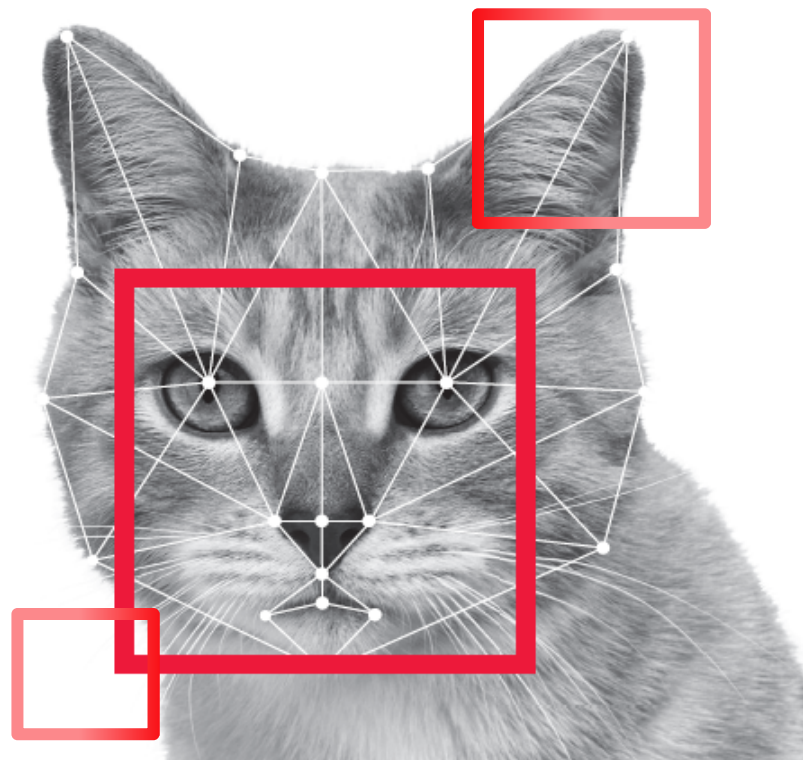


COMPUTER VISION 컴퓨터 비전

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 field of view

2.1 디지털 영상이란?

