영상처리
- Digital Image Fundamentals -

Elements of Visual Perception

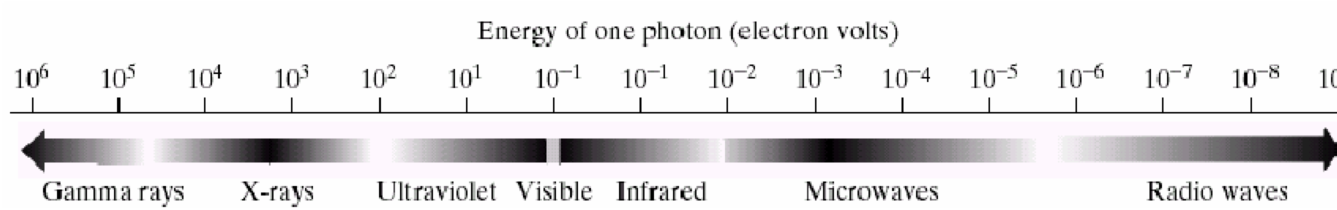
영상

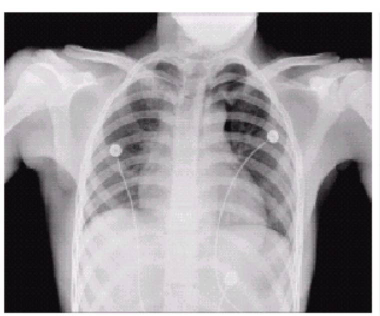
- 일반적인 의미
  - 가시광선을 센싱하여 자연 세계의 광학 현상을 2차원 이상의 데이터로 표현한 것

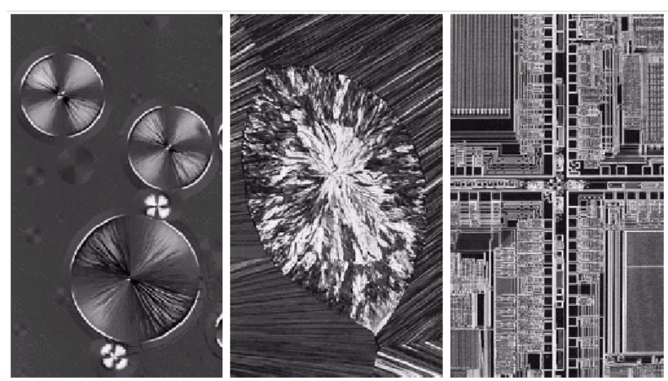
Elements of Visual Perception

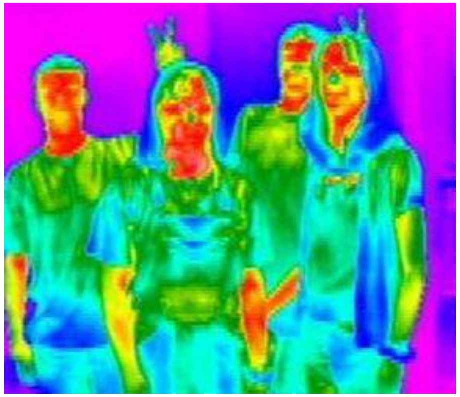
영상

- 넓은 의미의 영상
  - 가시광선 영역 외의 범위를 센싱하거나 컴퓨터 그래픽을 이용하여 생성한 것 (파동, signal을 계측해서 시각화 한 것)
  - X-ray – 의료영상, 공항검색대 등
  - 적외선 영상 – 군사, 항공, 의료, 우주 탐사 등 다양한 목적으로 사용









Elements of Visual Perception

Electromagnetic spectrum

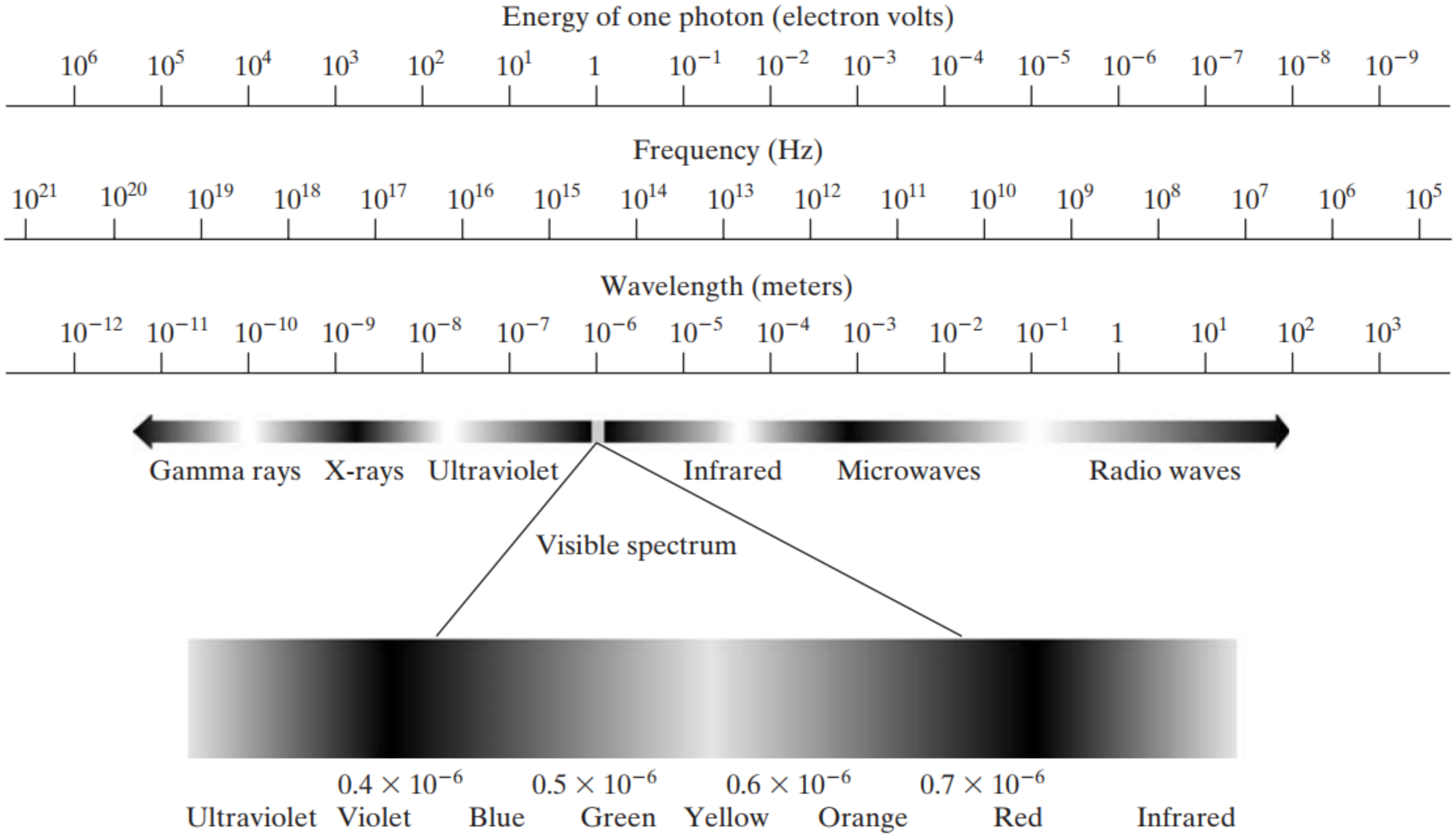


FIGURE 2.10 The electromagnetic spectrum. The visible spectrum is shown zoomed to facilitate explanation, but note that the visible spectrum is a rather narrow portion of the EM spectrum.

