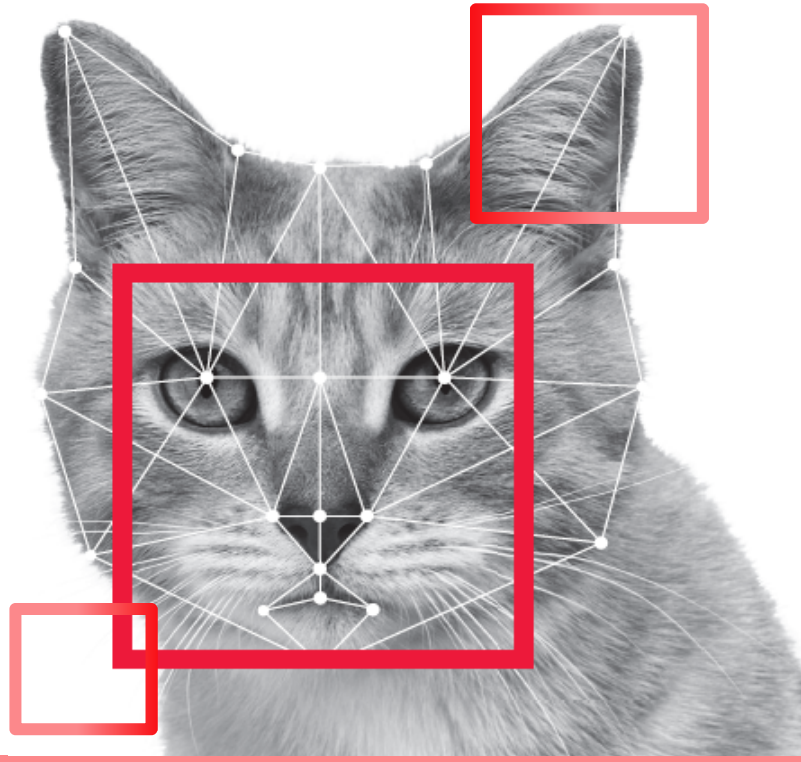
한빛아카데미 Hanbit Academy, Inc.

COMPUTER VISION 컴퓨터 비전

기본 개념부터 최신 모바일 응용 예까지



2장. 영상 처리

각 절에서 다루는 내용

1. 디지털 영상이란?
2. 히스토그램
3. 이진 영상
4. 영상 처리의 세 가지 기본 연산
5. 다해상도
6. 모폴로지
7. 컬러

PREVIEW

- Eye and Camera
- Image formation
- Camera model
  - Pinhole camera model
  - Perspective projections
  - Focal length and filed of view

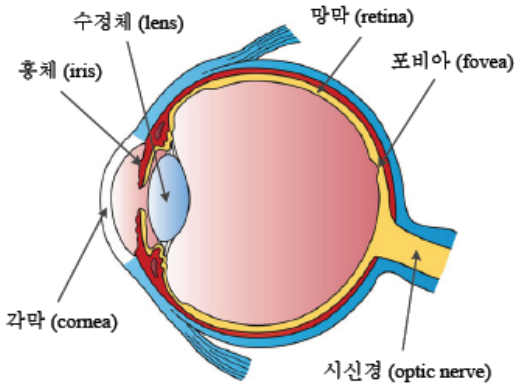
2.1 디지털 영상이란?

2.1.1 디지털 영상의 태동

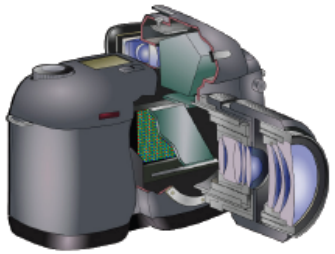
2.1.2 획득과 표현

2.1.2 획득과 표현

- 사람의 눈과 카메라
  - 수정체는 렌즈, 망막은 CCD 센서 (필름)에 해당

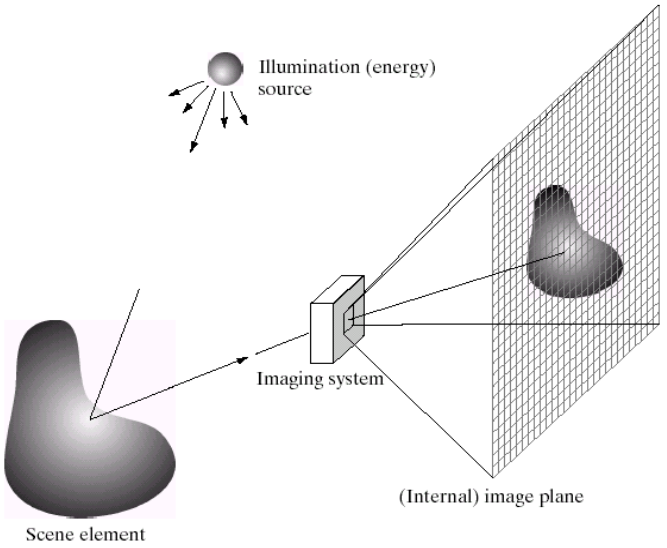


(a) 사람의 눈 구조

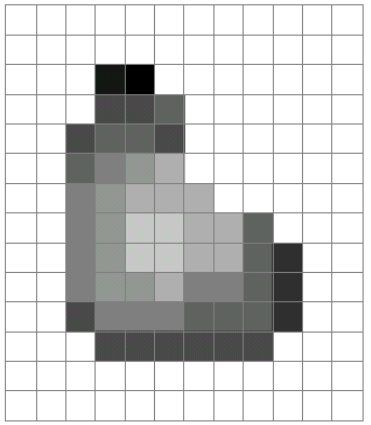


(b) 카메라의 구조

그림 2-3 사람의 눈과 카메라의 구조



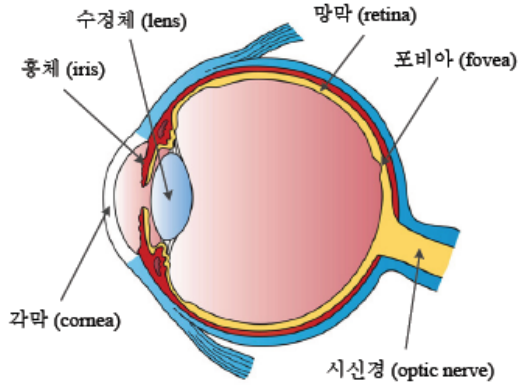
Film



Digital Camera

2.1.2 획득과 표현

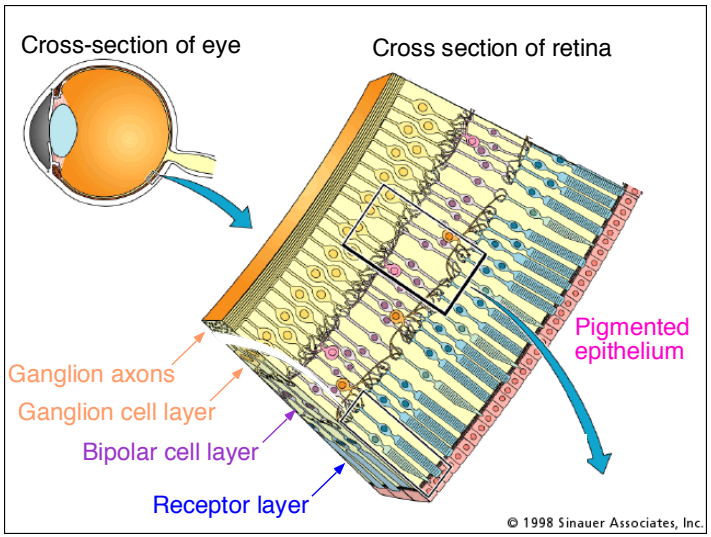
- The Eye



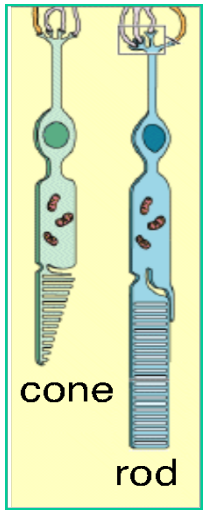
(a) 사람의 눈 구조

그림 2-3 사람의 눈과 카메라의 구조

망막(Retina)