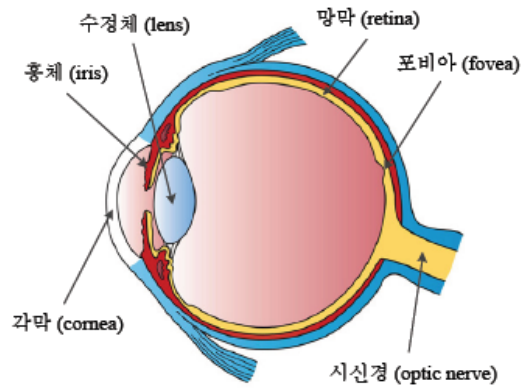
2.1.1 디지털 영상의 태동

2.1.2 획득과 표현

2.1.2 획득과 표현

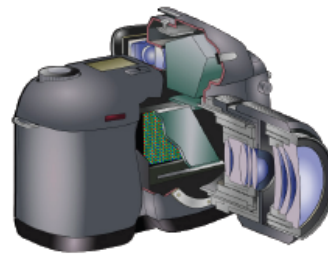
■ 사람의 눈과 카메라

- 수정체는 렌즈, 망막은 CCD 센서 (필름)에 해당

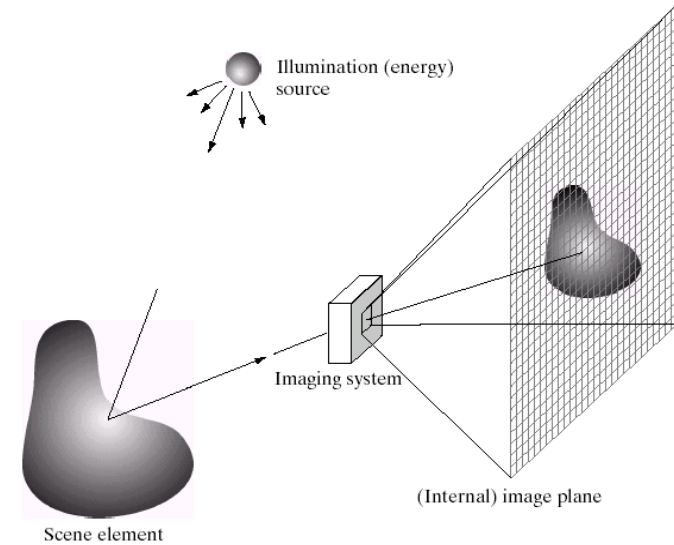


(a) 사람의 눈 구조

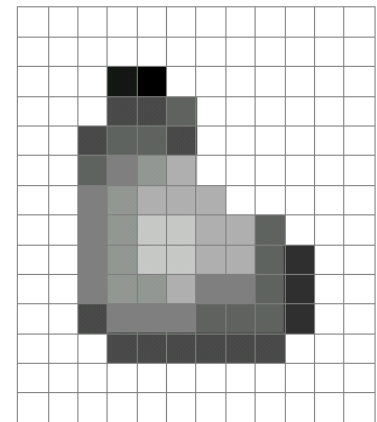
그림 2-3 사람의 눈과 카메라의 구조



(b) 카메라의 구조



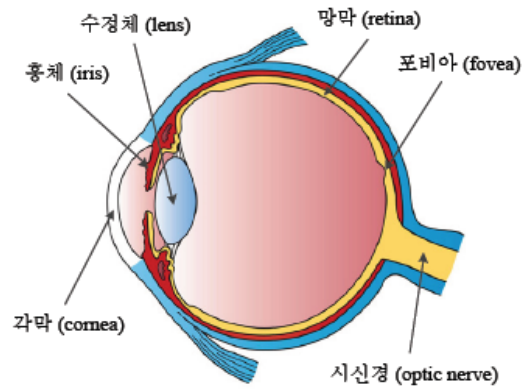
Film



Digital Camera

2.1.2 획득과 표현

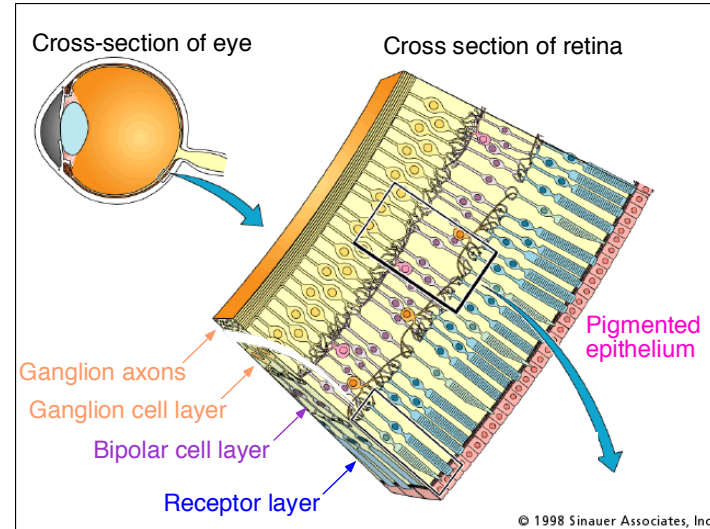
■ The Eye



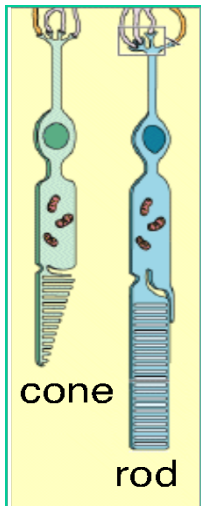
(a) 사람의 눈 구조

그림 2-3 사람의 눈과 카메라의 구조

망막(Retina)