Elements of Visual Perception

Electromagnetic spectrum

- **Light: the visible spectrum**
  - Visible range: 0.43μm(violet)-0.78μm(red)
  - Six bands: violet, blue, green, yellow, orange, red
  - The color of an object is determined by the nature of the light reflected by the object

  - Monochromatic light (Light that is void of color)
    → intensity(gray level): only attribute

Elements of Visual Perception

Human eye structure

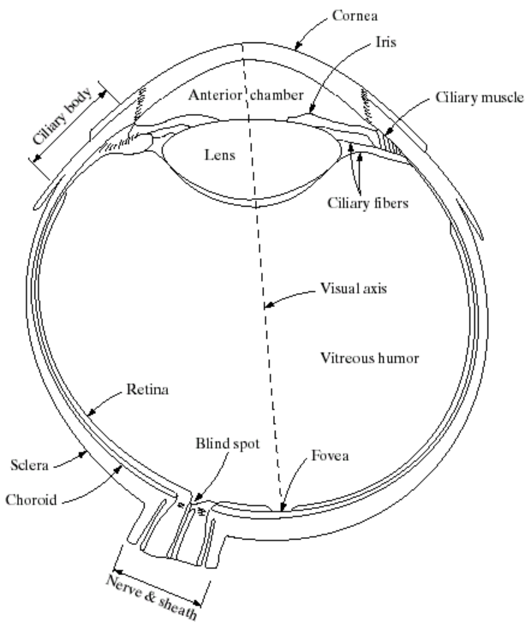


FIGURE 2.1 Simplified diagram of a cross section of the human eye.

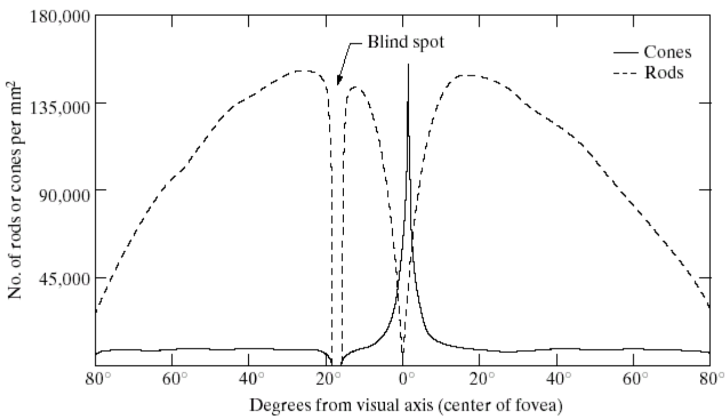


FIGURE 2.2 Distribution of rods and cones in the retina.

Cornea – 각막, Iris – 홍채, Lens – 수정체, Retina – 망막

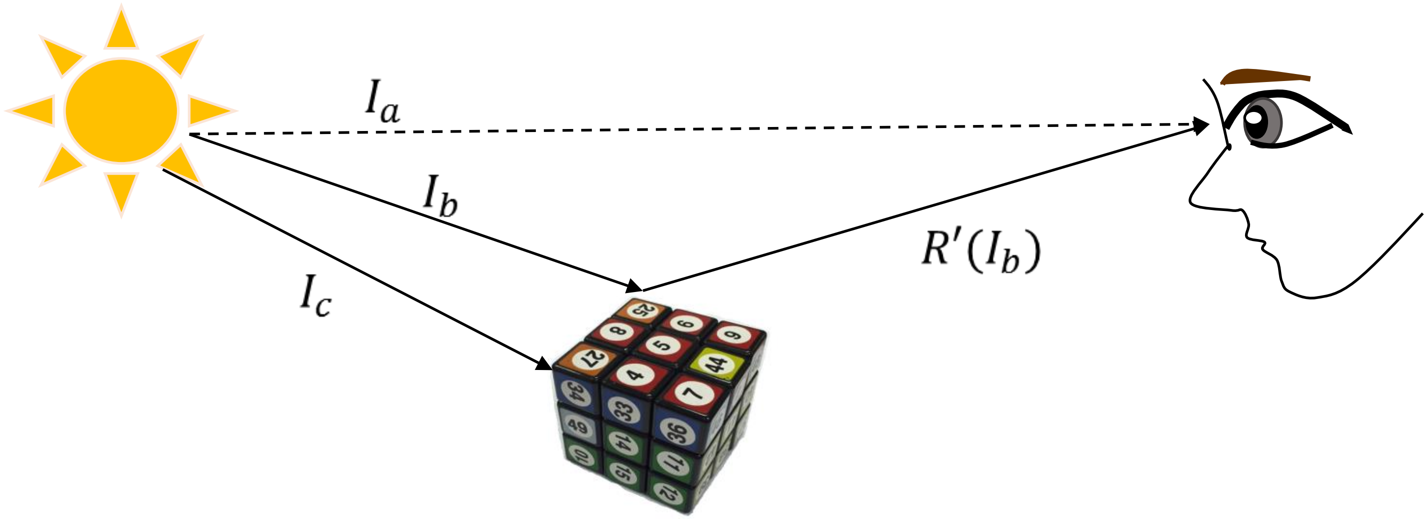
When the eye is properly focused, light from an outside object is imaged on the retina

Cone: 6-7 million in each eye, central part of retina (fovea) and highly sensitive to color
Rod: 75-150 million, all over the retina surface and sensitive to low levels of illumination

Elements of Visual Perception

Image formation in the Eye

- 실세계의 공간 정보가 인간의 눈으로 투영되는 과정



- I_a: 광원에서 발생한 빛이 직접 눈으로 향하는 경우
- I_b, I_c : 다양한 물체로 향하는 경우
- $R'(I_b)$: 물체가 반사한 빛의 일부가 눈으로 향하는 경우

- 카메라 센서 (Charged-Coupled Devide, Complementary Metal-Oxide Semiconductor)는 사람의 망막을 모방하여 이미지를 센싱

Elements of Visual Perception

Image formation in the Eye

- 실세계의 공간 정보가 인간의 눈으로 투영되는 과정

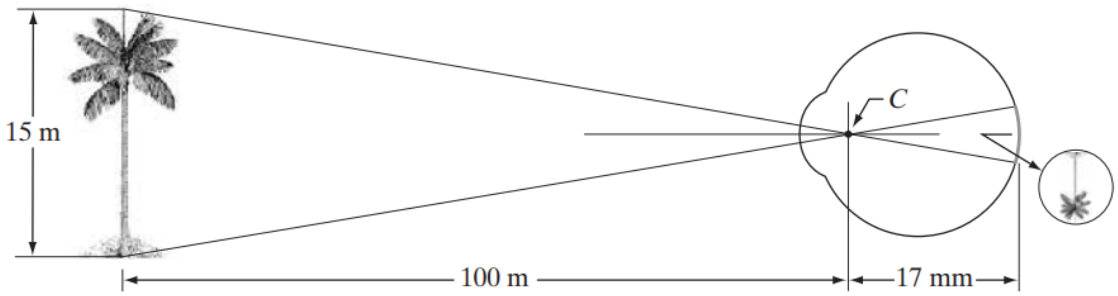


FIGURE 2.3 Graphical representation of the eye looking at a palm tree. Point *C* is the optical center of the lens.

- 역상이 기본상태
- Lens의 모양을 변화 시키면서 focal length(C위치)를 조절
- 사람의 focal length는 약 14~17mm (3M 이상 떨어져 있을 때 most relaxed)
- 위 사진에서 망막에 맺힌 나무의 크기는 약 2.55mm

100m : 15m = 17mm : H mm

Elements of Visual Perception

Bright adaptation and discrimination

- Bright adaptation
    - 사람의 인식하는 빛의 강도 = log(실제 강도)
    - 인식할 수 있는 빛의 dynamic range가 매우 넓음
      → 단 전체 범위를 한번에 인식할 수는 없음
    - 따라서 밝기에 대한 sensitivity를 조정 → bright adaptation

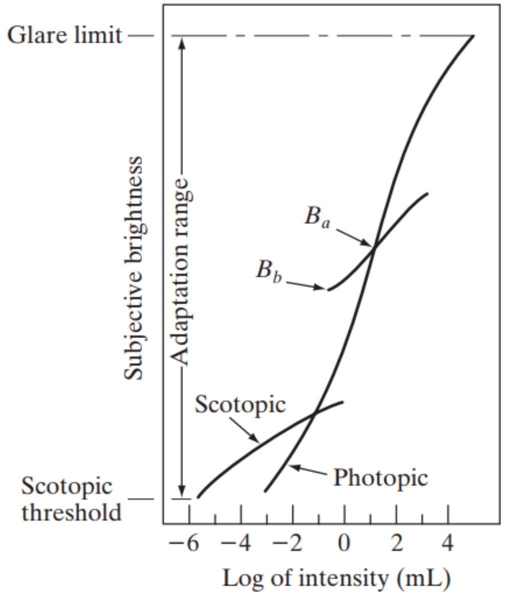


FIGURE 2.4 Range of subjective brightness sensations showing a particular adaptation level.