Light

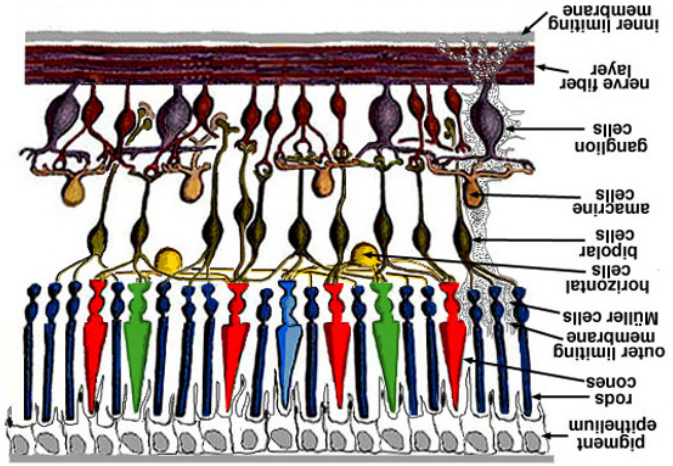


Cones

cone-shaped less sensitive
operate in high light
color vision

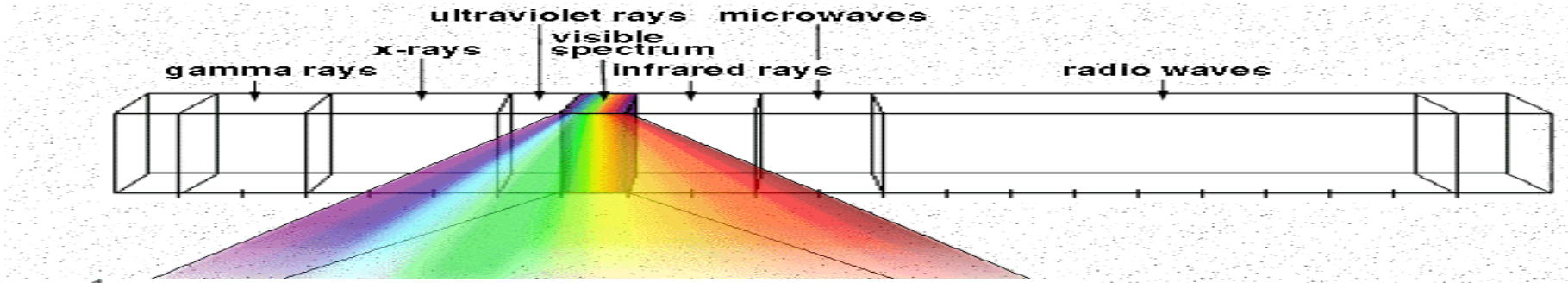
Rods

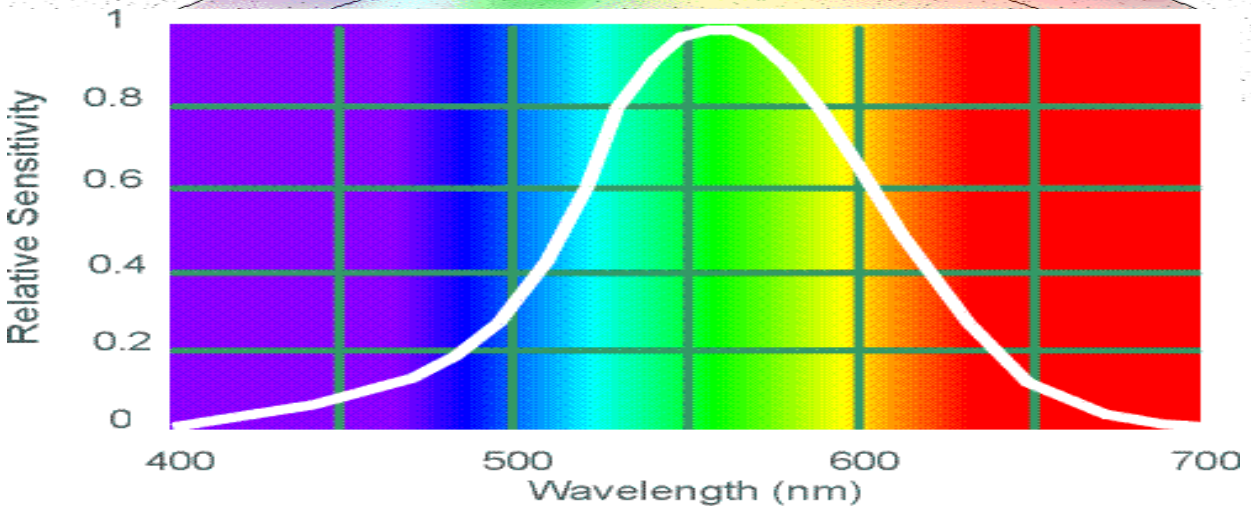
rod-shaped highly sensitive
operate at night gray-scale vision



2.1.2 획득과 표현

- Electromagnetic spectrum

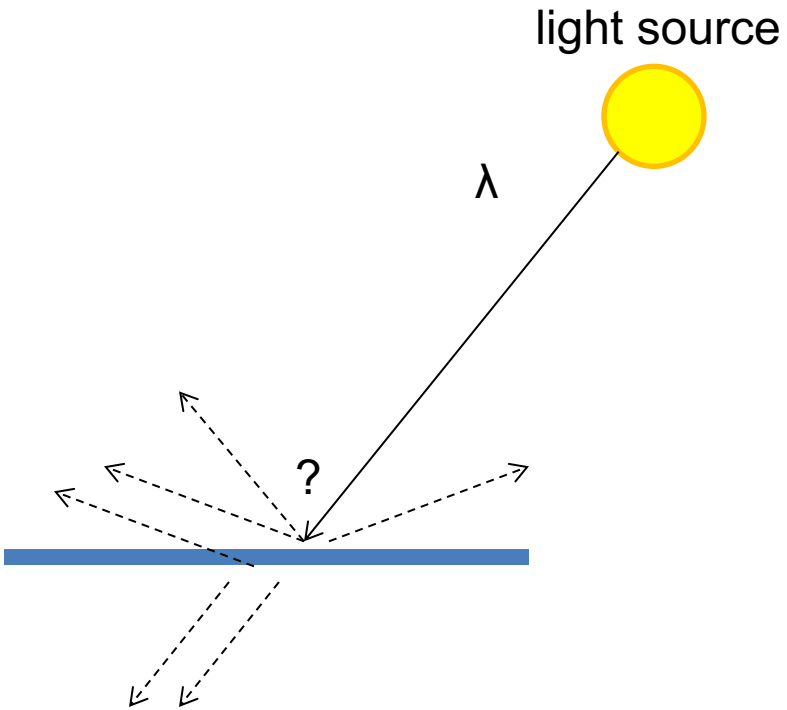




Human Luminance Sensitivity Function

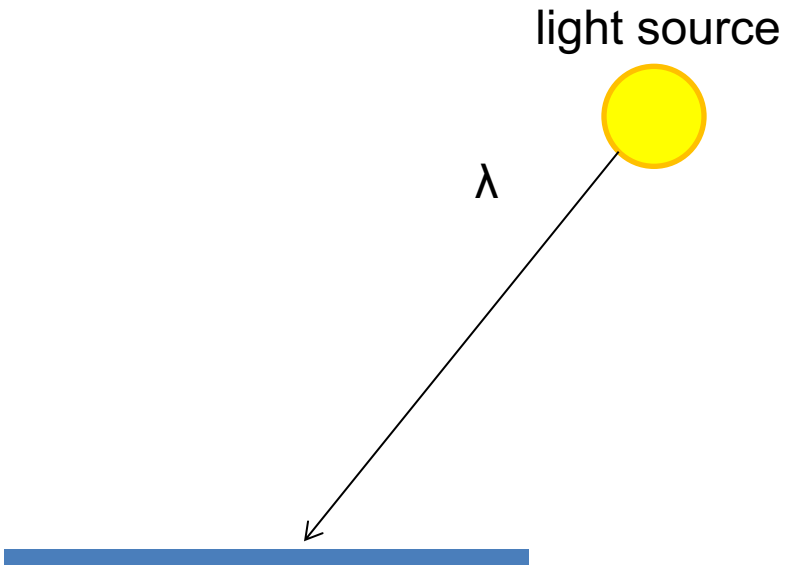
A photon's life choices

- Absorption
- Diffusion
- Reflection
- Transparency
- Refraction
- Fluorescence
- Subsurface scattering
- Phosphorescence
- Interreflection