Light

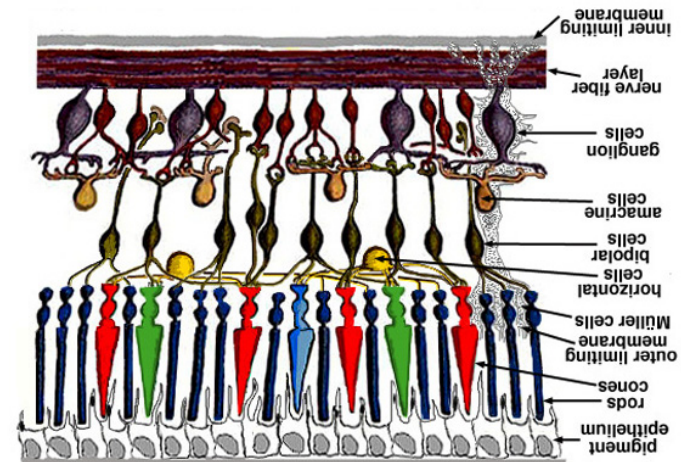


Cones

cone-shaped less sensitive
operate in high light
color vision

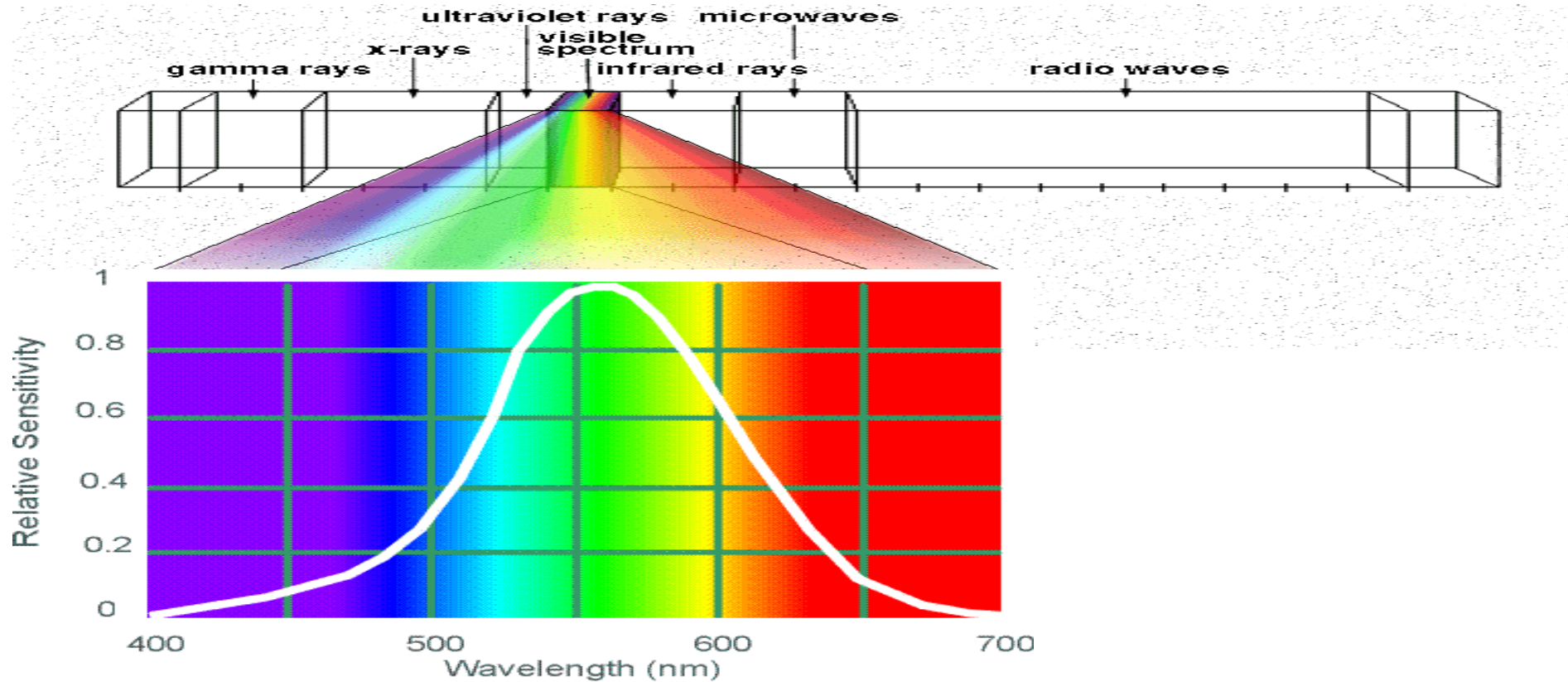
Rods

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



2.1.2 획득과 표현

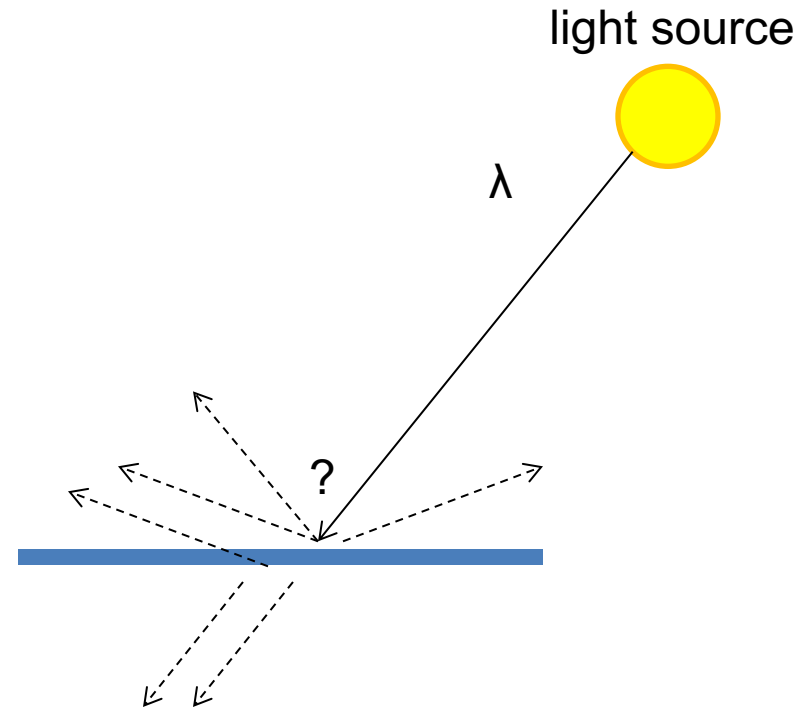
■ Electromagnetic spectrum



