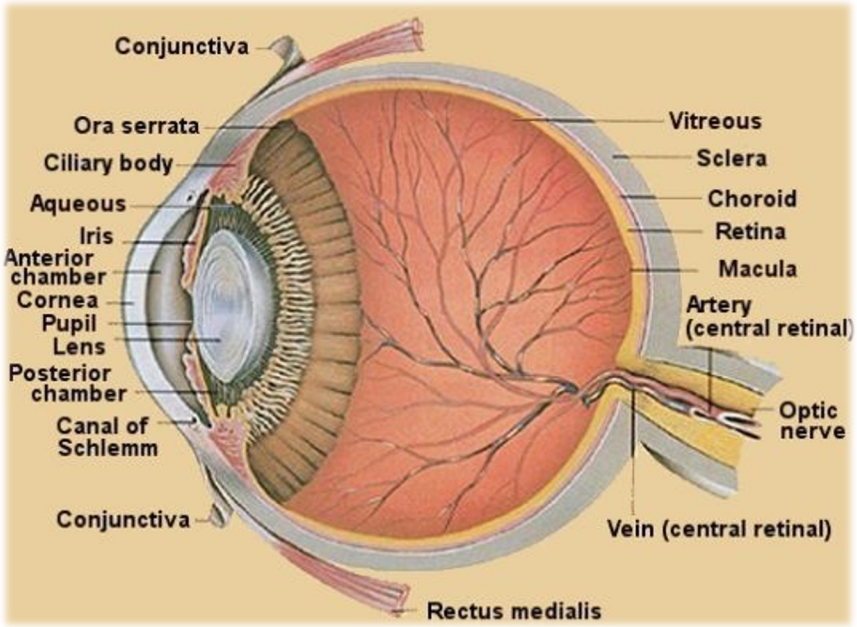
Lecture 01 - Part II

Image Quality

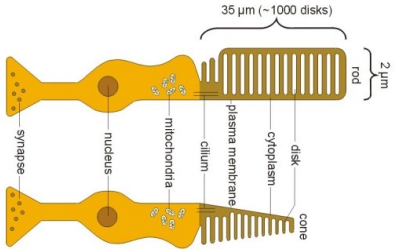
- **Objective / subjective**
  - Machine/human beings
  - Mathematical and Probabilistic/ human intuition and perception

Structure of the Human Eye



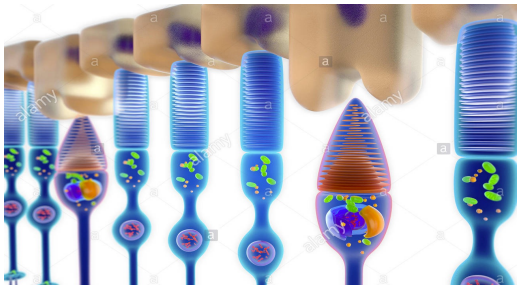


photoreceptor cells

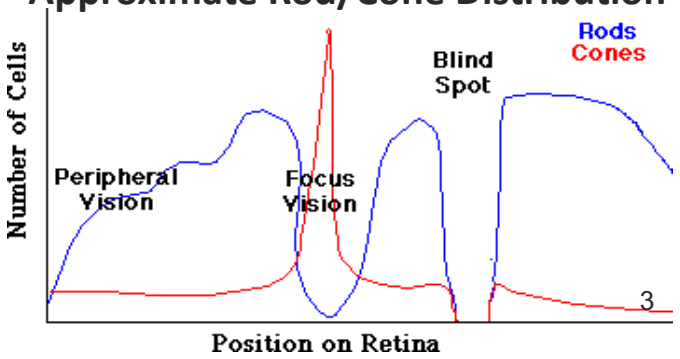


Rod cell 75~150 million

Cone cell 6~7 million



Approximate Rod/Cone Distribution



alamy.com & http://en.wikipedia.org/wiki/Blind_spot_(vision)

Structure of the Human Eye

- **The Blind Spot**

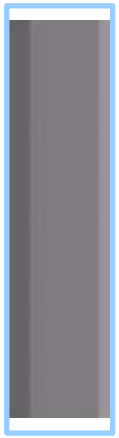
R **L**

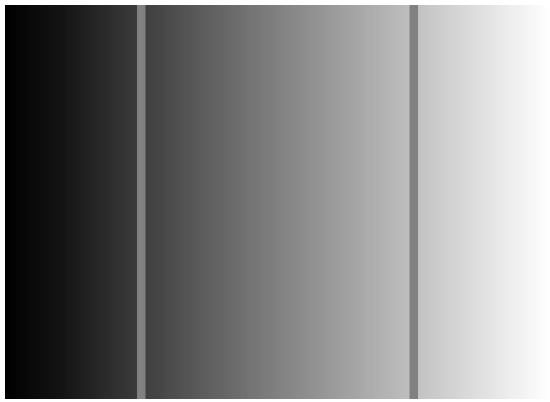
Instructions: Close one eye and focus the other on the appropriate letter (**R** for right or **L** for left). Place your eye a distance from the screen approximately equal to 3× the distance between the **R** and the **L**. Move your eye towards or away from the screen until you notice the other letter disappear. For example, close your right eye, look at the "L" with your left eye, and the "R" will disappear

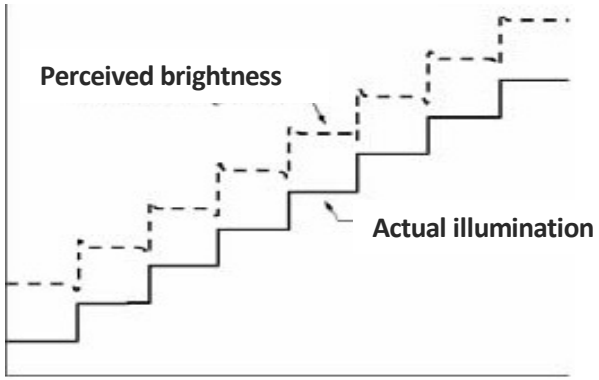
http://en.wikipedia.org/wiki/Blind_spot_(vision)