Brightness adaptation level (B_a, B_b)에 따라 subjective brightness곡선의 기울기가 달라짐 → 같은 밝기의 광원을 다른 밝기로 인식함

Elements of Visual Perception

Bright adaptation and discrimination

- Bright discrimination
  - 변화하는 빛의 강도를 감지할 때 발생하는 현상
    → 밝기 변화 인지 과정은 linear하지 않음

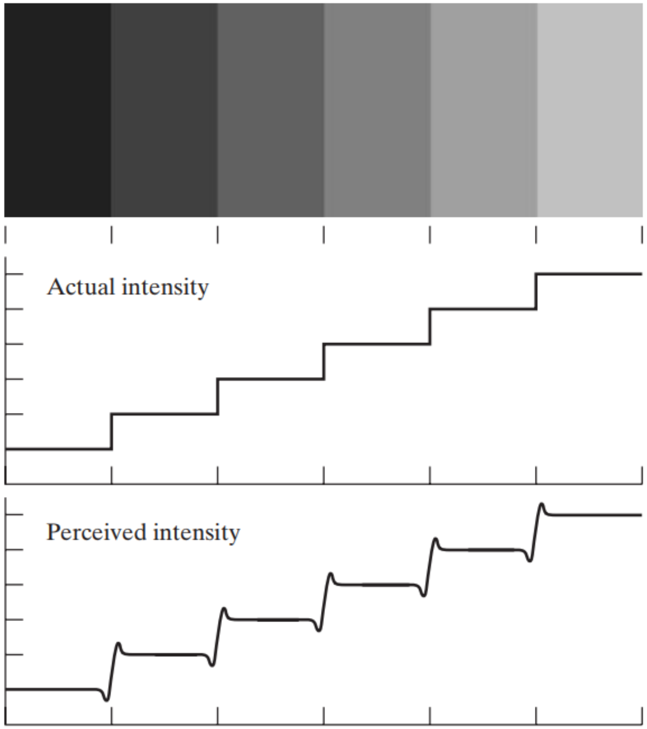
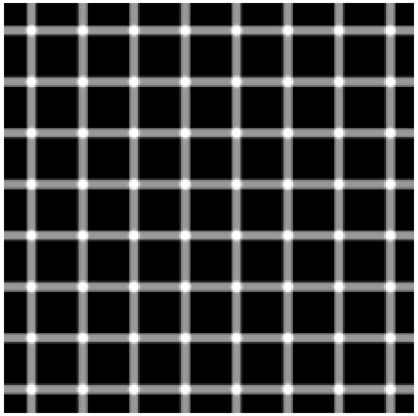


FIGURE 2.8 Examples of simultaneous contrast. All the inner squares have the same intensity, but they appear progressively darker as the background becomes lighter.

Elements of Visual Perception

Bright adaptation and discrimination

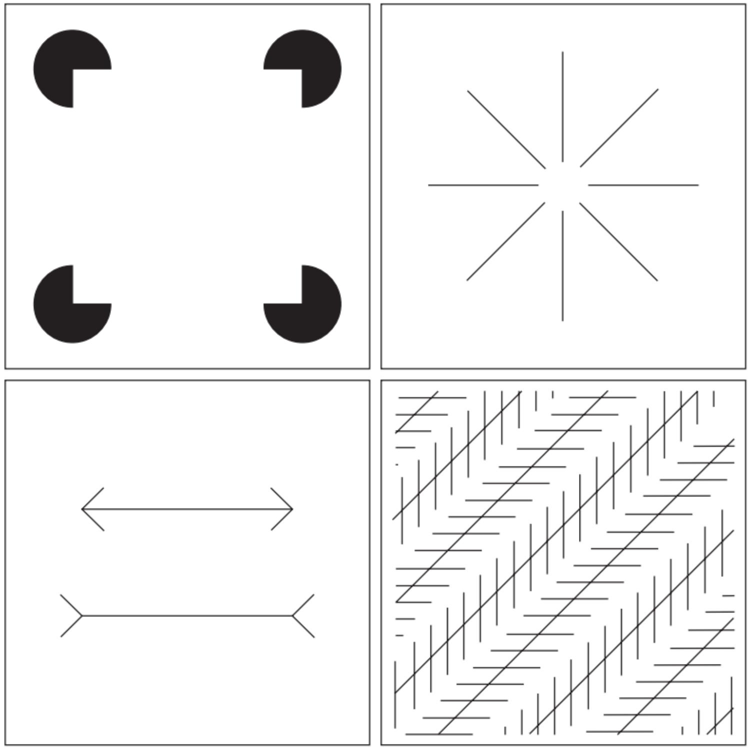
- Bright discrimination
  - 변화하는 빛의 강도를 감지할 때 발생하는 현상
    → 밝기 변화 인지 과정은 linear하지 않음



Elements of Visual Perception

Bright adaptation and discrimination

- Other human perception phenomenon - Optical illusion
    - 시각정보 인지과정에서 상실되었거나 예측 가능한 정보를 interpolation



a b
c d

FIGURE 2.9 Some well-known optical illusions.

Elements of Visual Perception

시각적 인지

- 인간이 인지하는 시각
  - 3차원 공간에 존재하는 빛이 눈으로 입력되어 뇌가 인지하는 모든 과정
- 시각 인지 단계
  - 감각 단계 – 빛이 망막의 신경세포에서 전기적 신호로 변환된 후 신경계를 통해 뇌로 보내지는 단계
  - 선택 단계 – 보고자 하는 대상을 분리하는 단계
  - 지각 단계 – 기억 데이터를 근거로 대상을 이해하여 지각하는 단계

Elements of Visual Perception

시각적 인지

- 디지털 영상처리 단계

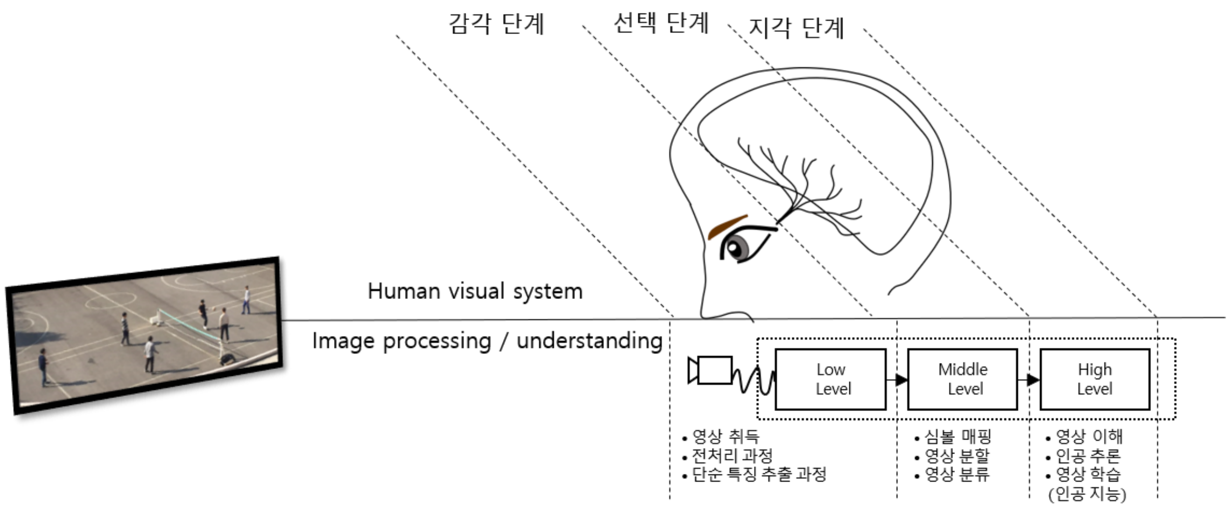
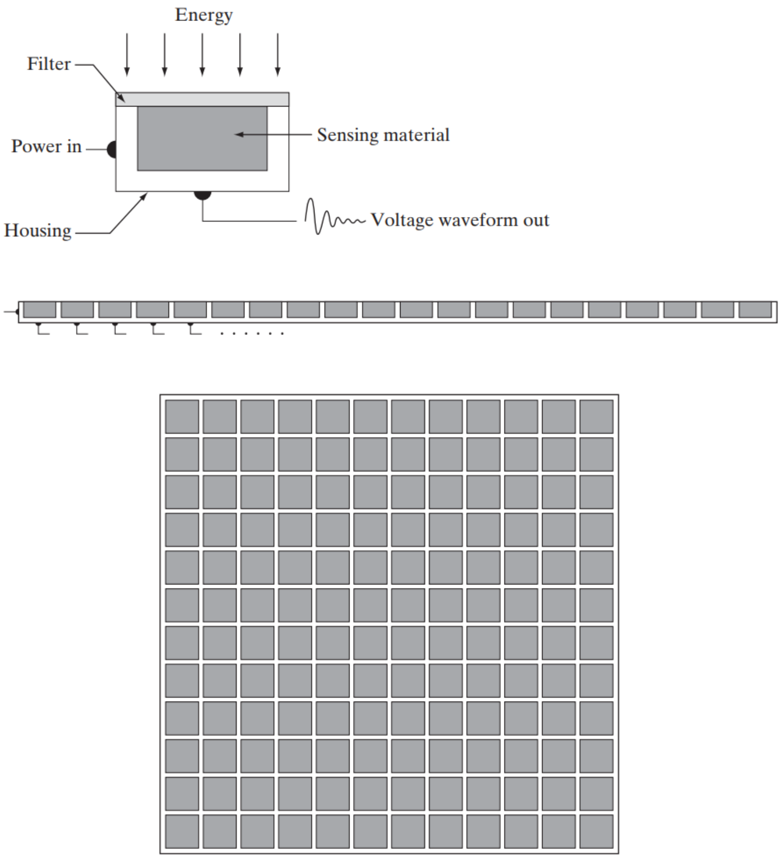