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

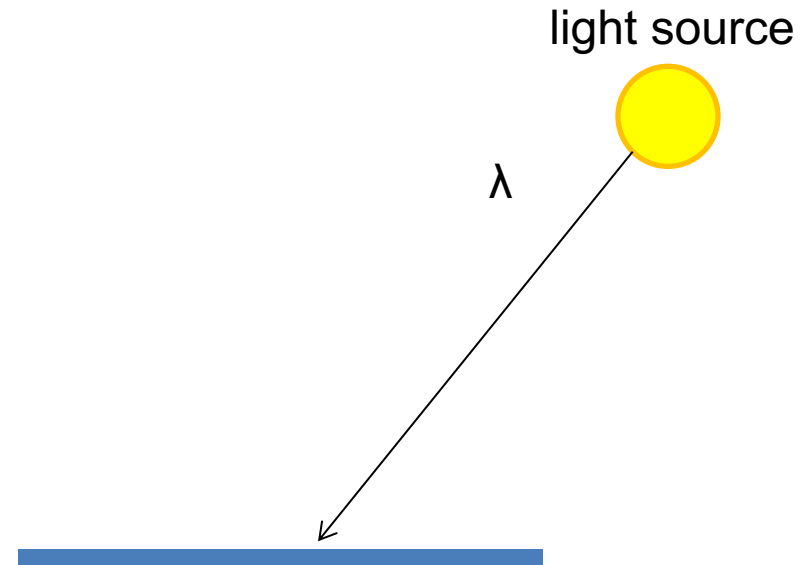
- Refraction

- Fluorescence

- Subsurface scattering

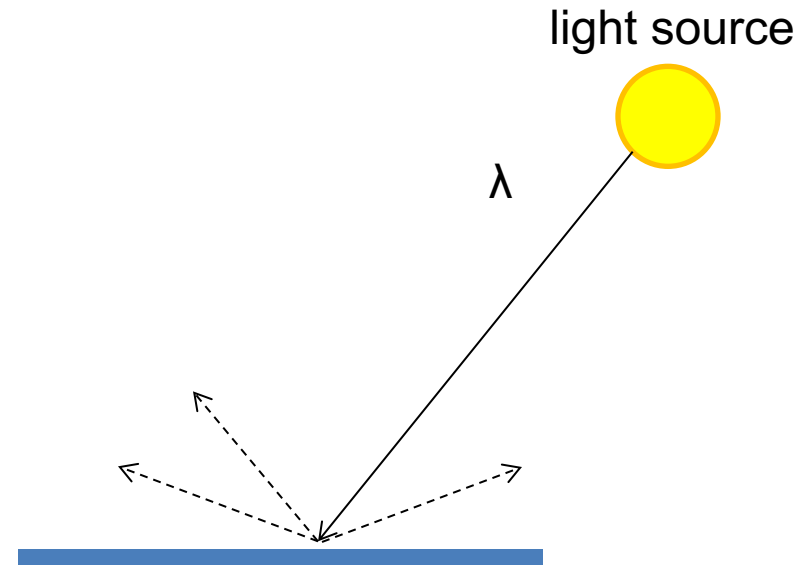
- Phosphorescence

- Interreflection



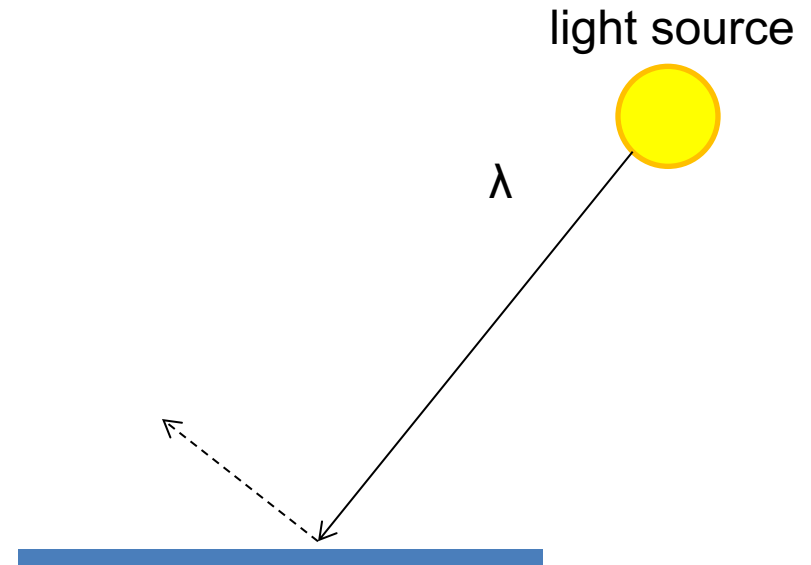