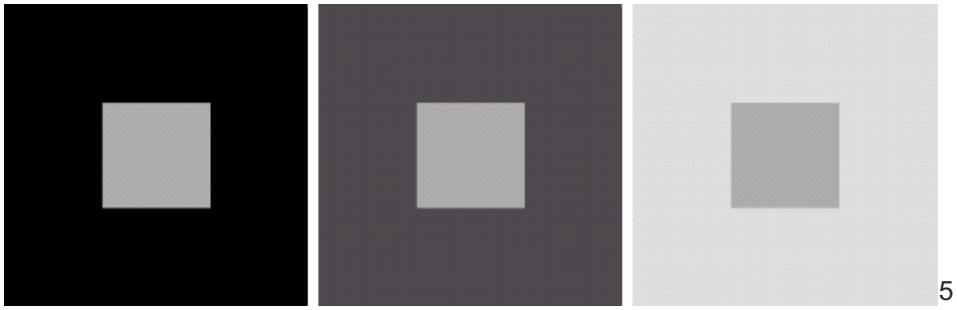
Human Visual Perception

- Perceived brightness is NOT a simple function of intensity



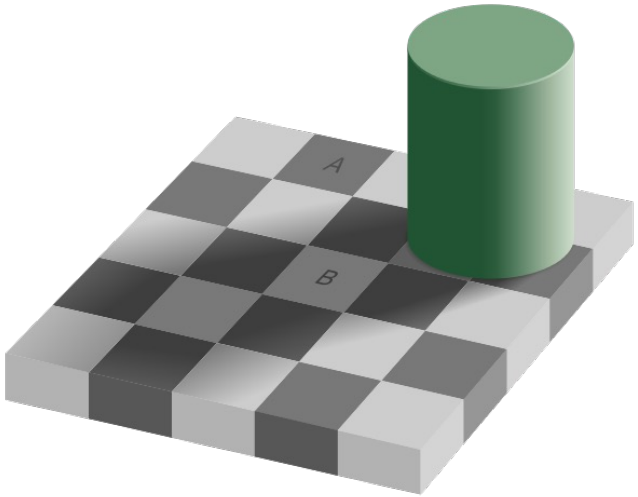


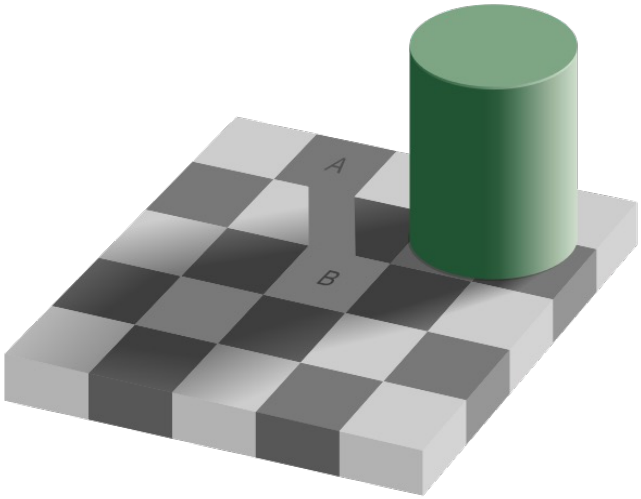


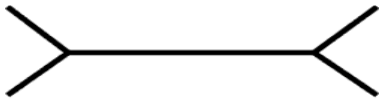


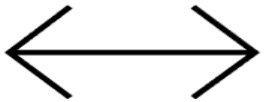
Human Visual Perception

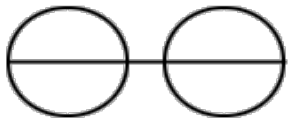
- Optical Illusion





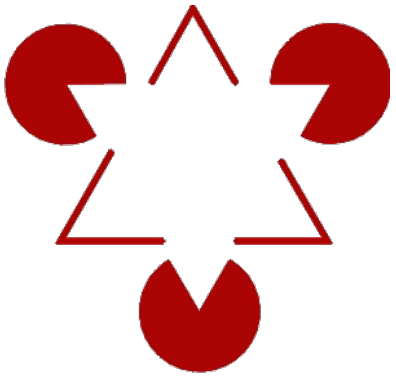


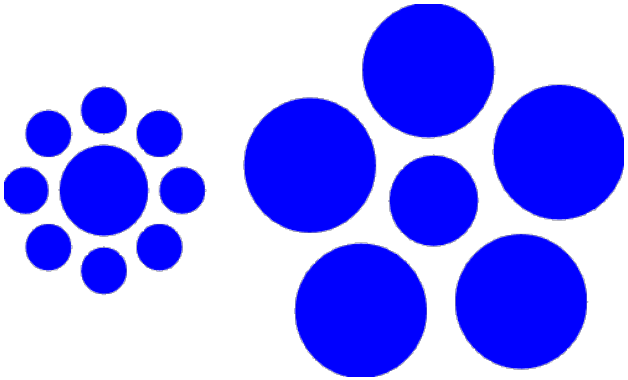


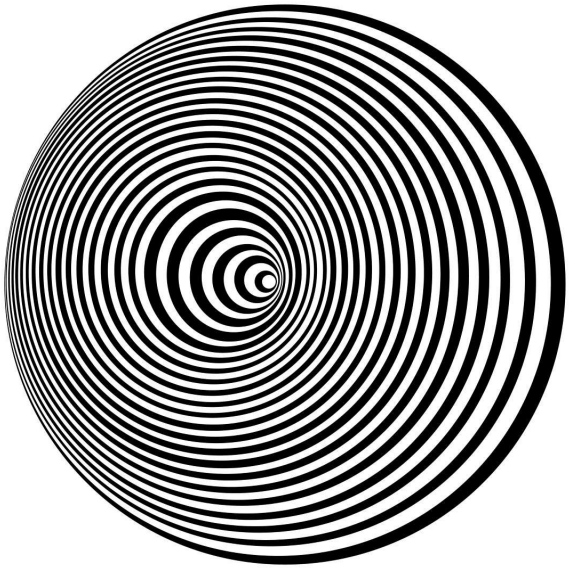


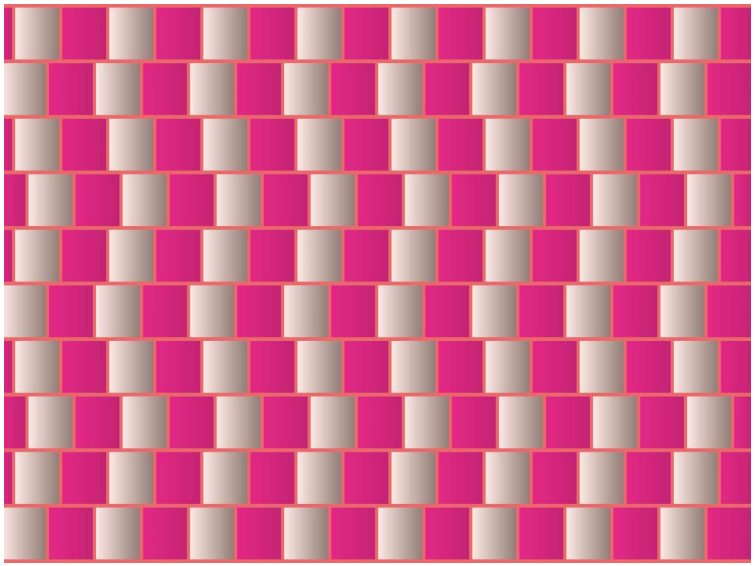