Image Sensing and Acquisition

- **Imaging sensor arrangements**



a
b
c

FIGURE 2.12
(a) Single imaging sensor.
(b) Line sensor.
(c) Array sensor.

Image Sensing and Acquisition

- **Imaging sensor arrangements**
  - Imaging 3차원 공간의 물체를 2D array로 투영시키는 것

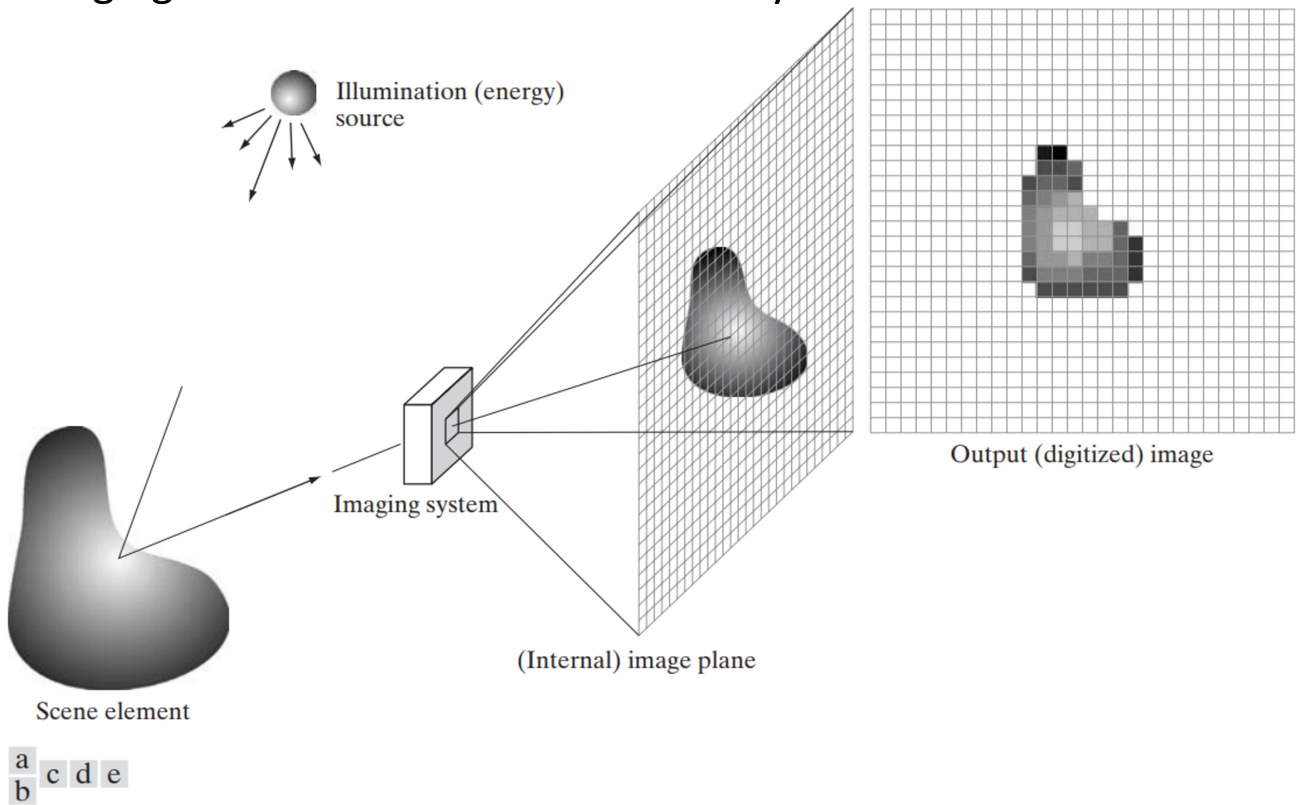


FIGURE 2.15 An example of the digital image acquisition process. (a) Energy ("illumination") source. (b) An element of a scene. (c) Imaging system. (d) Projection of the scene onto the image plane. (e) Digitized image.

Image Sensing and Acquisition

- **Linear sensor, circular sensor strip**

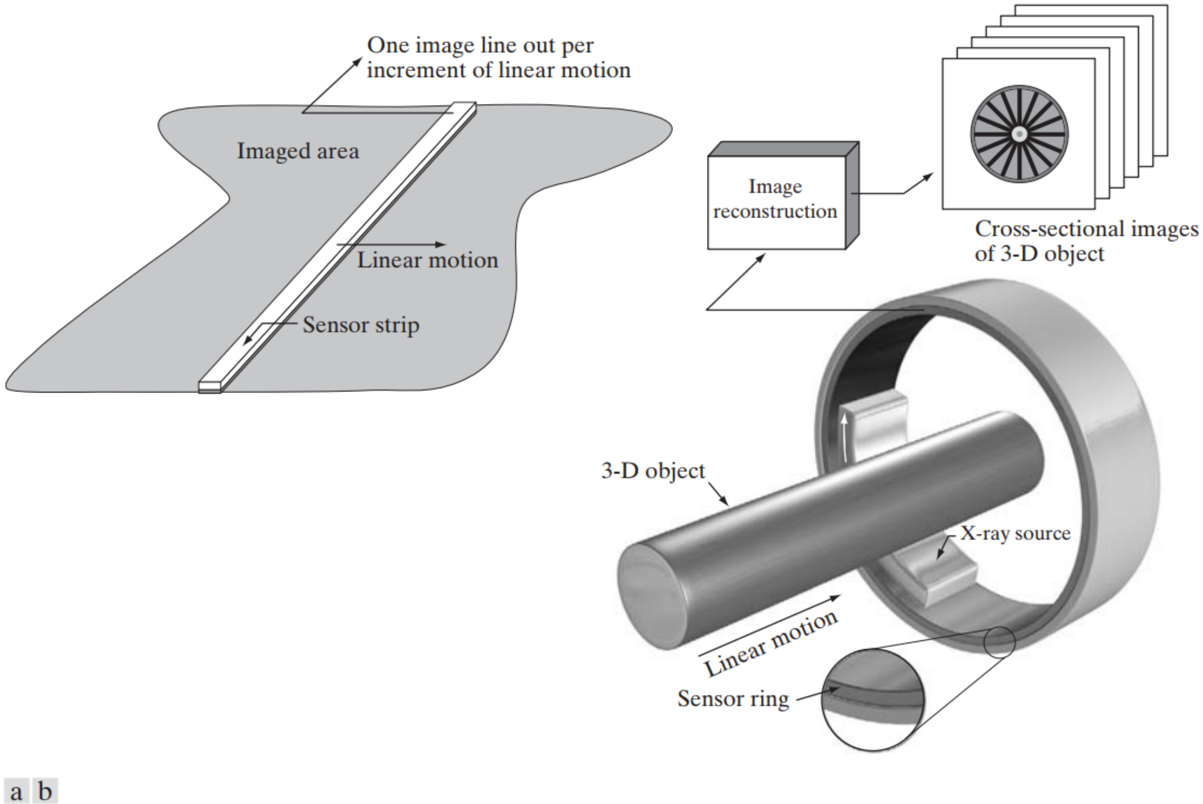


FIGURE 2.14 (a) Image acquisition using a linear sensor strip. (b) Image acquisition using a circular sensor strip.