A photon's life choices

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



A photon's life choices

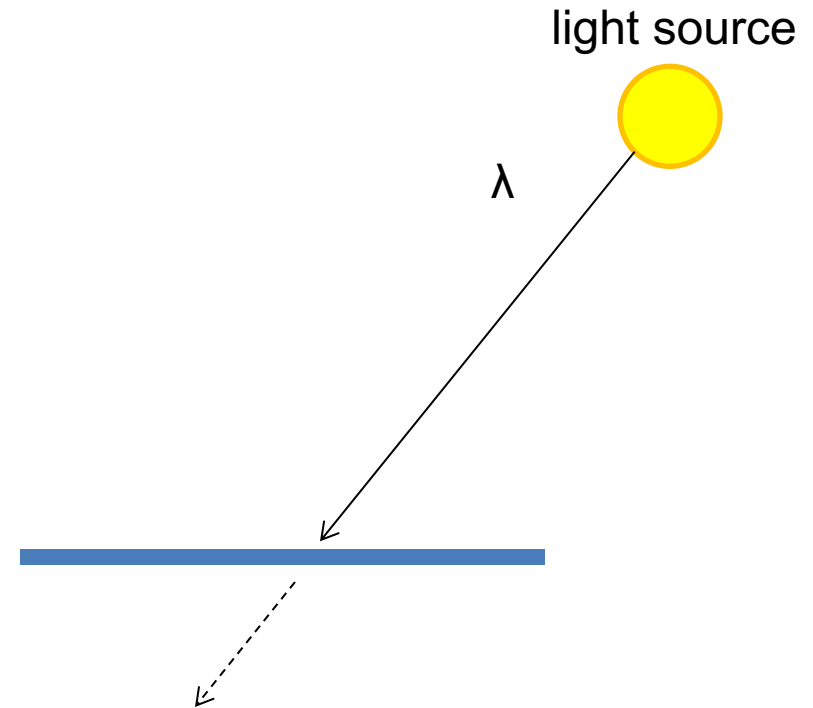
- Absorption
- Diffusion
- **Specular Reflection**
- Transparency
- Refraction
- Fluorescence
- Subsurface scattering
- Phosphorescence
- Interreflection