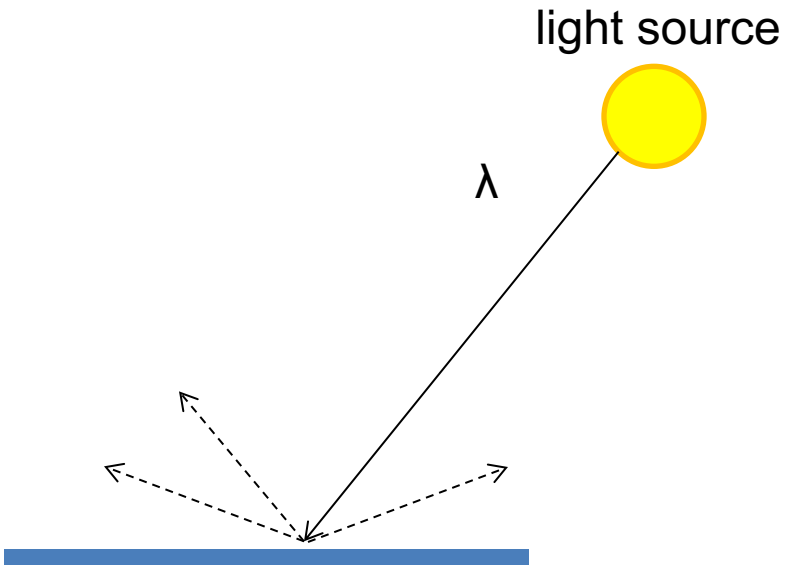
A photon's life choices

- **Absorption**
- Diffusion
- Reflection
- Transparency
- Refraction
- Fluorescence
- Subsurface scattering
- Phosphorescence
- Interreflection



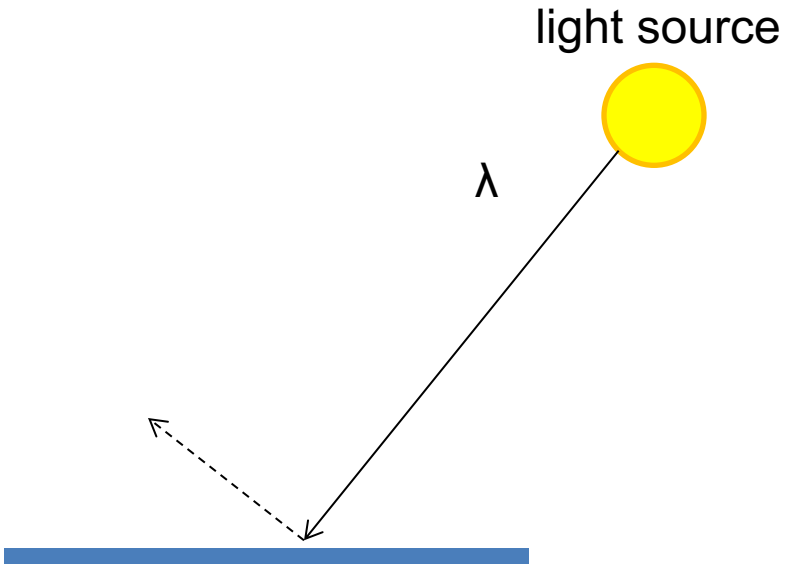
A photon's life choices

- Absorption
- **Diffuse Reflection**
- Reflection
- Transparency
- Refraction
- Fluorescence
- Subsurface scattering
- Phosphorescence
- Interreflection



A photon's life choices

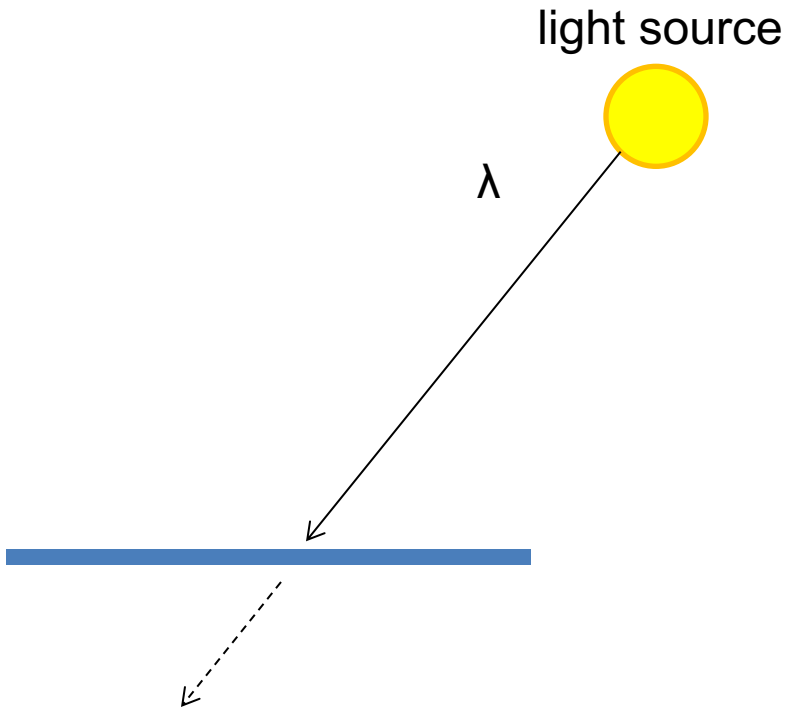
- Absorption
- Diffusion
- **Specular Reflection**
- Transparency
- Refraction
- Fluorescence
- Subsurface scattering
- Phosphorescence
- Interreflection



카메라의 색상은 여기에 해당

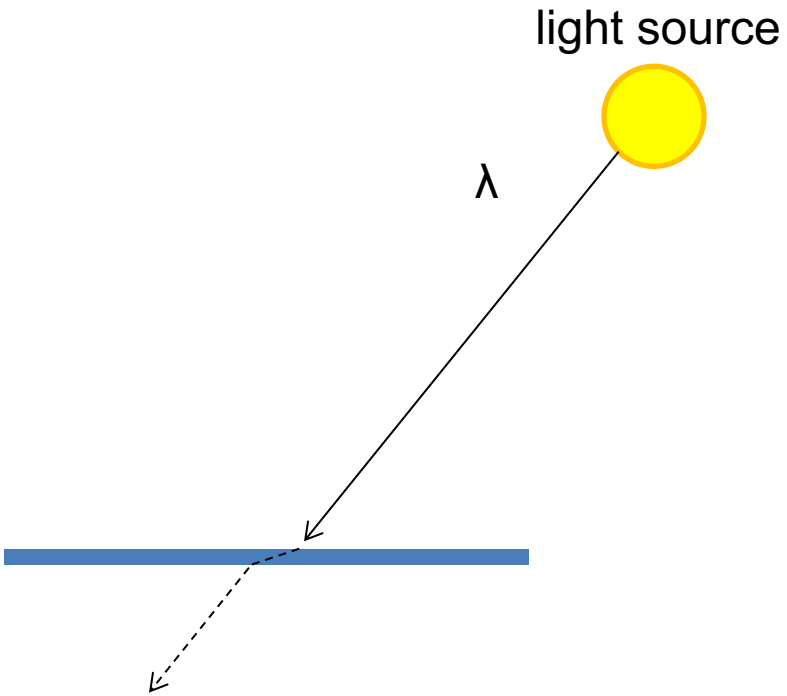
A photon's life choices

- Absorption
- Diffusion
- Reflection
- **Transparency**
- Refraction
- Fluorescence
- Subsurface scattering
- Phosphorescence
- Interreflection



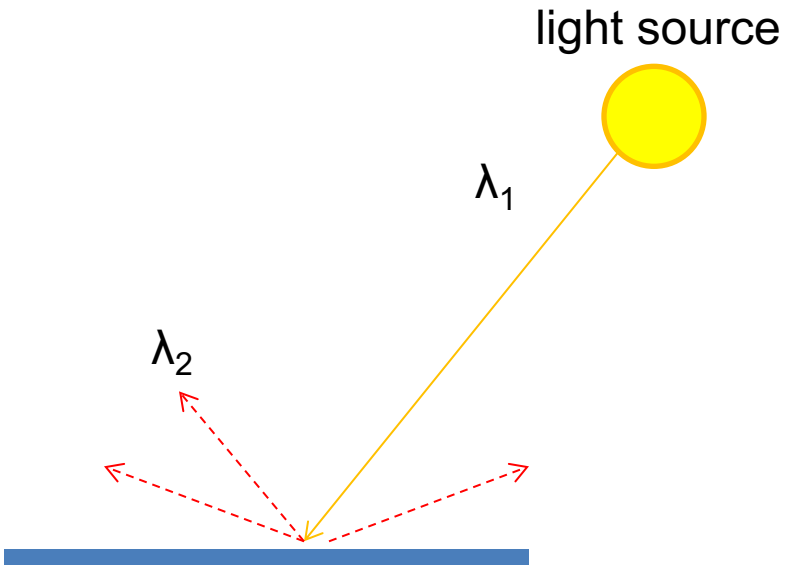
A photon's life choices

- Absorption
- Diffusion
- Reflection
- Transparency
- **Refraction**
- Fluorescence
- Subsurface scattering
- Phosphorescence
- Interreflection