Image Sensing and Acquisition

Image formation

- 위치 x, y

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

$0<f(x,y)<\infty$ — Intensity – proportional to energy radiated by a physical source

$0<i(x,y)<\infty$ — Illumination, lights src dependent

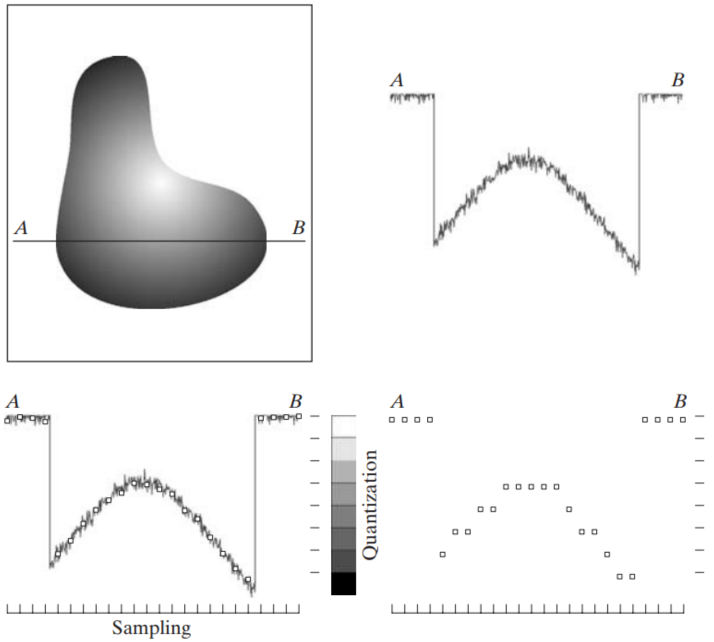
$0<r(x,y)<1$ — reflectance

Obj dependent, 0:absoprtion, 1:relfectance

$n(x,y)$ — noise

Image Sampling and Quantization

Basic Concepts in Sampling and Quantization



a b
c d

FIGURE 2.16 Generating a digital image. (a) Continuous image. (b) A scan line from A to B in the continuous image, used to illustrate the concepts of sampling and quantization. (c) Sampling and quantization. (d) Digital scan line.

- **Sampling – Digitizing the coordinate values**
- **Quantization – Digitizing the amplitude values**

Image Sampling and Quantization

Basic Concepts in Sampling and Quantization

- **Sampling – Digitizing the coordinate values**

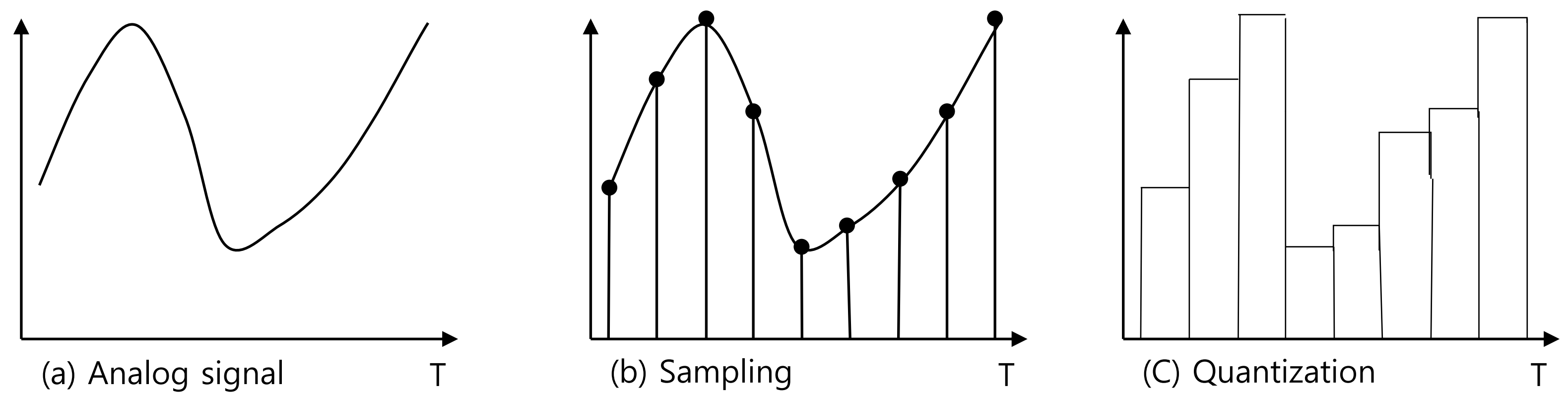
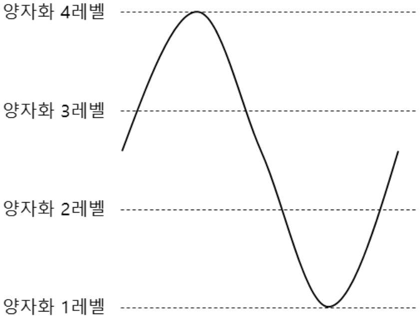


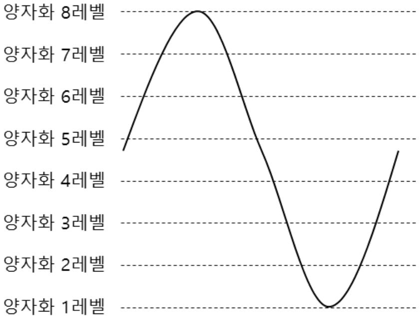
Image Sampling and Quantization

Basic Concepts in Sampling and Quantization

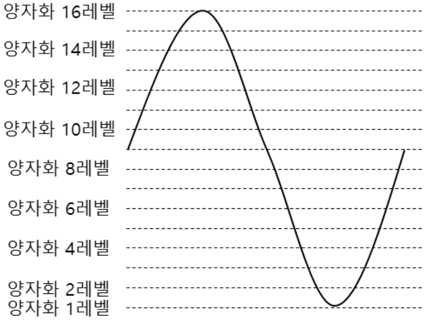
- **Quantization – Digitizing the amplitude values**