카메라의 색상은 여기에 해당

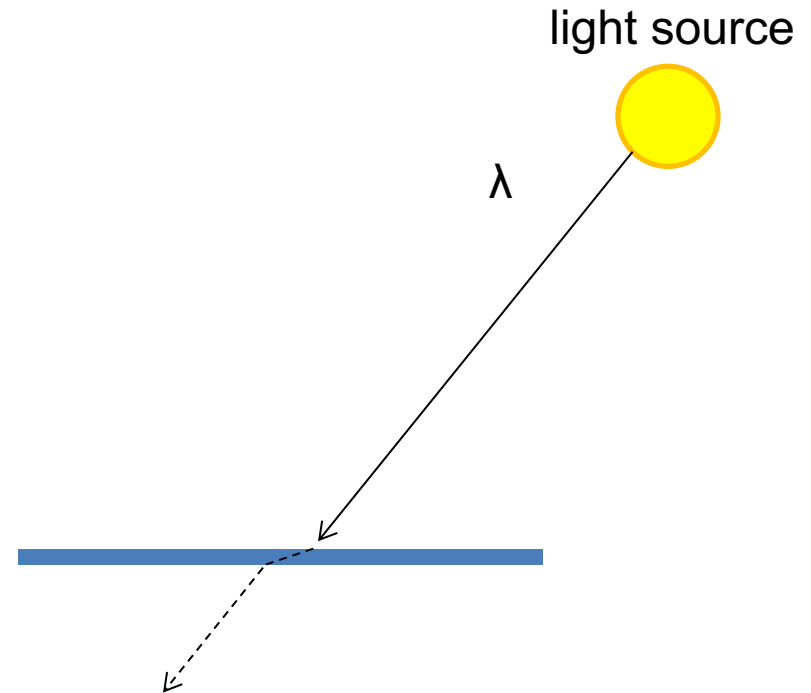
A photon's life choices

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



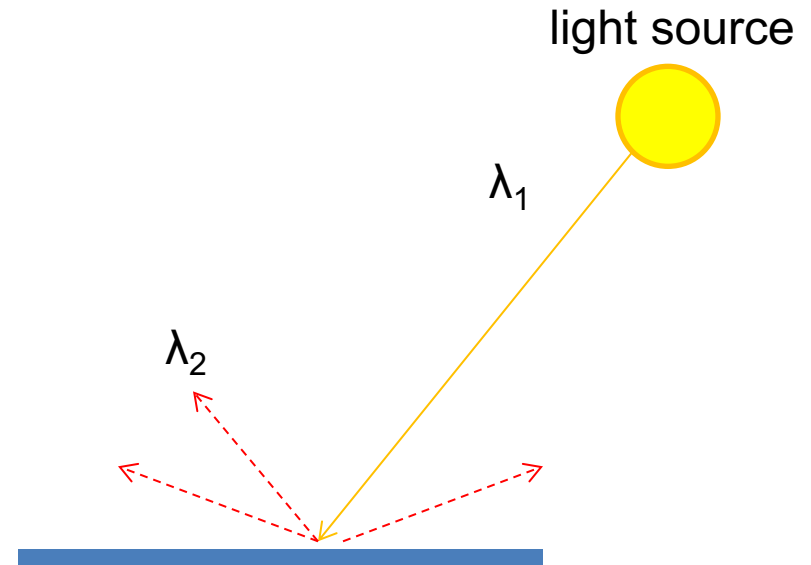
A photon's life choices

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