Human Visual Perception

- Optical Illusion



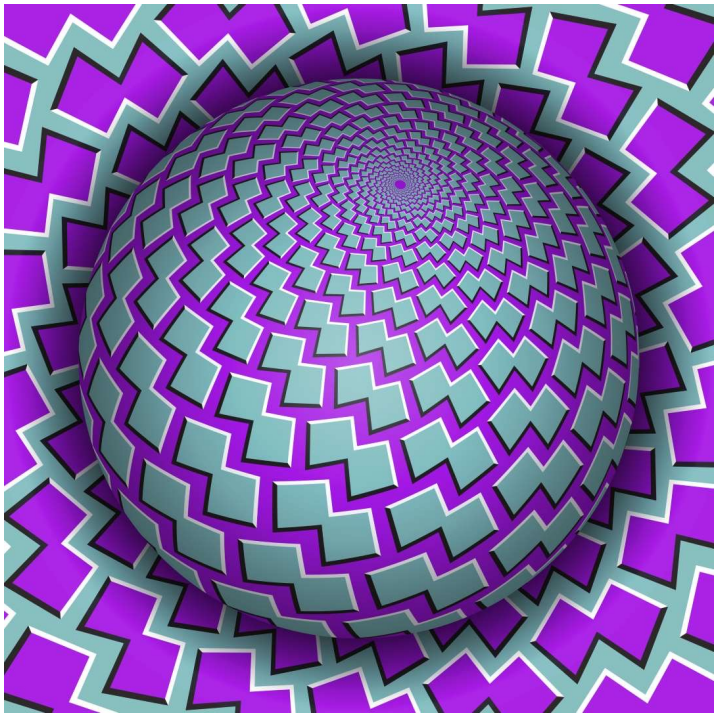


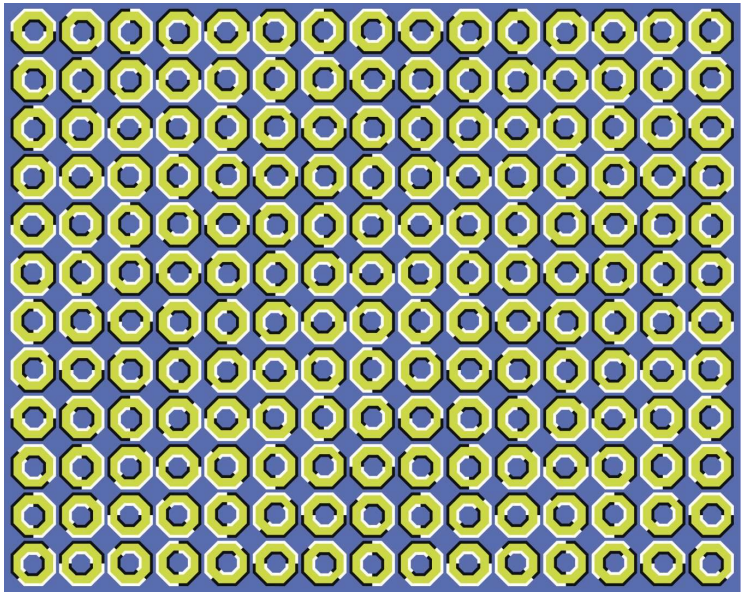




Human Visual Perception

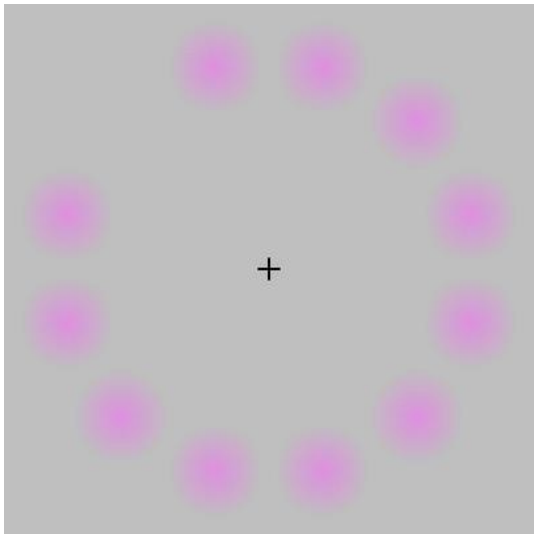
- Optical Illusion

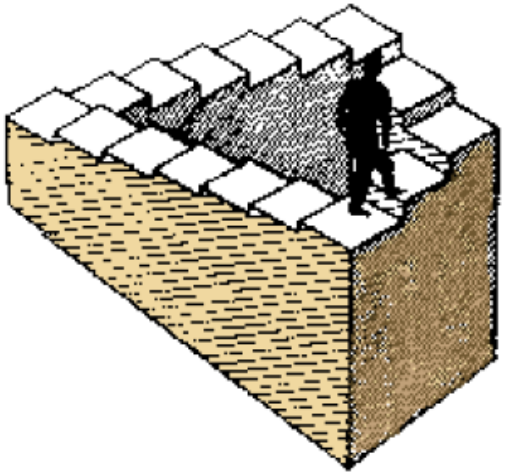


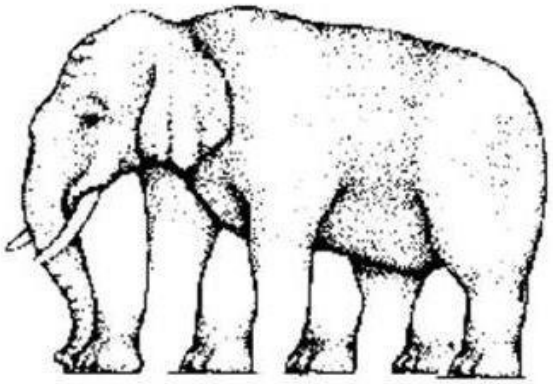


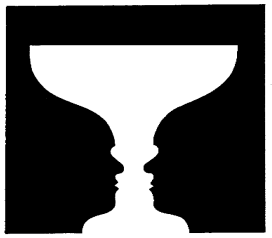
Human Visual Perception

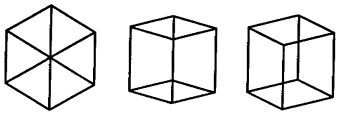
- Optical Illusion

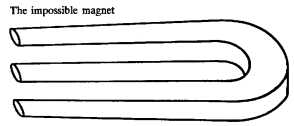


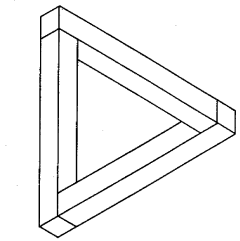