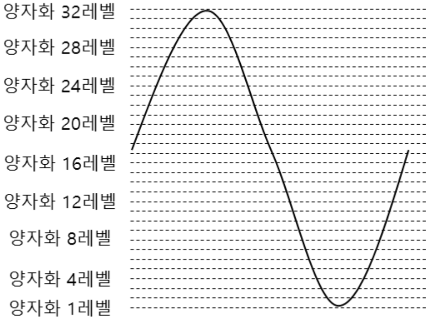
(a) 4단계: 2비트 양자화



(b) 8단계: 3비트 양자화



(c) 16단계: 4비트 양자화

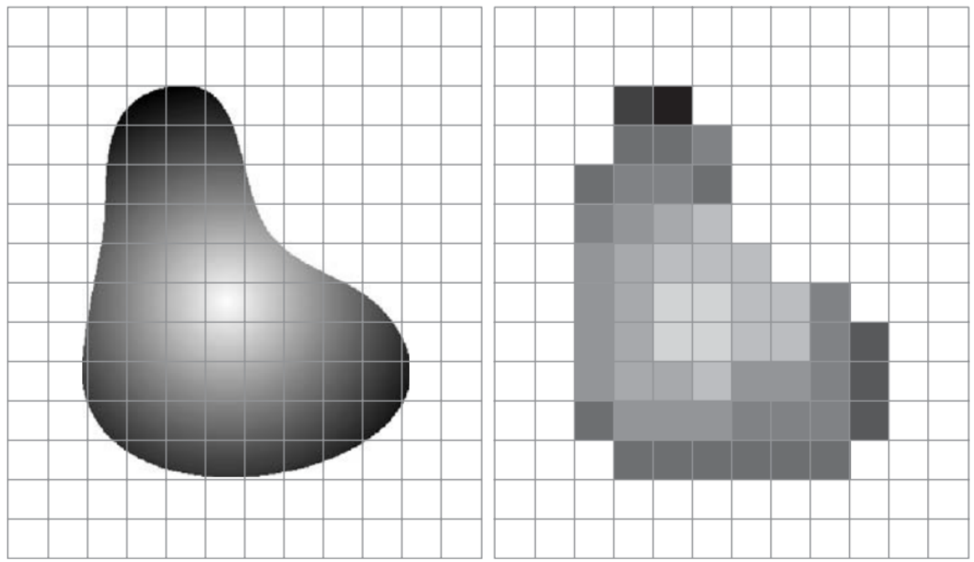


(d) 32단계: 5비트 양자화

Image Sampling and Quantization

Basic Concepts in Sampling and Quantization

- Result of sampling and quantization



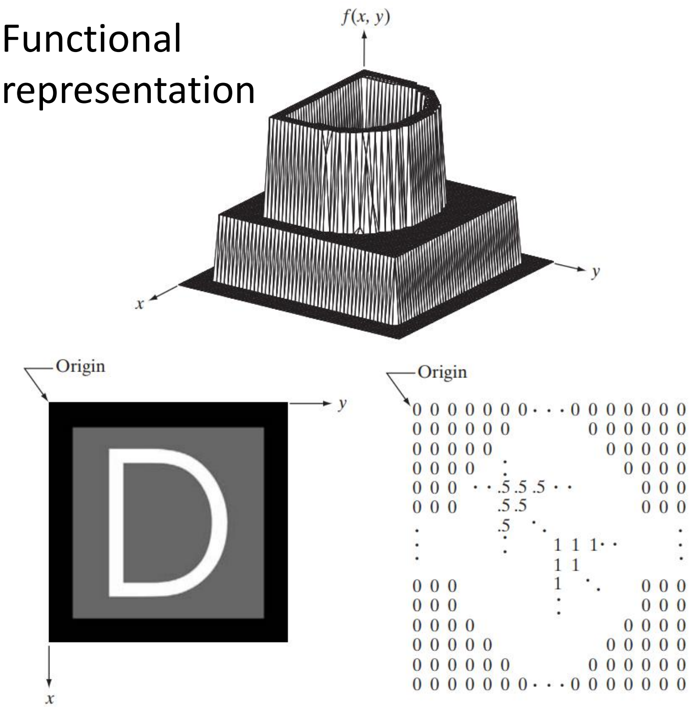
a b

FIGURE 2.17 (a) Continuous image projected onto a sensor array. (b) Result of image sampling and quantization.

Image Sampling and Quantization

Representing Digital Images

Functional representation



a
b c

FIGURE 2.18
(a) Image plotted as a surface.
(b) Image displayed as a visual intensity array.
(c) Image shown as a 2-D numerical array (0, .5, and 1 represent black, gray, and white, respectively).

Visual intensity

Numerical array (Matrix)

- Visual intensity

A monitor or printer simply converts these three values to black, gray, or white, respectively, as Fig. 2.18(b) shows.

- Numerical array

When developing algorithms, however, this representation is quite useful when only parts of the image are printed and analyzed as numerical values.

Image Sampling and Quantization

Representing Digital Images

- 알고리즘 개발을 위해서는 보통 행렬의 형태로 표현함

Pixel

$$\underset{\text{Image}}{f(x, y)} = \begin{bmatrix} f(0,0) & f(0,1) & \cdots & \boxed{f(0, N-1)} \\ f(1,0) & f(1,1) & \cdots & f(1, N-1) \\ \vdots & \vdots & & \vdots \\ f(M-1,0) & f(M-1,1) & \cdots & f(M-1, N-1) \end{bmatrix} \quad (2.4\text{-}1)$$

- Intensity level
  - Due to storage and quantizing hardware considerations, the number of intensity levels typically is an integer power of 2.

$$L = 2^k$$

  - Dynamic range: [0,L-1]

- Total bit - $M \times N \times k$

Image Sampling and Quantization

Dynamic range

- Upper limit – saturation, Lower limit Noise
- Total range - contrast

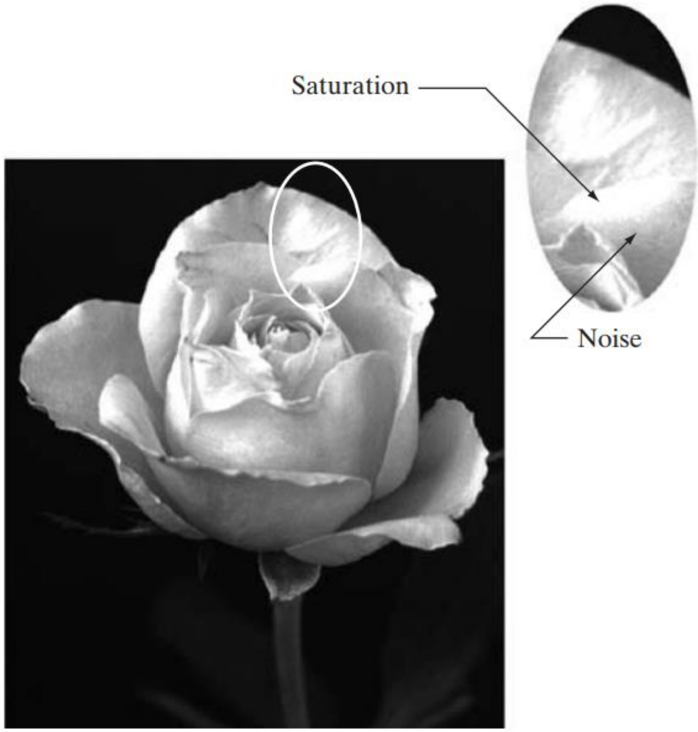
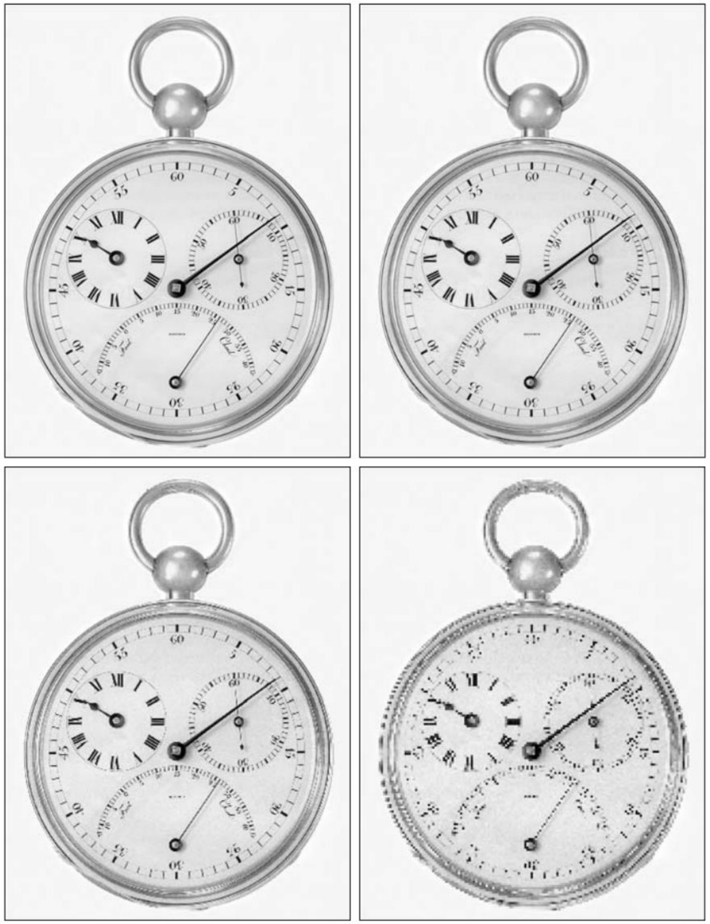


Image Sampling and Quantization

Spatial and Intensity Resolution

- Spatial resolution
  - pixels per unit distance
    - (e.g. 3 pixel per 1mm)
  - Line pairs per unit distance
    - (e.g. 100 line pair per 1 mm)
  - US measure – dots per inch (dpi)

  - Sometimes.. Physical size of pixel
    - 3x3mm per pixel
      → Pixel spacing



a b
c d

FIGURE 2.20 Typical effects of reducing spatial resolution. Images shown at: (a) 1250 dpi, (b) 300 dpi, (c) 150 dpi, and (d) 72 dpi. The thin black borders were added for clarity. They are not part of the data.