A photon's life choices

- Absorption
- Diffusion
- Reflection
- Transparency
- Refraction
- **Fluorescence**
- Subsurface scattering
- Phosphorescence
- Interreflection



A photon's life choices

- Absorption
- Diffusion
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- Fluorescence
- **Subsurface scattering**
- Phosphorescence
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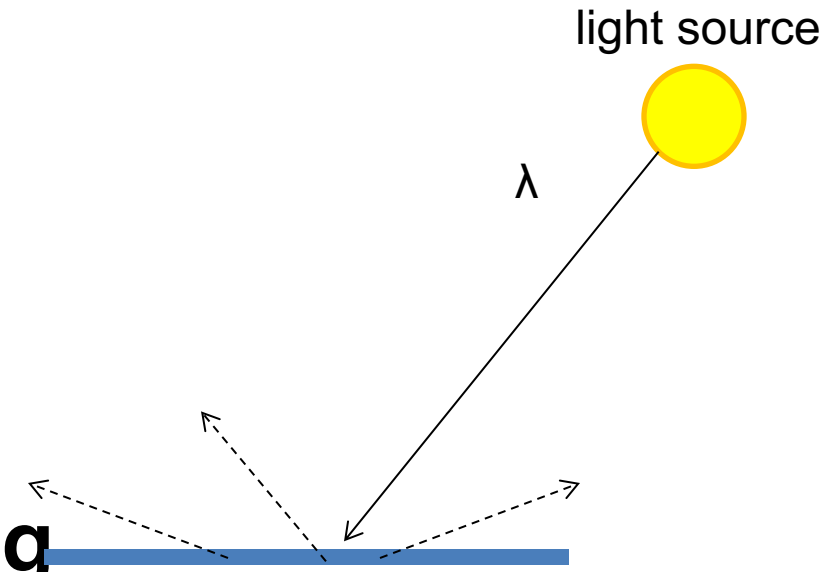

A photon's life choices

- Absorption
- Diffusion
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- Transparency
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- Fluorescence
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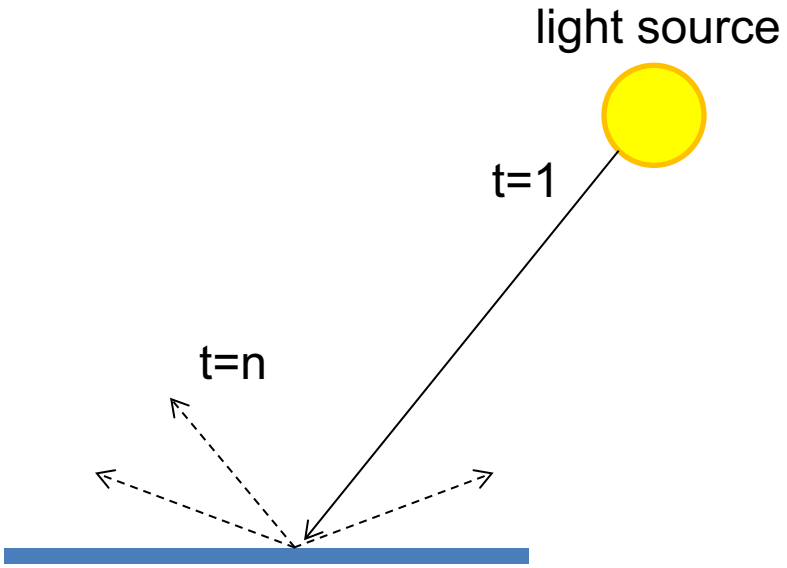
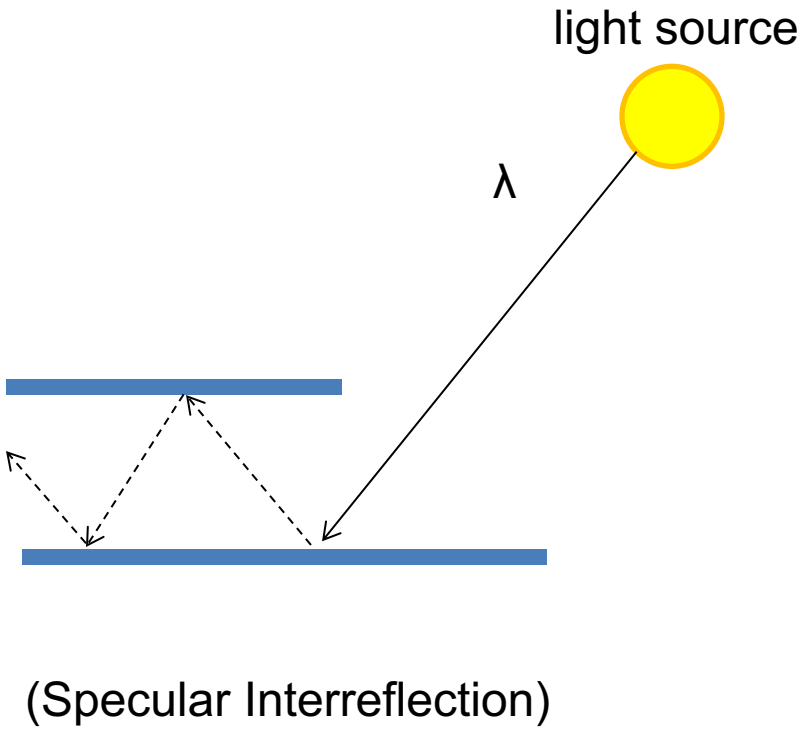
- **Phosphorescence**
- Interreflection



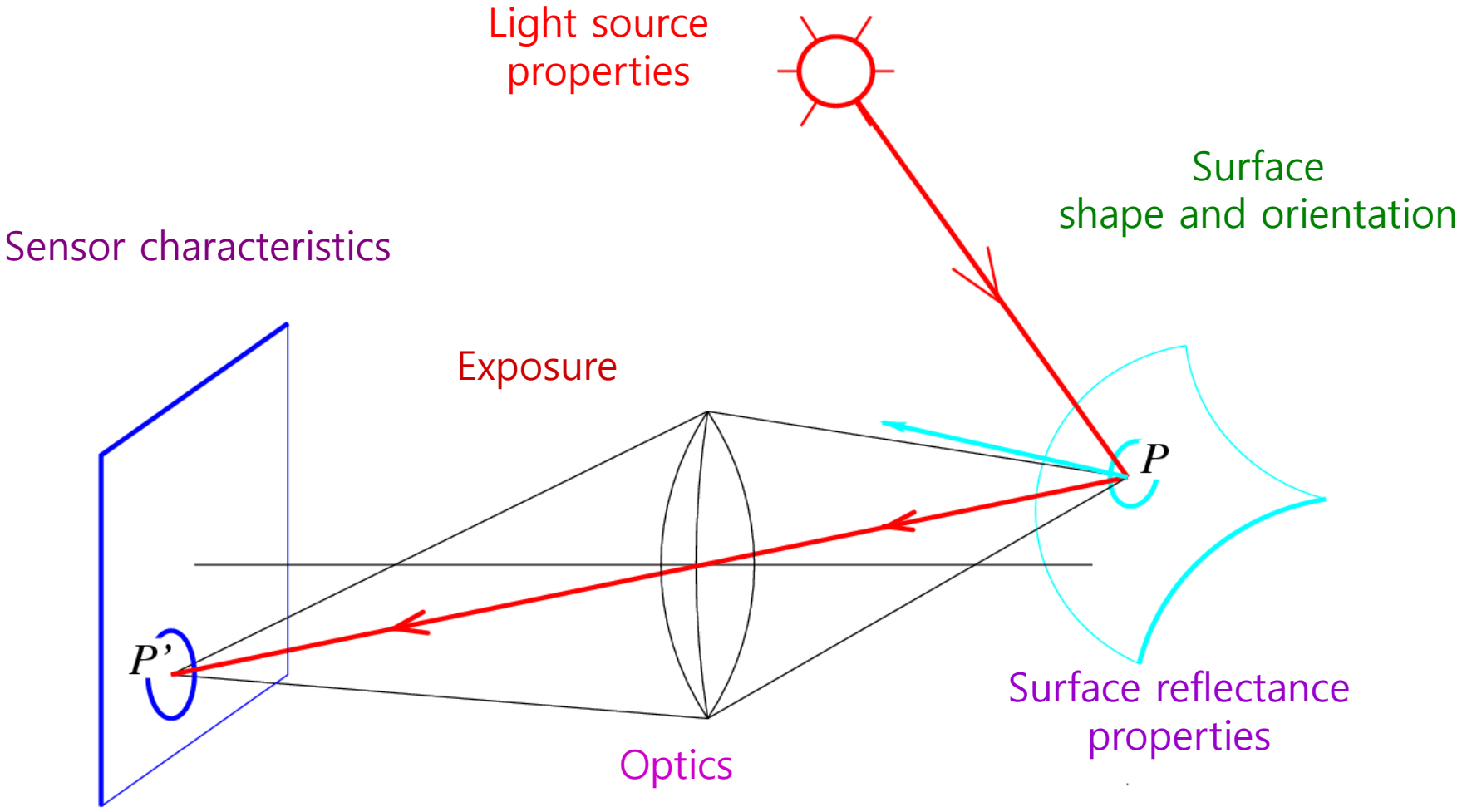
A photon's life choices

- Absorption
- Diffusion
- Reflection
- Transparency
- Refraction
- Fluorescence
- Subsurface scattering
- Phosphorescence
- **Interreflection**