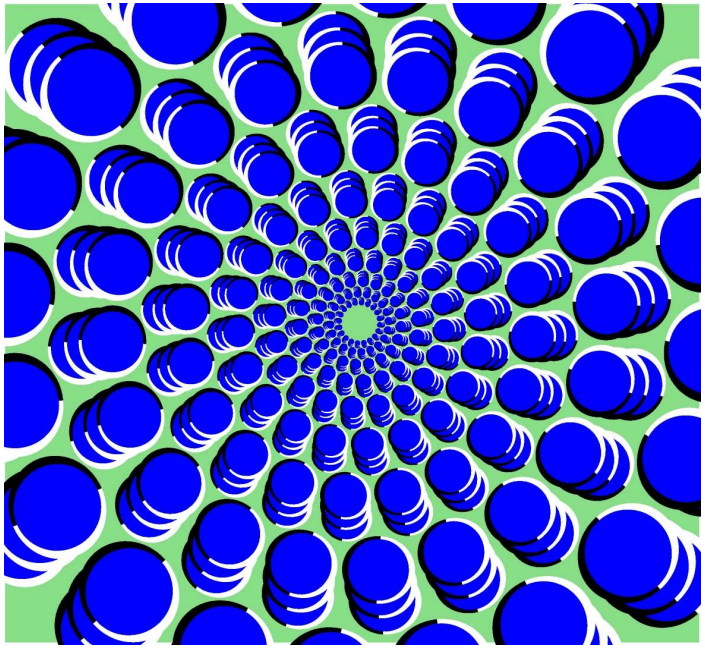


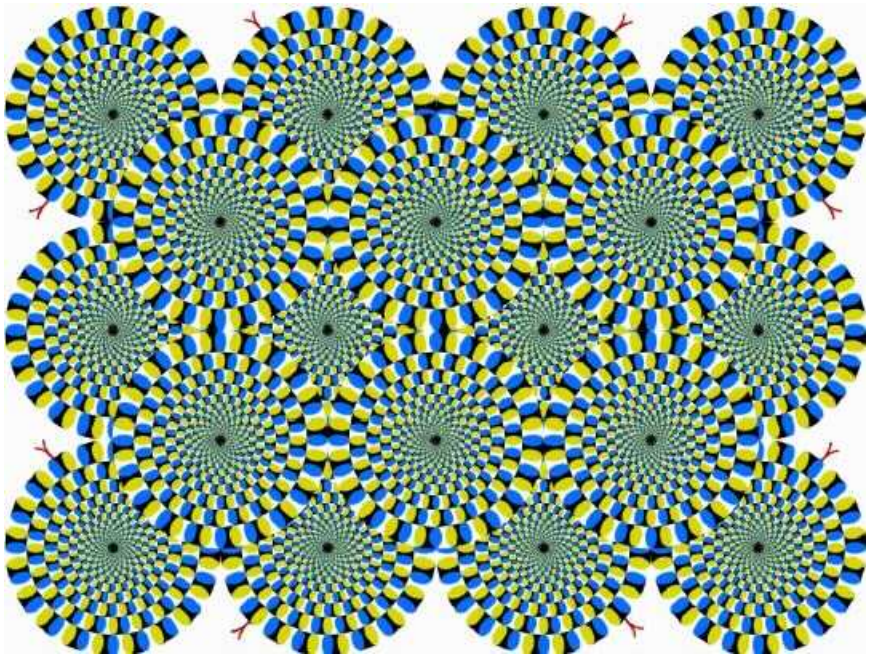




Human Visual Perception

- Optical Illusion



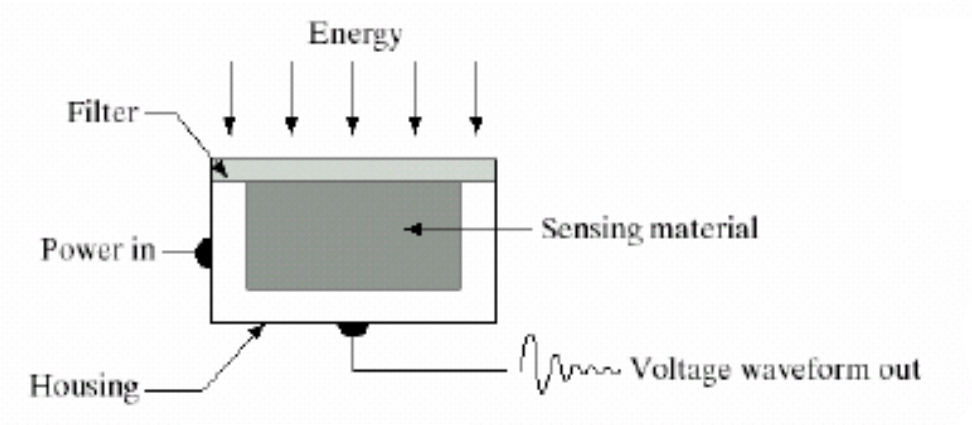


http://architecturehell.wordpress.com/

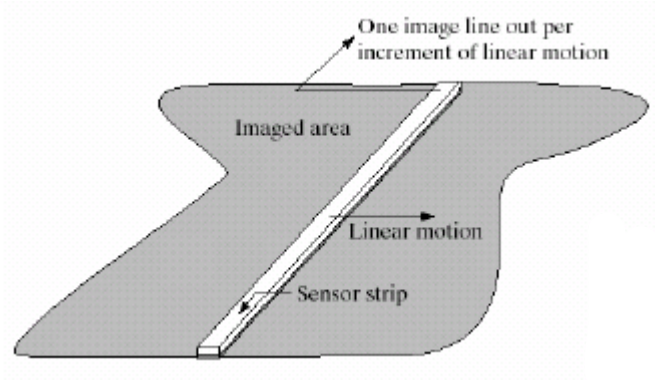
Image Sensing and Acquisition

- **Illumination Source**
  - EM energy, ultrasound, synthesized, …
- **Scene Element**
  - Objects, human organs, buried mineral,…
- **Sensing Material**
  - Single sensor: photodiode
  - Sensor strips: require extensive processing
  - Sensor arrays: CCD & CMOS