Image Sampling and Quantization

Spatial and Intensity Resolution

- Intensity resolution (Bit-depth resolution)
  - smallest discernible change in intensity level
  - it is common practice to refer to the number of bits used to quantize intensity as the *intensity resolution*
  - Most common intensity level: 8bit (256 level)

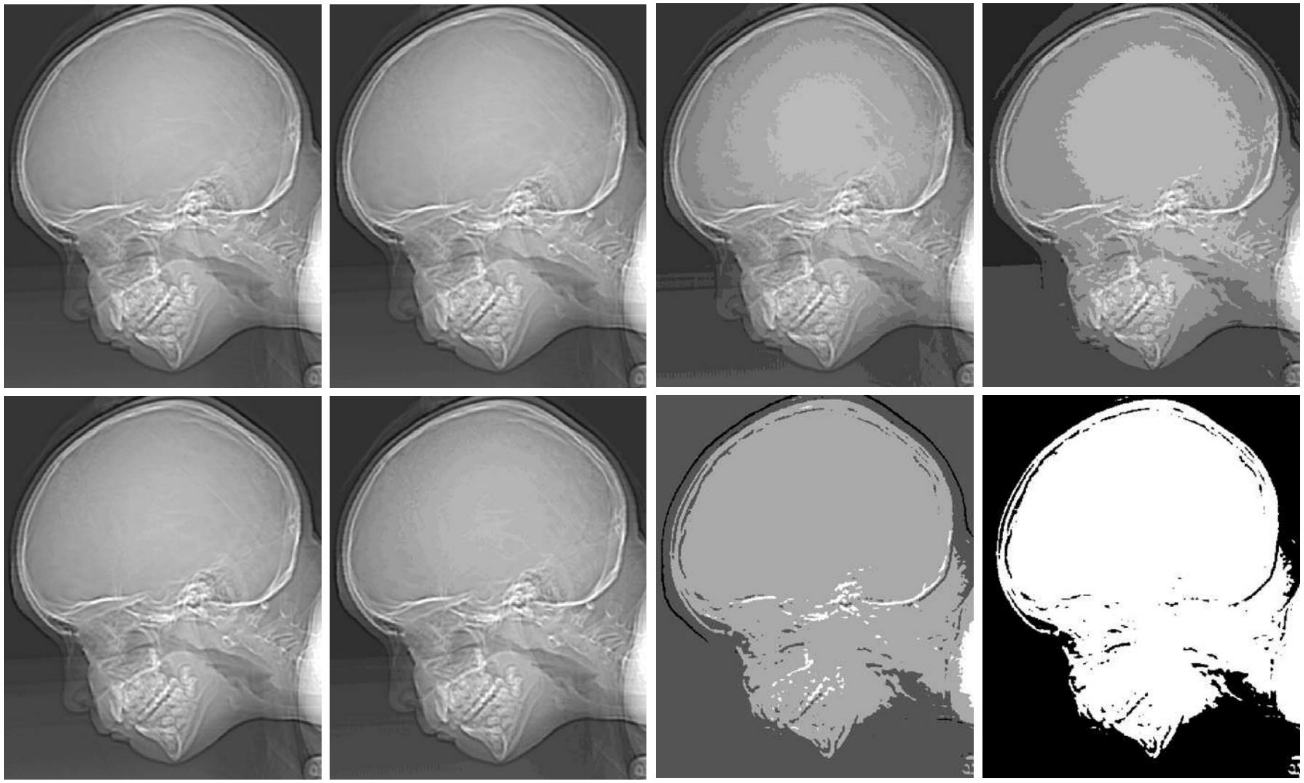


Image Sampling and Quantization

Image Interpolation – zoom, shrink, rotation etc.

- Zooming and shrinking image (resampling)

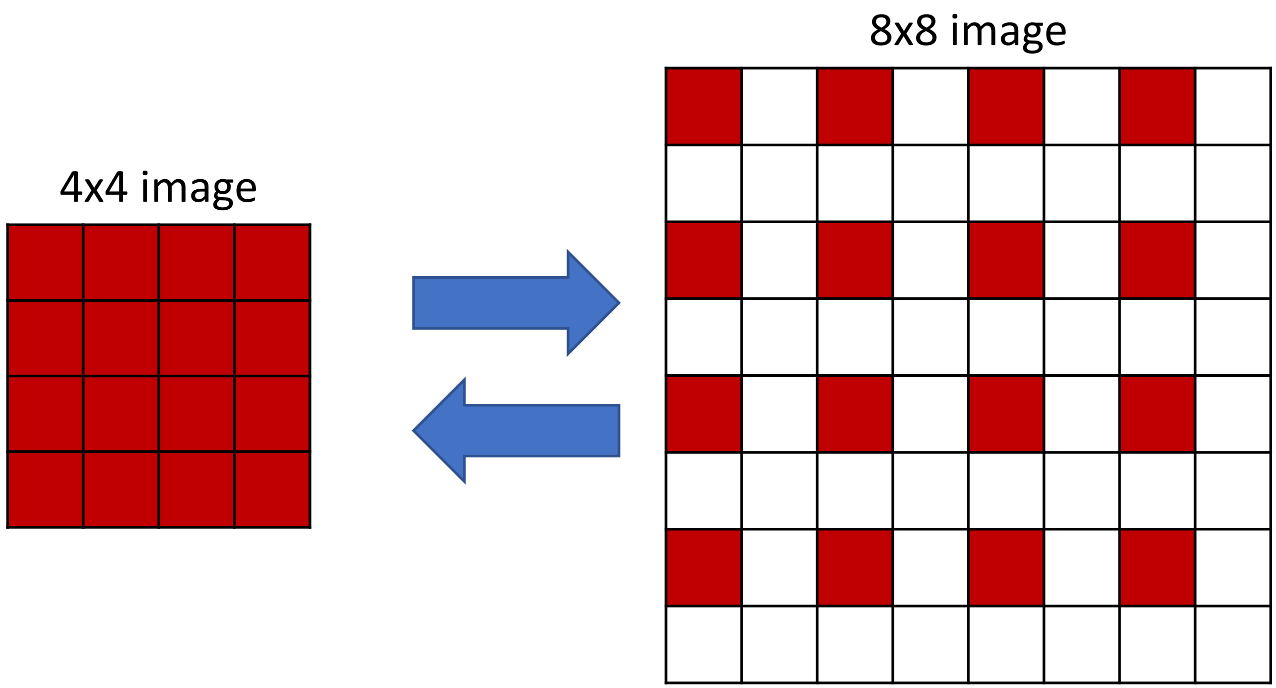
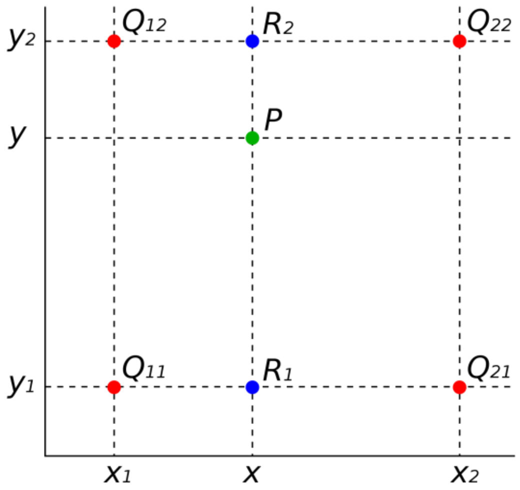


Image Sampling and Quantization

Image Interpolation – zoom, shrink, rotation etc.

- Fundamentally, interpolation is the process of using known data to estimate values at unknown locations



- Nearest neighbor

it assigns to each new location the intensity of its nearest neighbor in the original image

- Bilinear

Linearly estimate new location's intensity (1차식)
Using 4 neighbor points

$$v(x, y) = ax + by + cxy + d$$

- Bicubic

2차식
Using 6 neighbor point

$$v(x, y) = \sum_{i=0}^{3} \sum_{j=0}^{3} a_{ij} x^i y^j$$

Image Sampling and Quantization

Image Interpolation – zoom, shrink, rotation etc.