2.1.2 획득과 표현

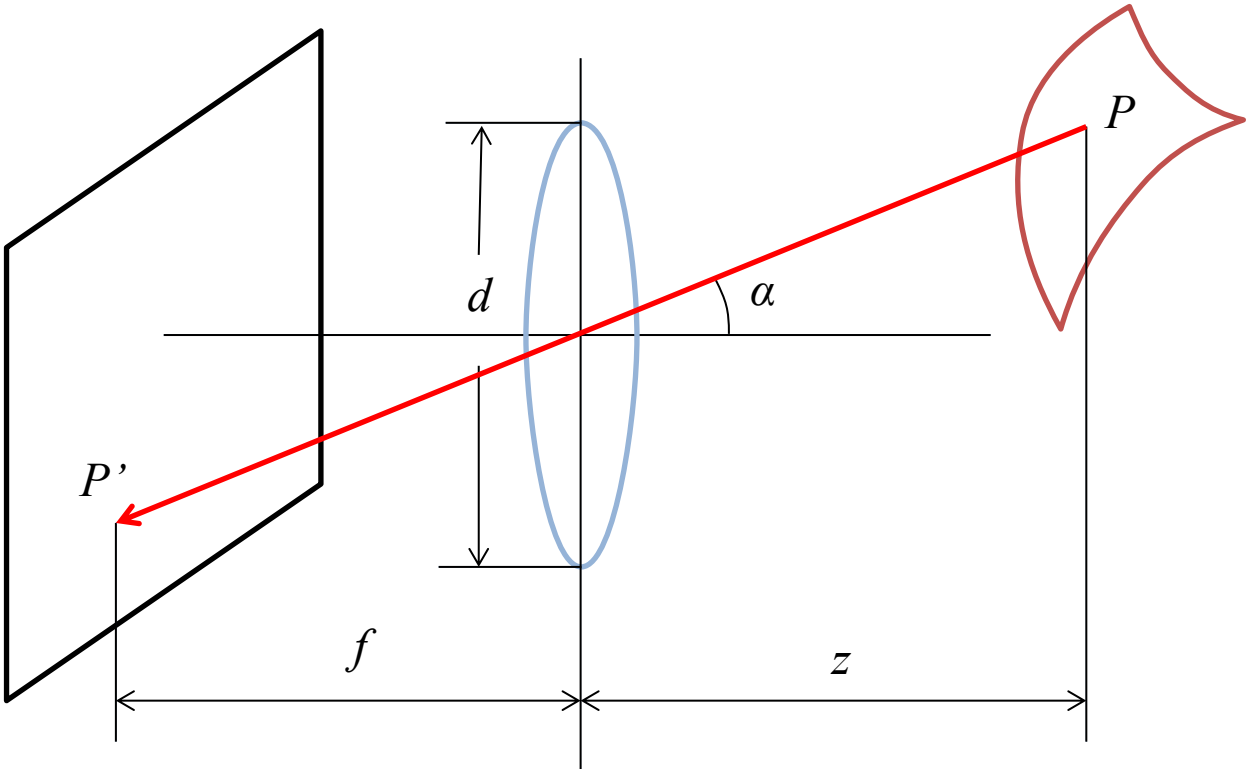
- Image formation



Slide by L. Fei-Fei

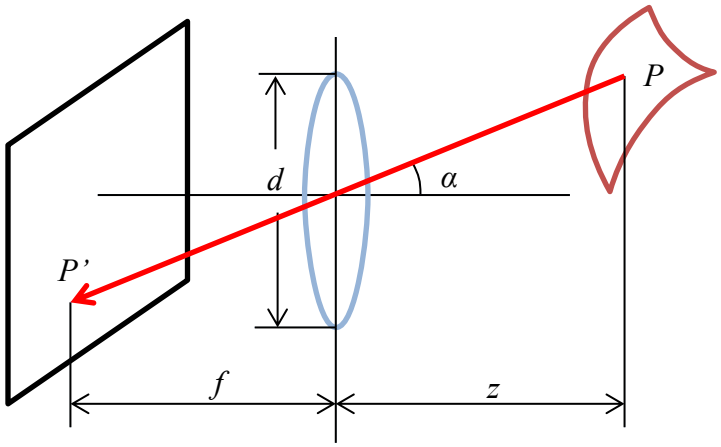
Fundamental radiometric relation

- *L*: Radiance emitted from *P* toward *P'*
- *E*: Irradiance falling on *P'* from the lens



What is the relationship between *E* and *L*?

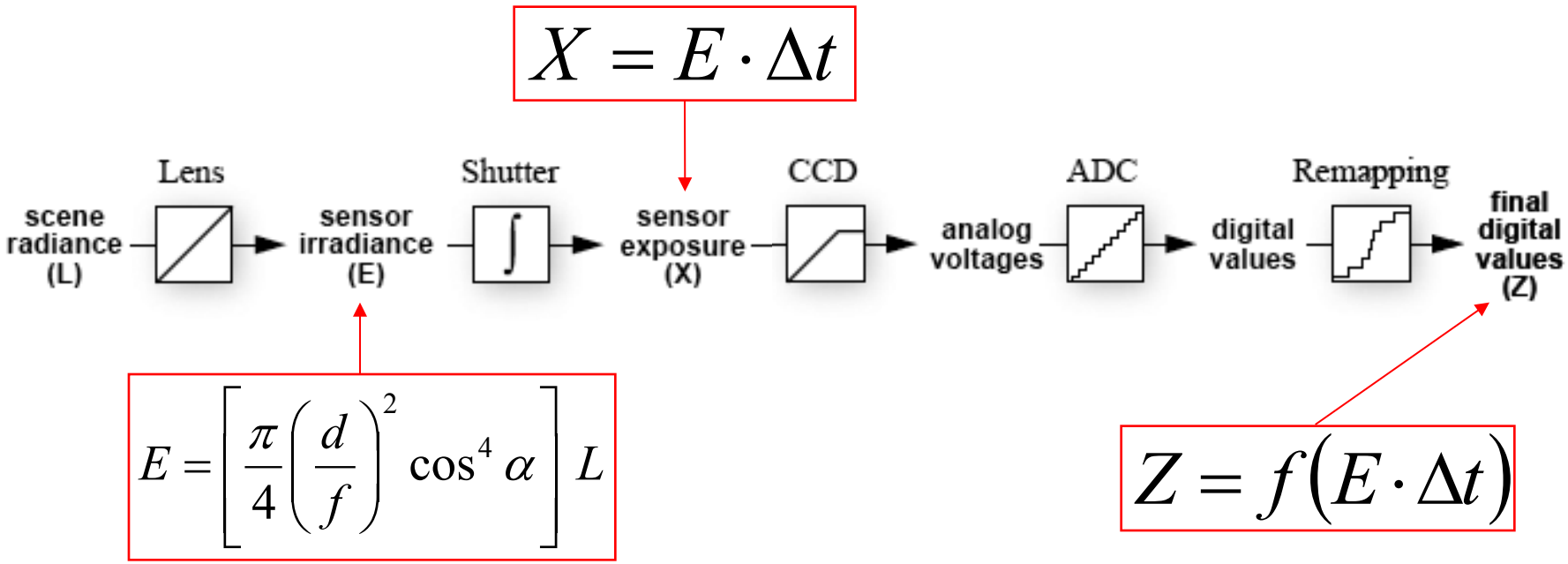
Fundamental radiometric relation



$$E = \left[\frac{\pi}{4} \left(\frac{d}{f} \right)^2 \cos^4 \alpha \right] L$$

- Image irradiance is linearly related to scene radiance
- Irradiance is proportional to the area of the lens and inversely proportional to the squared distance between the lens and the image plane
- The irradiance falls off as the angle between the viewing ray and the optical axis increases