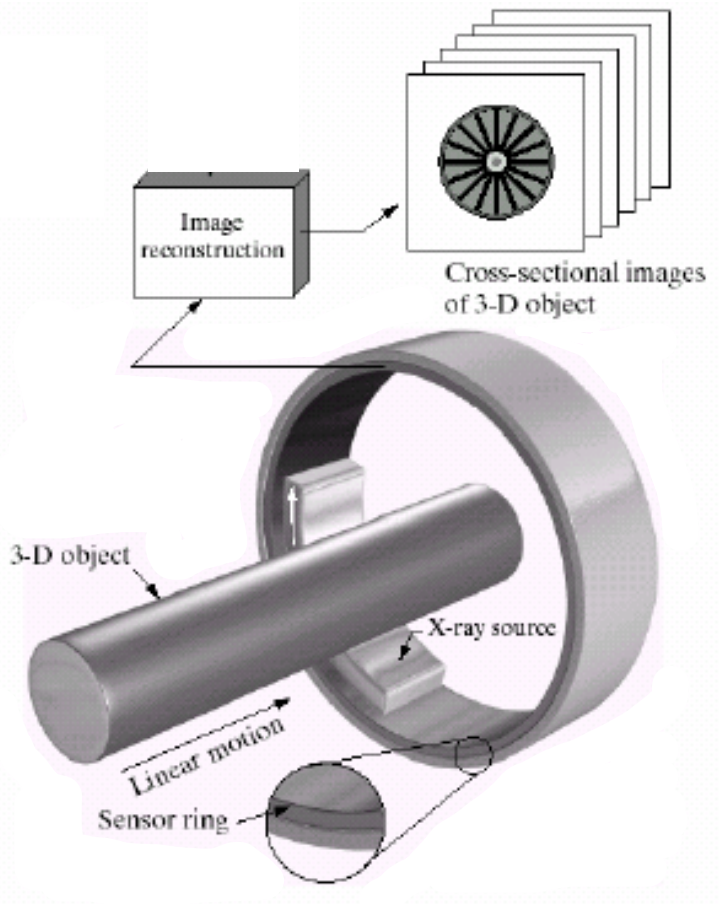
Image Sensing and Acquisition



Single sensor



Sensor Strip



Circular Sensor Strip

Image Sensing and Acquisition

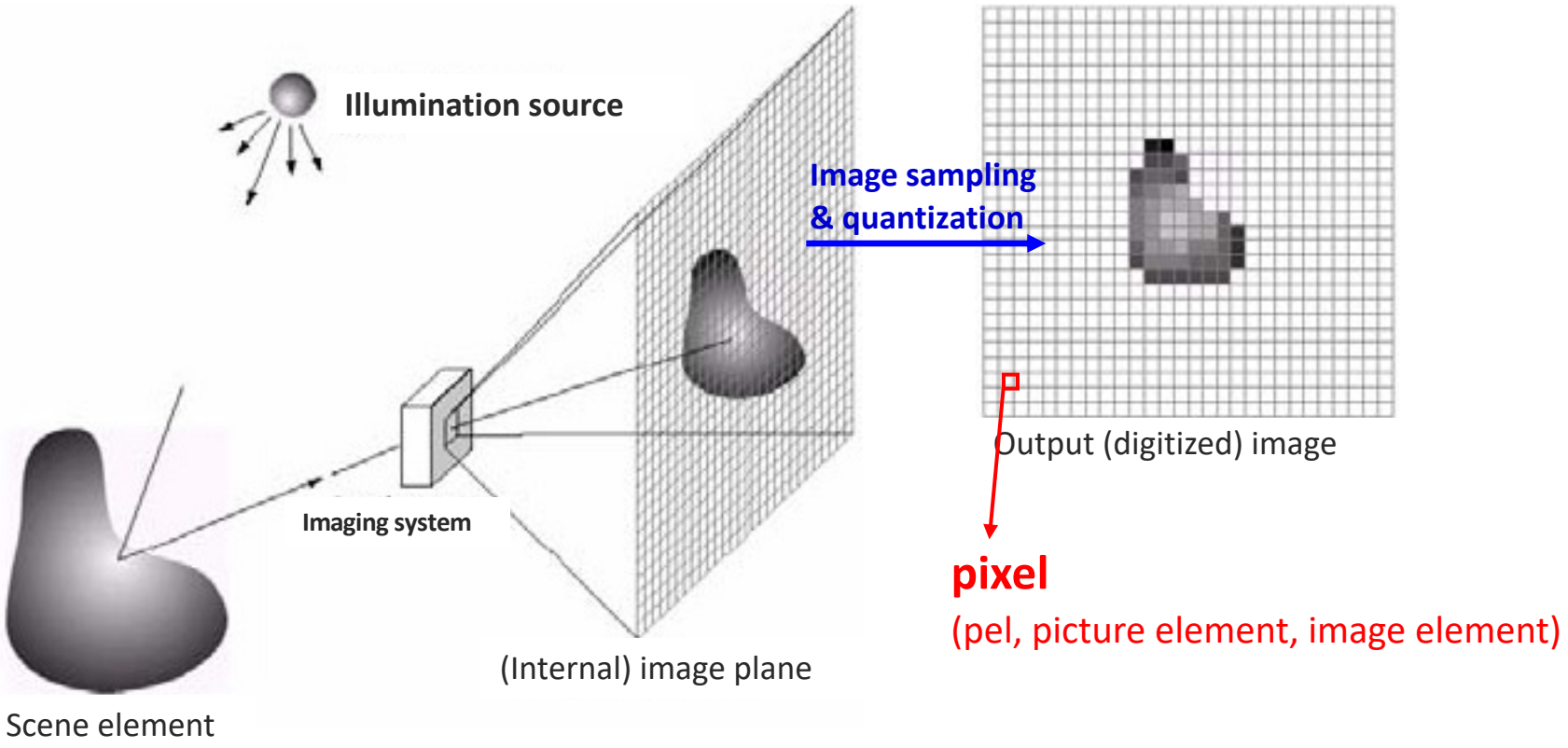
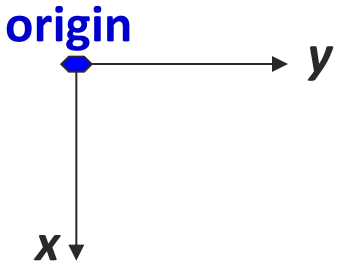


Image Formation Model

- **An image → 2D function**

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

where *x* and *y* are spatial coordinates

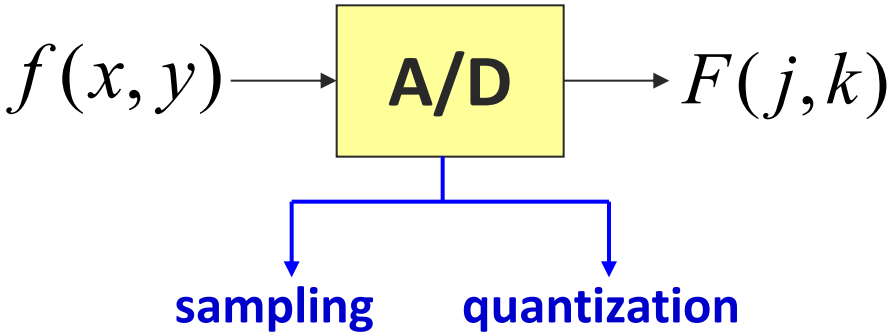


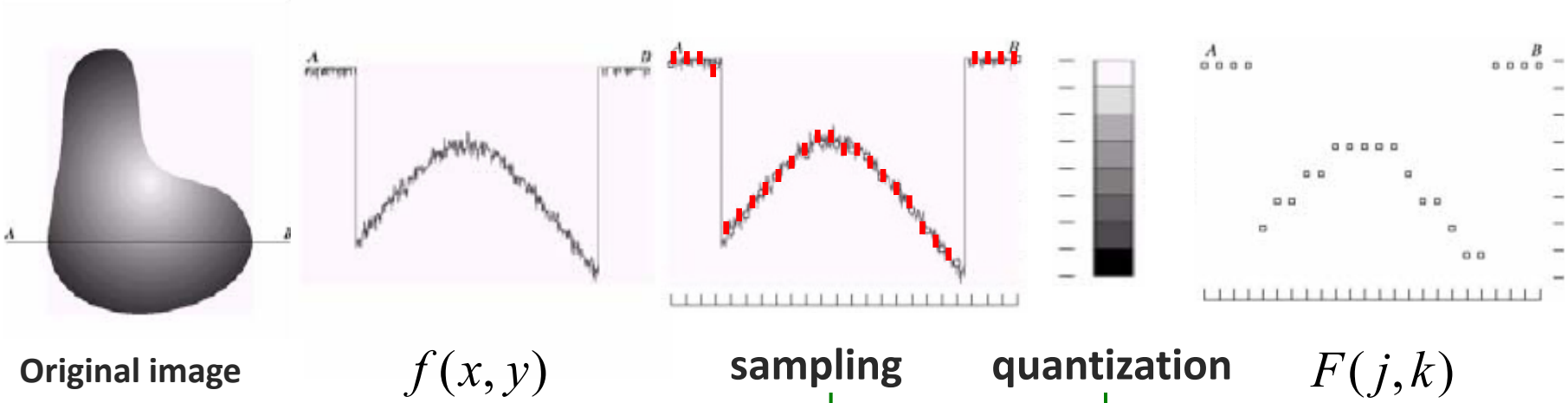
- **Categorized by two components**

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

  - **Illumination:** $0 < i(x, y) < \infty$
  - **Reflectance:** $0 < r(x, y) < 1$
    - black velvet/ flat-white wall paint/ snow/ silver-plated metal
      0.1 0.8 0.93 0.9