- Fundamentally, interpolation is the process of using known data to estimate values at unknown locations

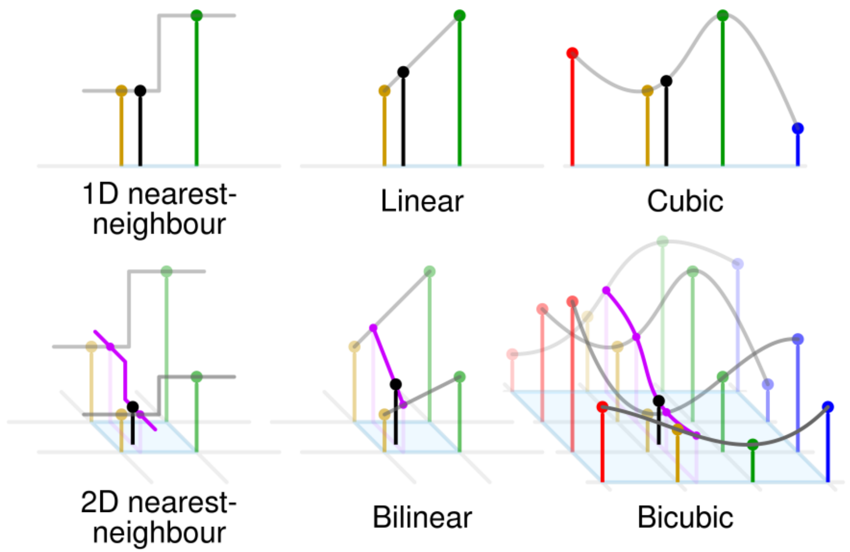
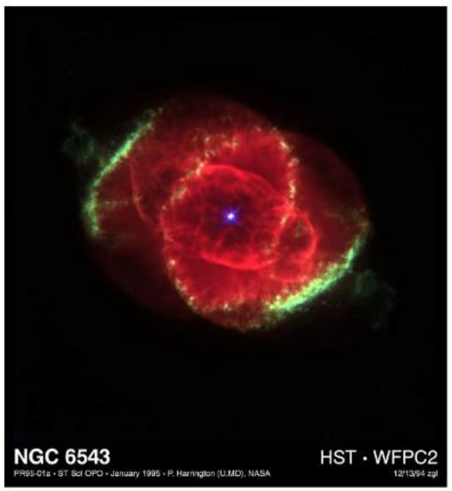


Image Sampling and Quantization

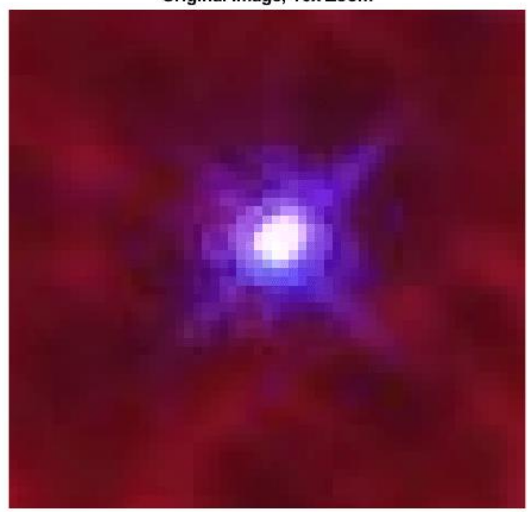
Image Interpolation – zoom, shrink, rotation etc.

- Fundamentally, interpolation is the process of using known data to estimate values at unknown locations

Lower Resolution



Original Image, 10x Zoom



Linear method

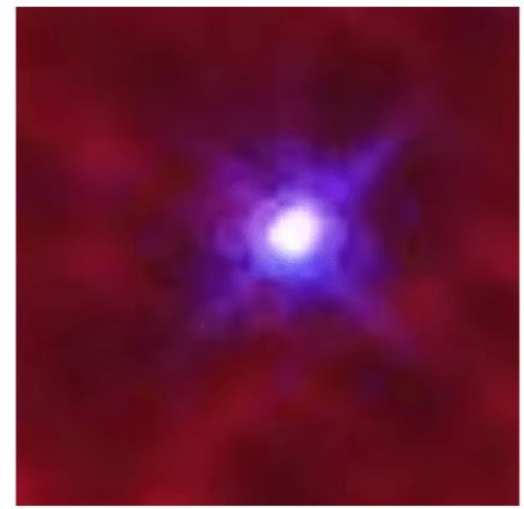
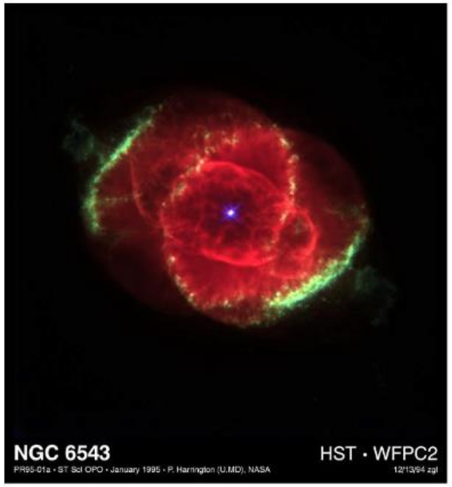


Image Sampling and Quantization

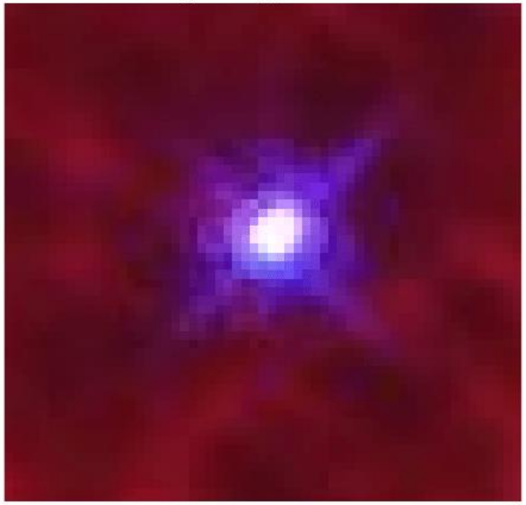
Image Interpolation – zoom, shrink, rotation etc.

- Fundamentally, interpolation is the process of using known data to estimate values at unknown locations

Lower Resolution



Original Image, 10x Zoom

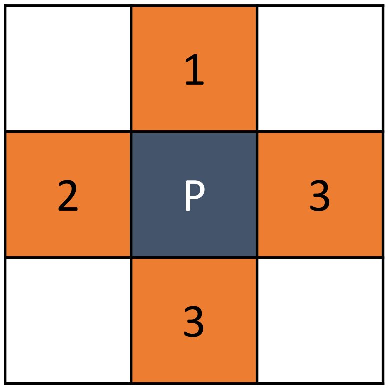


Cubic method

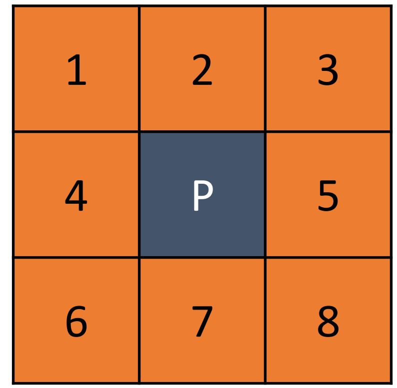
Image Sampling and Quantization

Neighbor of a Pixel

4-Neighbor



8-Neighbor



$N_4(p)=\{(i-1,j),(i+1,j),(i,j-1),(i,j+1)\}$

$N_8(p)=\{(i-1,j),(i+1,j),(i,j-1),(i,j+1),(i-1,j-1),(i-1,j+1),(i+1,j-1),(i+1,j+1)\}$

<u>Adjacency</u>

4-adjacency: p,q are 4-adjacent if p is in the set $N_4(q)$

8-adjacency: p,q are 8-adjacent if p is in the set $N_8(q)$

Note that if p is in $N_{4/8}(q)$, then q must be also in $N_{4/8}(p)$