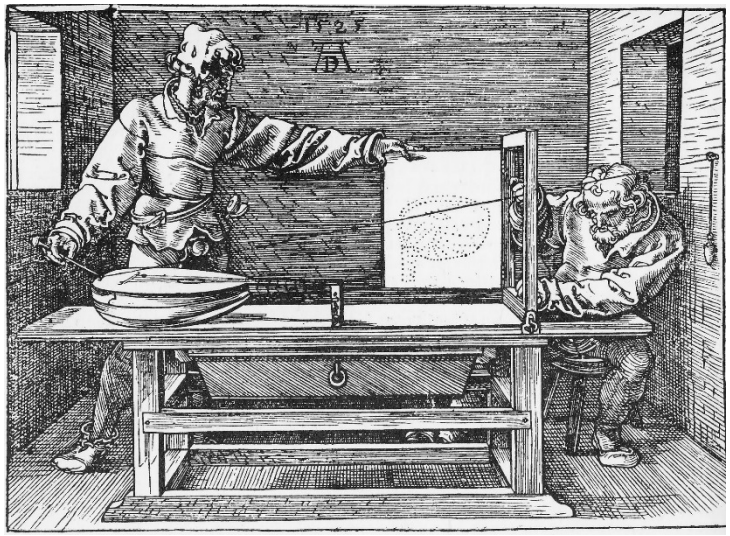
From light rays to pixel values

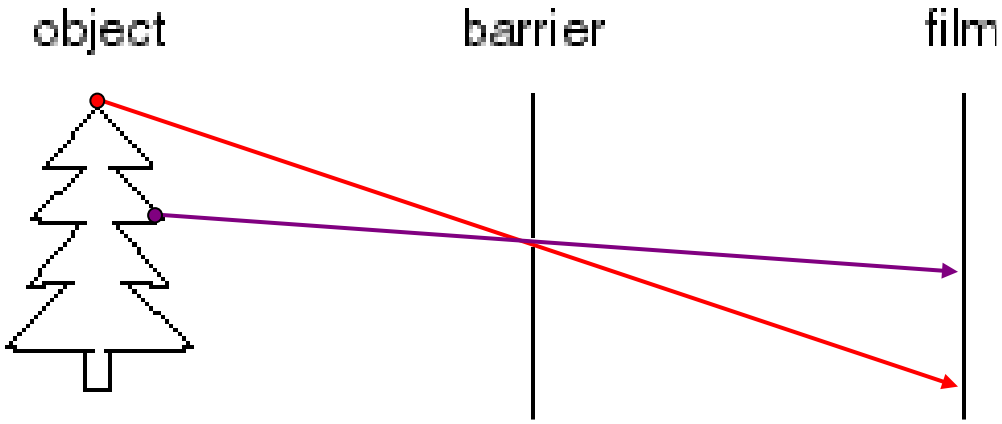


- Camera response function: the mapping f from irradiance to pixel values
  - Useful if we want to estimate material properties
  - Enables us to create high dynamic range images
  - For more info: P. E. Debevec and J. Malik, *Recovering High Dynamic Range Radiance Maps from Photographs*, SIGGRAPH 97

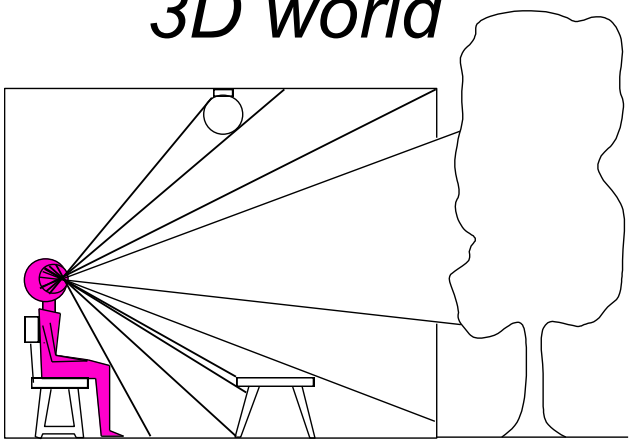
2.1.2 획득과 표현

- Perspective projection



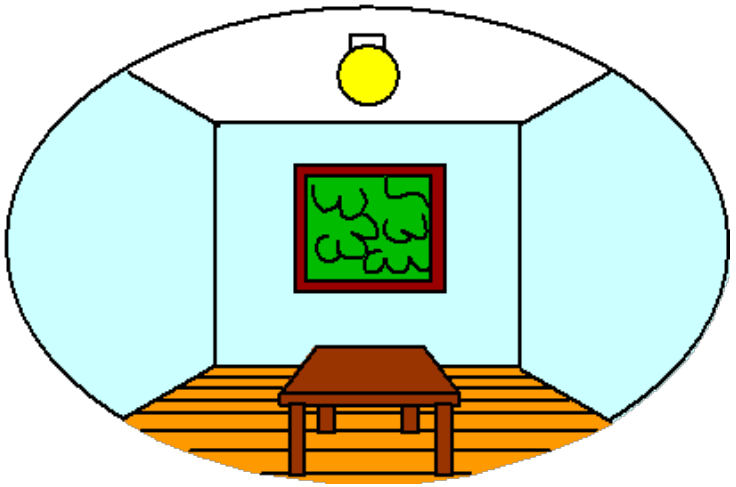


3D world



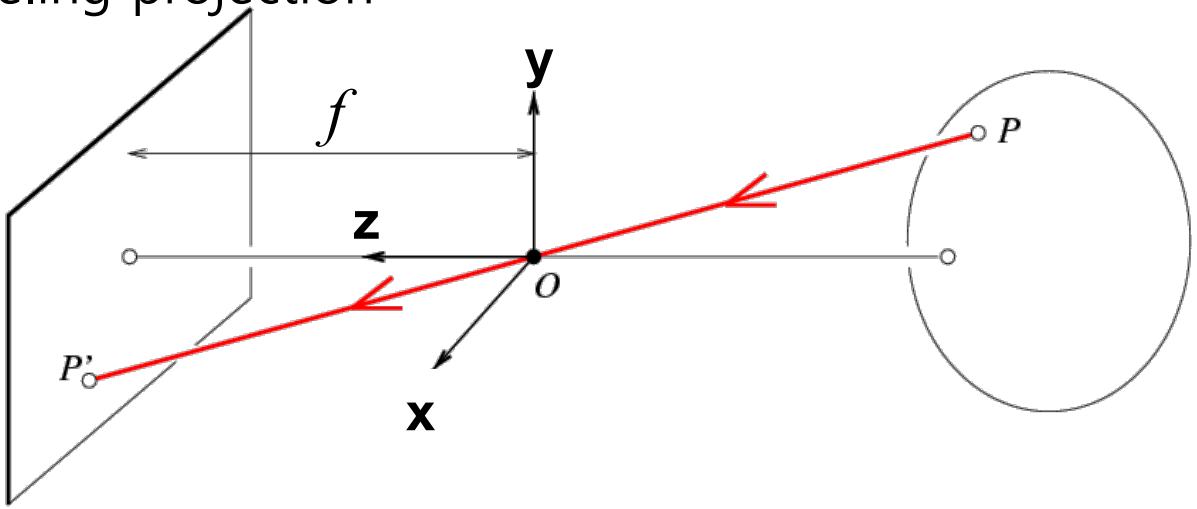
Point of observation

2D image



2.1.2 획득과 표현

- Modeling projection



  - 3차원 공간상에서의 P는 2차원 영상 평명(image plane)에서 P′으로 투영됨
  - P와 P′의 상관관계를 나타낼 수 있는 방법 필요
    - Optical center (**O**) 가 3차원 공간상의 원점
    - Projection equations