Image Sampling & Quantization





Original image

$f(x,y)$

sampling

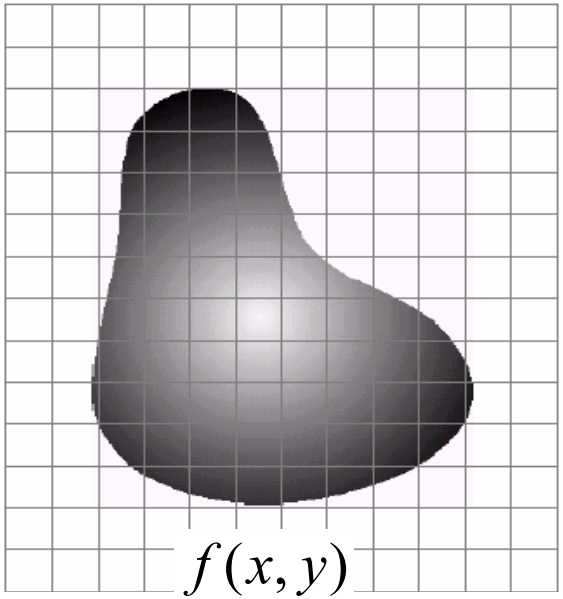
quantization

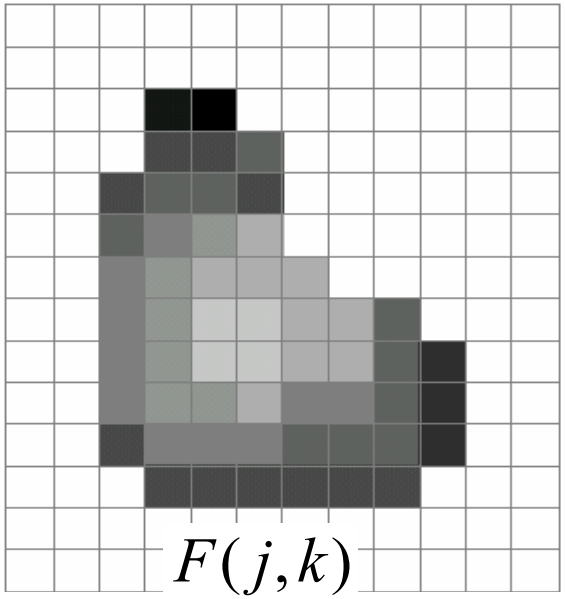
$F(j,k)$

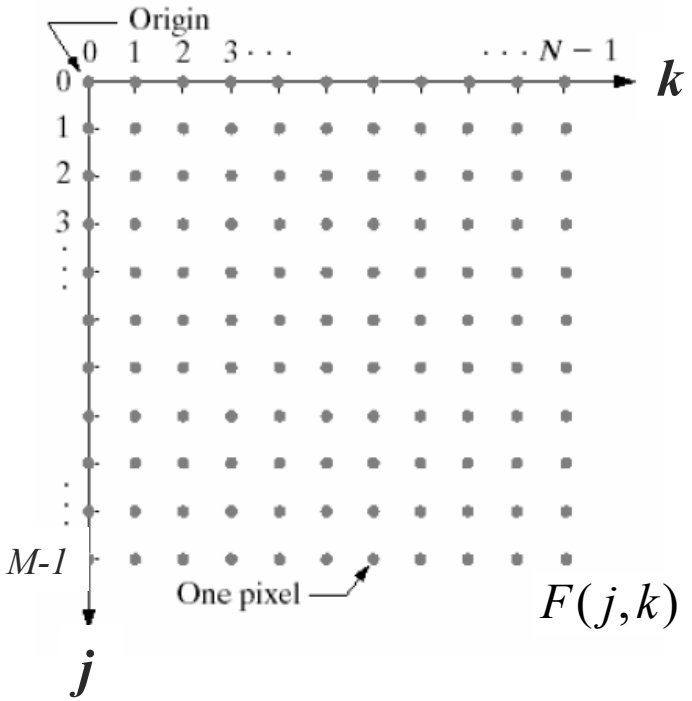
coordinates

amplitude

Image Sampling & Quantization







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

$$F(j,k) = \begin{bmatrix} F(0,0) & F(0,1) & \cdots & F(0,N-1) \\ F(1,0) & F(1,1) & \cdots & F(1,N-1) \\ \vdots & \vdots & \ddots & \vdots \\ F(M-1,0) & F(M-1,1) & \cdots & F(M-1,N-1) \end{bmatrix}$$

Digital Image Representation

- **Dynamic Range**
  - The range of values spanned by the gray scale

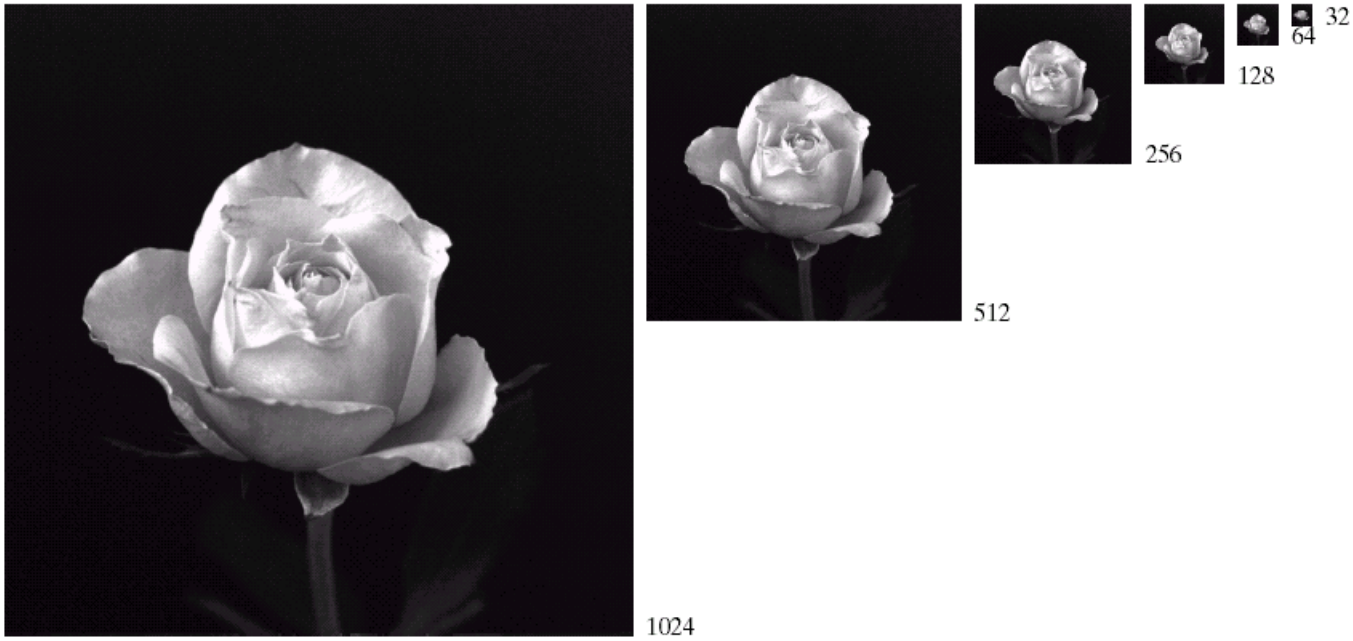
    $\{0, 1, \ldots, L-1\}$ $L = 2^k$
- **Image Size**
  - for a square image, $M = N$

    total number of bits required to store the image: $b = N^2 \cdot k$

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

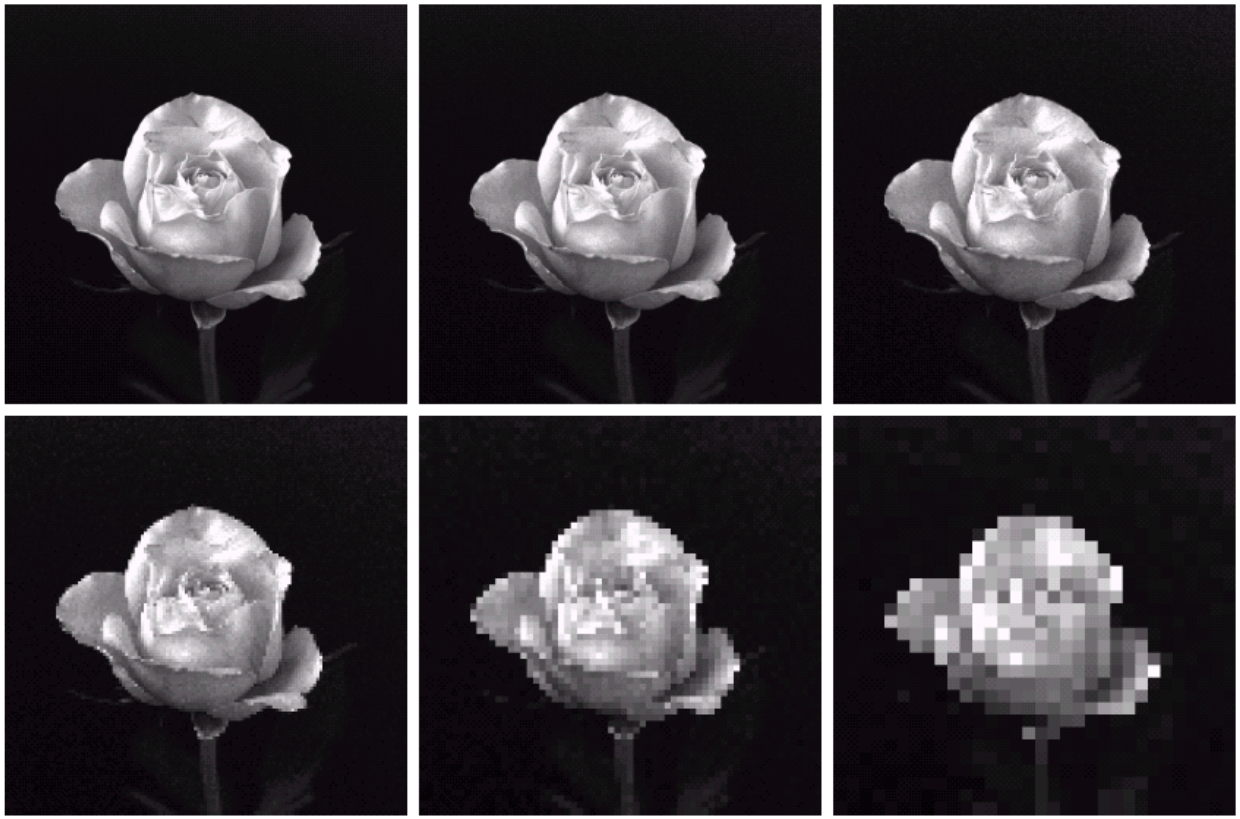
Downsampling

- 1024x1024 → 32x32
  - Downsampled by a factor of 2

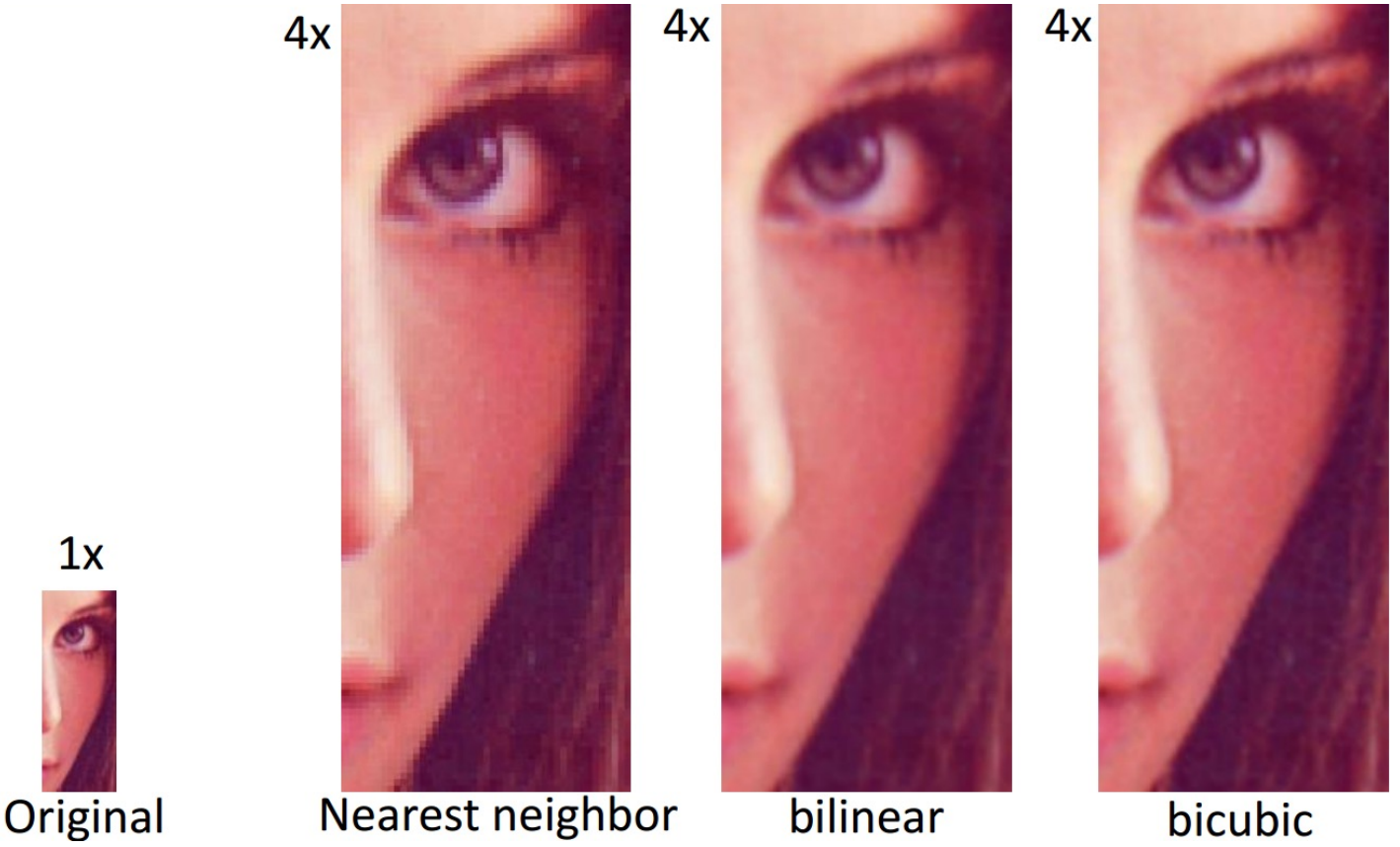


Re-Sampling

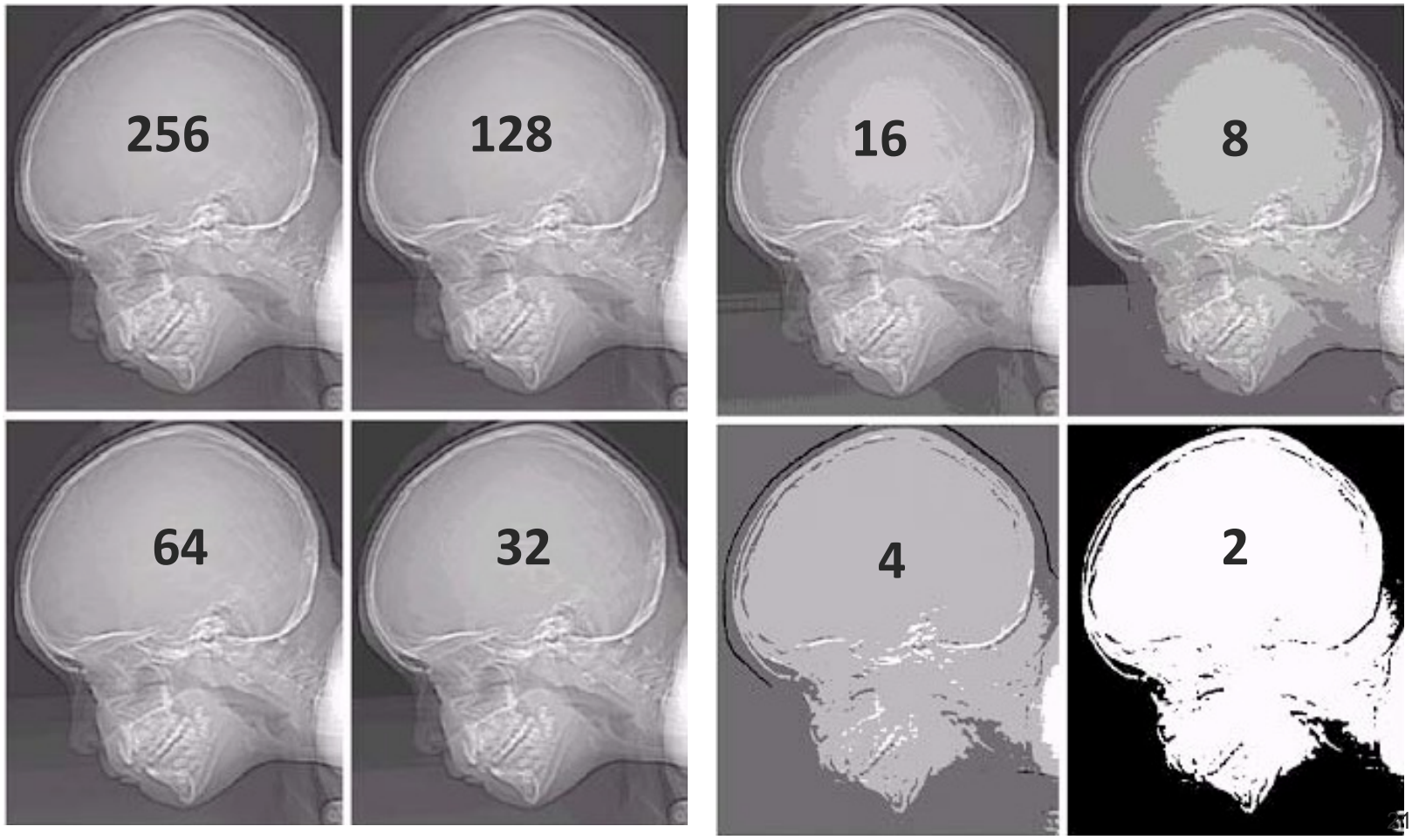