$$(x, y, z) \rightarrow (f\frac{x}{z}, f\frac{y}{z})$$

2.1.2 획득과 표현

- Perspective projection matrix

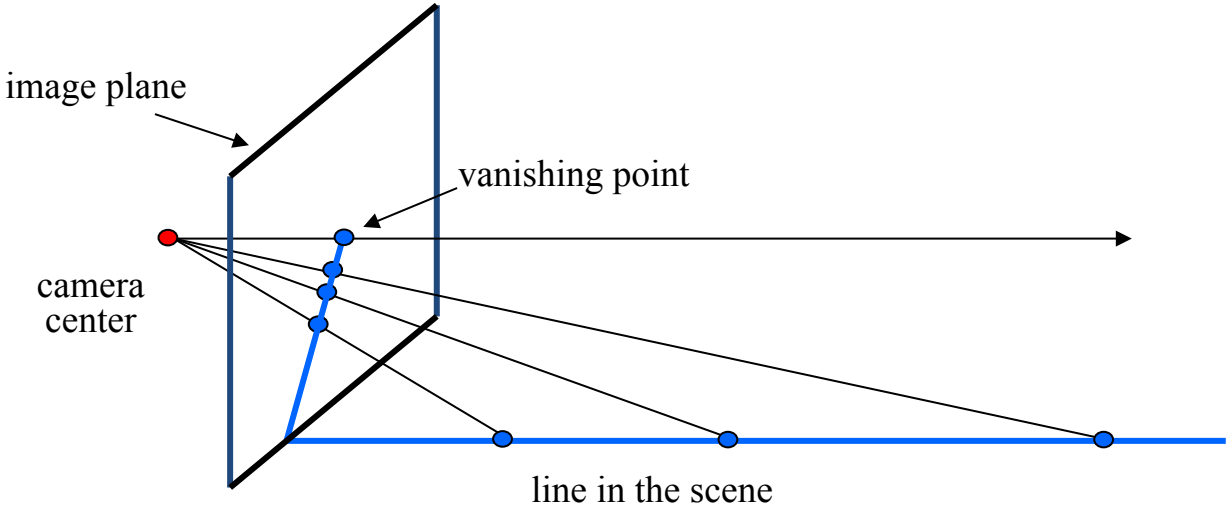
$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1/f & 0 \end{bmatrix} \begin{bmatrix} x \\ y \\ z \\ 1 \end{bmatrix} = \begin{bmatrix} x \\ y \\ z/f \end{bmatrix} \Rightarrow \left(f\frac{x}{z}, f\frac{y}{z}\right)$$

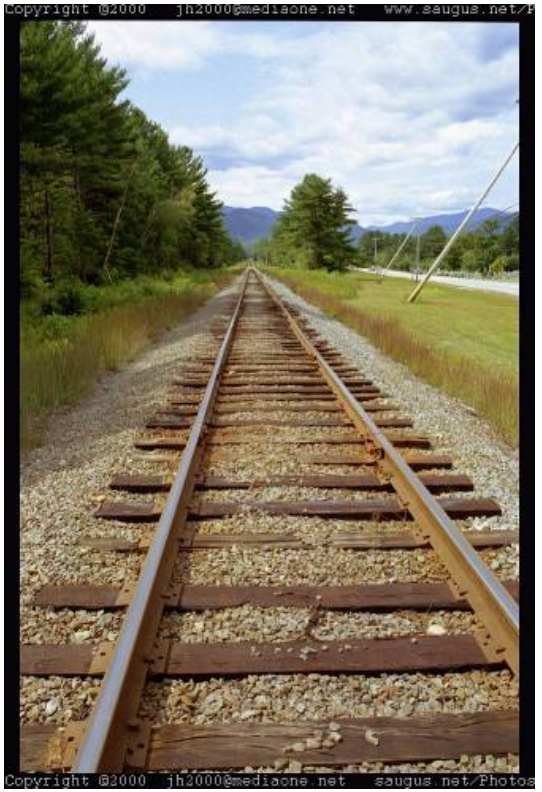
divide by the third co ordinate

$$\begin{pmatrix} \text{2D point (3x1)} \end{pmatrix} = \begin{pmatrix} \text{Camera to pixel coord. trans. matrix (3x3)} \end{pmatrix} \begin{pmatrix} \text{Perspective projection matrix (3x4)} \end{pmatrix} \begin{pmatrix} \text{World to camera coord. trans. matrix (4x4)} \end{pmatrix} \begin{pmatrix} \text{3D point (4x1)} \end{pmatrix}$$

2.1.2 획득과 표현

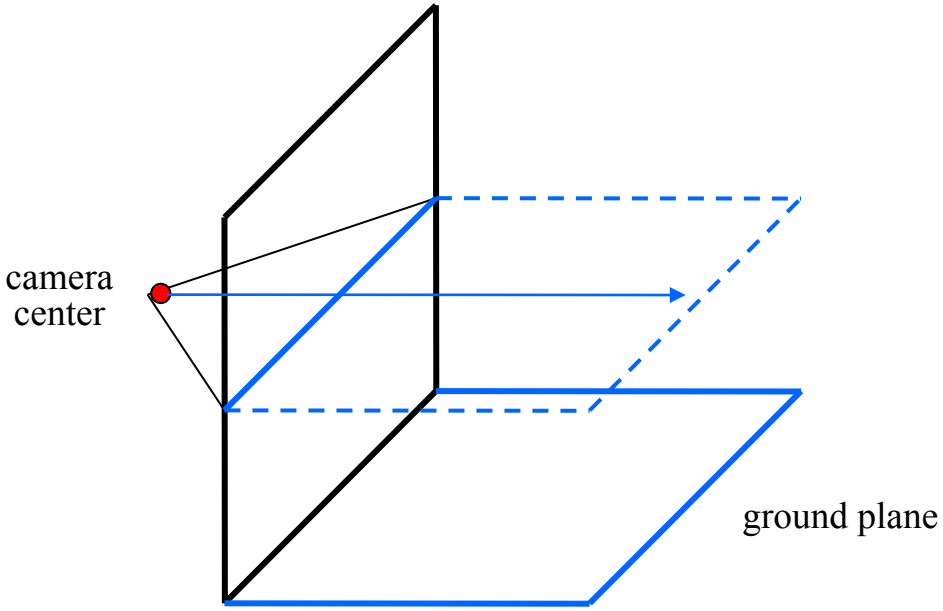
- Projection of a line





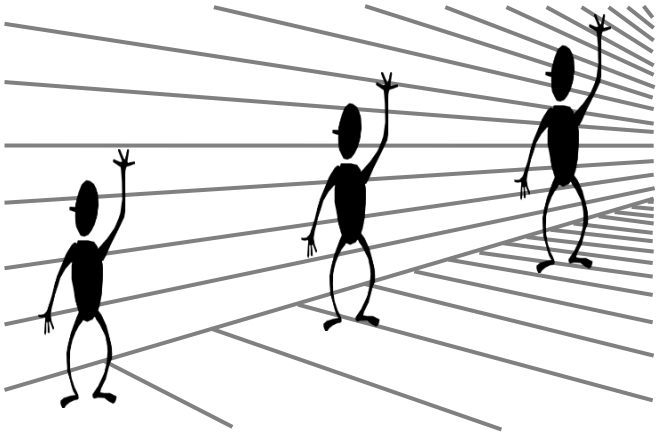
2.1.2 획득과 표현

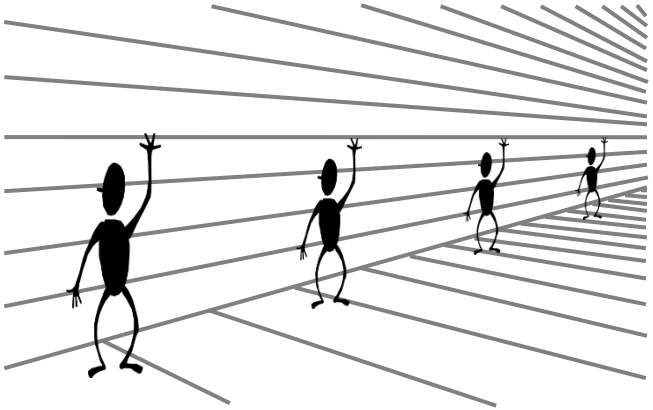
- The horizon

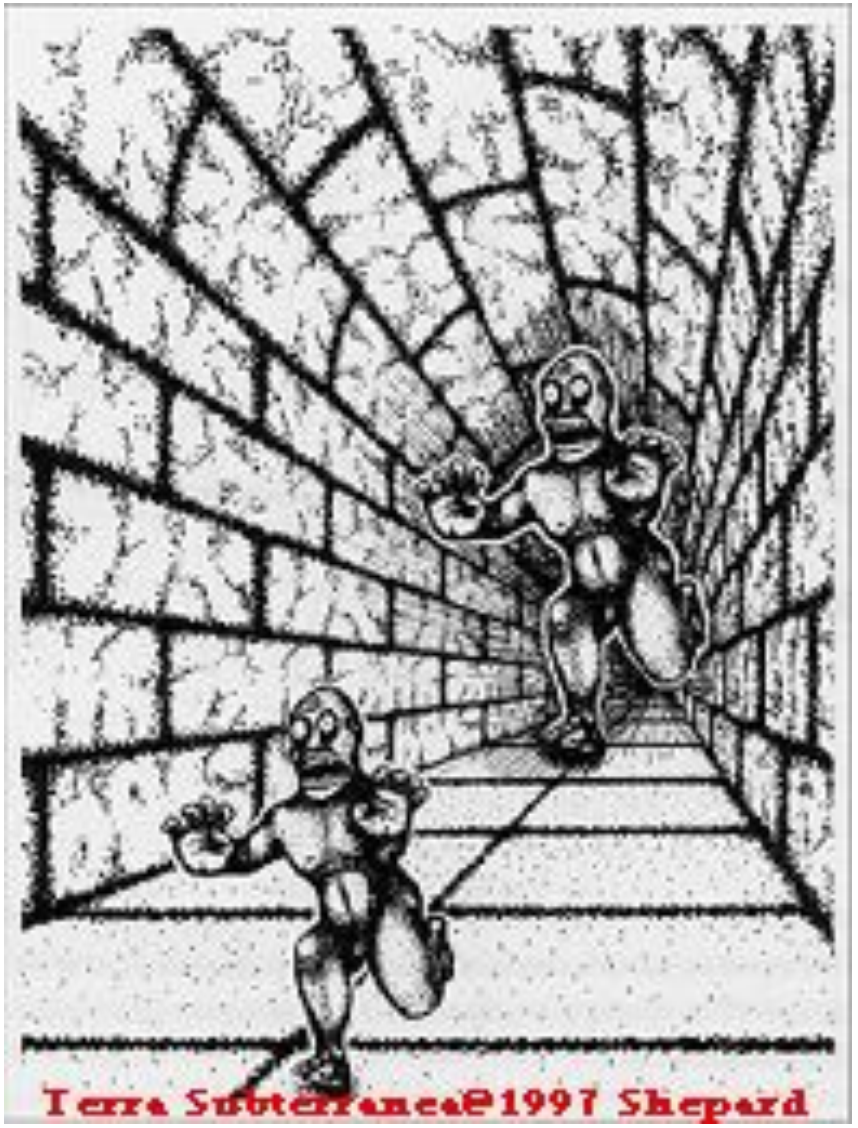


2.1.2 획득과 표현

- The perspective cues



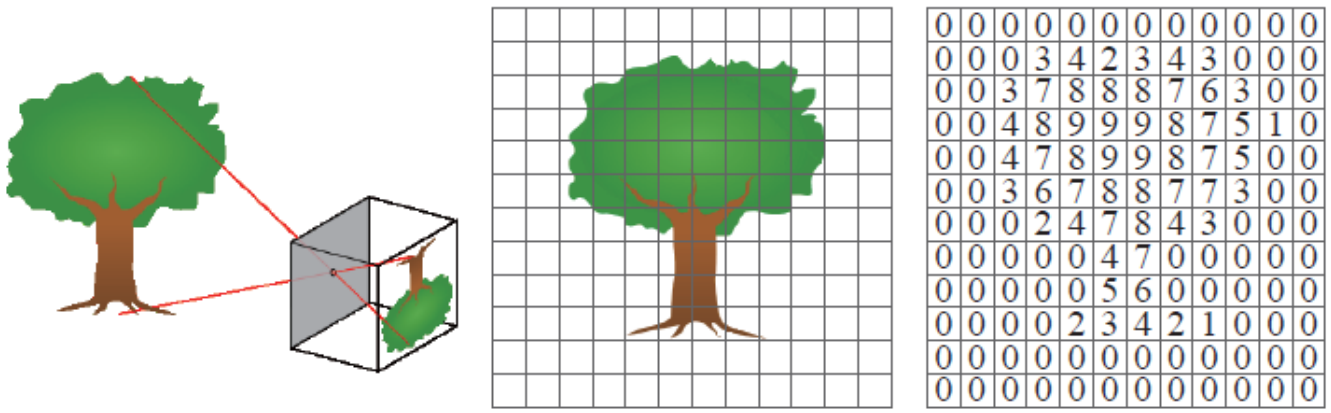




2.1.2 획득과 표현

샘플링과 양자화

- 2차원 영상 공간을 *M***N*으로 샘플링 (*M***N*을 해상도라 부름)
- 명암을 *L* 단계로 양자화 (*L*을 명암 단계라 부름, 즉 명암은 [0,*L*-1] 사이 분포)
- 아래 예) *M*=12, *N*=12, *L*=10인 경우



0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	3	4	2	3	4	3	0	0	0
0	0	3	7	8	8	8	7	6	3	0	0
0	0	4	8	9	9	9	8	7	5	1	0
0	0	4	7	8	9	9	8	7	5	0	0
0	0	3	6	7	8	8	7	7	3	0	0
0	0	0	2	4	7	8	4	3	0	0	0
0	0	0	0	0	4	7	0	0	0	0	0
0	0	0	0	0	5	6	0	0	0	0	0
0	0	0	0	2	3	4	2	1	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0

(a) 핀홀 카메라 모델 (b) 샘플링과 양자화 (c) 디지털 영상

그림 2-4 디지털 영상 획득

2.1.2 획득과 표현

- 영상 좌표계
  - 화소 위치는 **x**=(*j*,*i*) 또는 **x**=(*y*,*x*)로 표기
  - 영상은 *f*(**x**) 또는 *f*(*j*,*i*), 0≤*j*≤*M*-1, 0≤*j*≤*N*-1로 표기

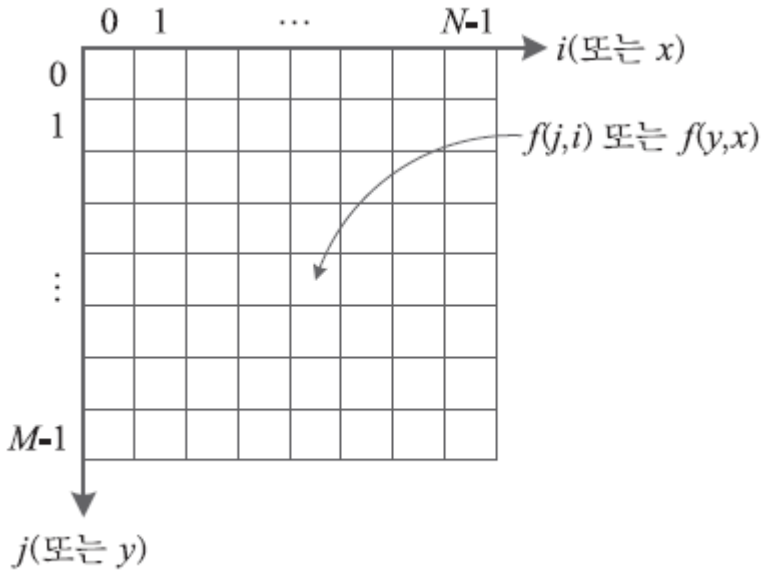
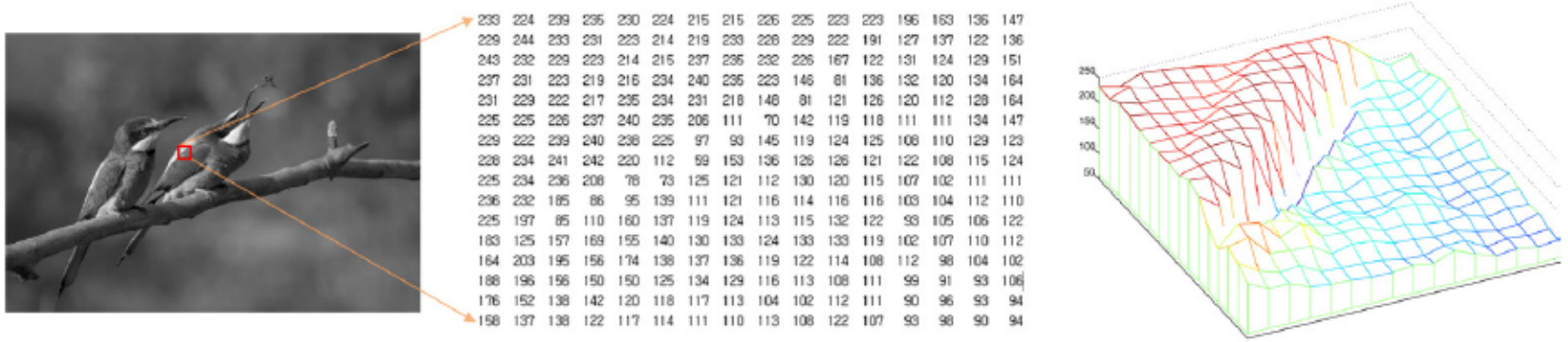


그림 2-5 디지털 영상의 좌표계

- 컬러 영상은 fr(x), fg(x), fb(x)의 세 채널로 구성

2.1.2 획득과 표현

- 영상 표시 방법



(a) 영상 (b) 숫자 배열 (c) 지형

그림 2-6 디지털 영상 표시 방법