- Zero-Order-Hold Method (ZOH)
  - Row and column duplication



Re-Sampling

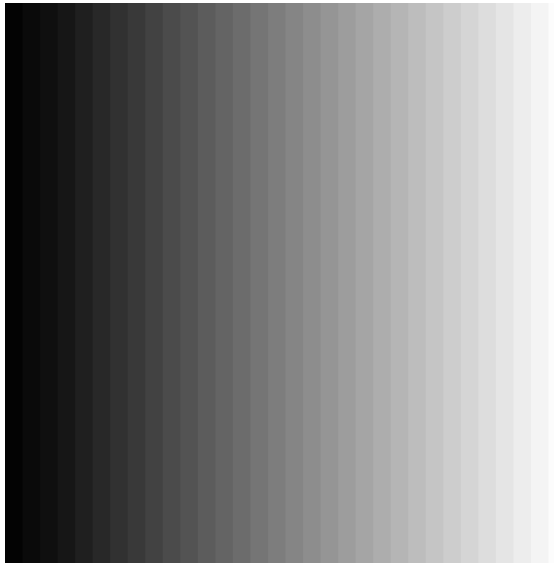


L=256,128,64,32,16,8,4,2

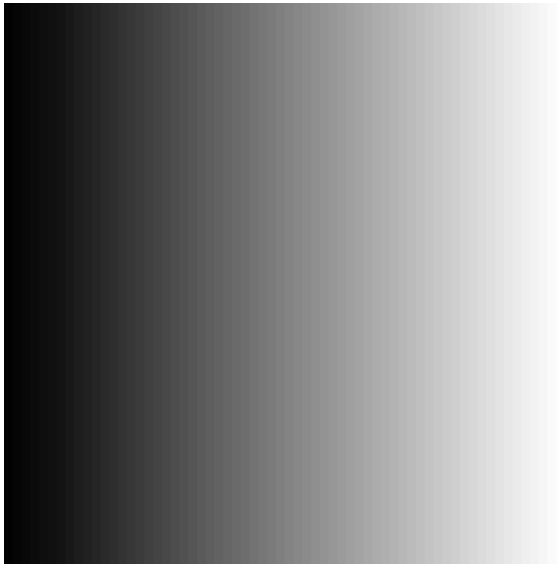


Digital Image Representation

- 8-bit image is commonly used
  - Storage
  - Human perception



32 steps (5 bits) in gray level



64 steps (6 bits) in gray level