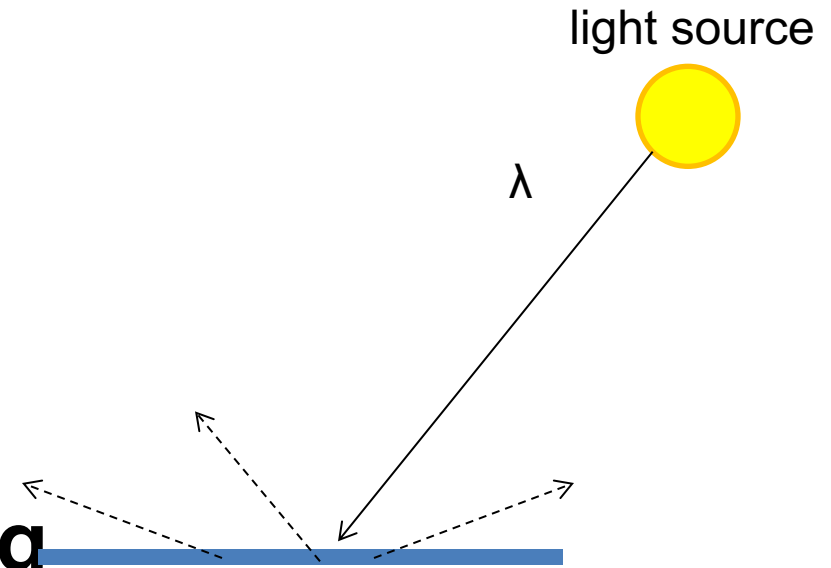
A photon's life choices

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



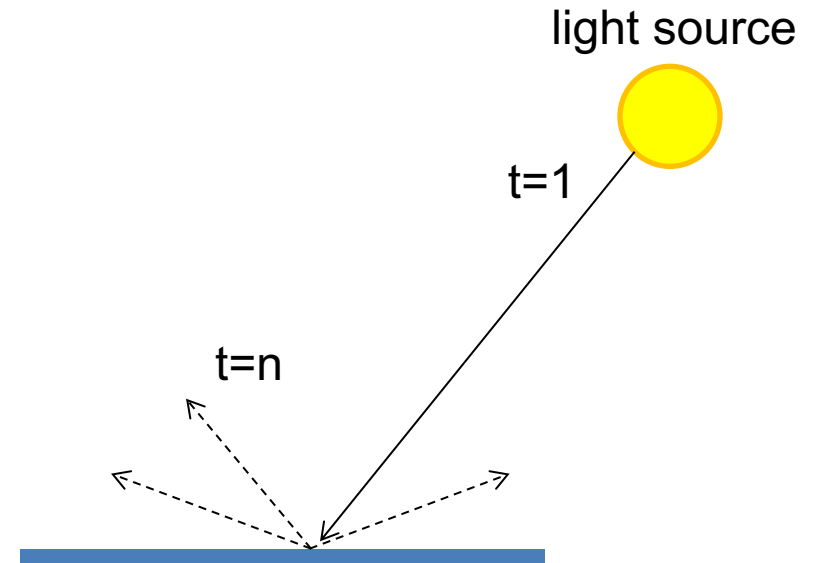
A photon's life choices

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



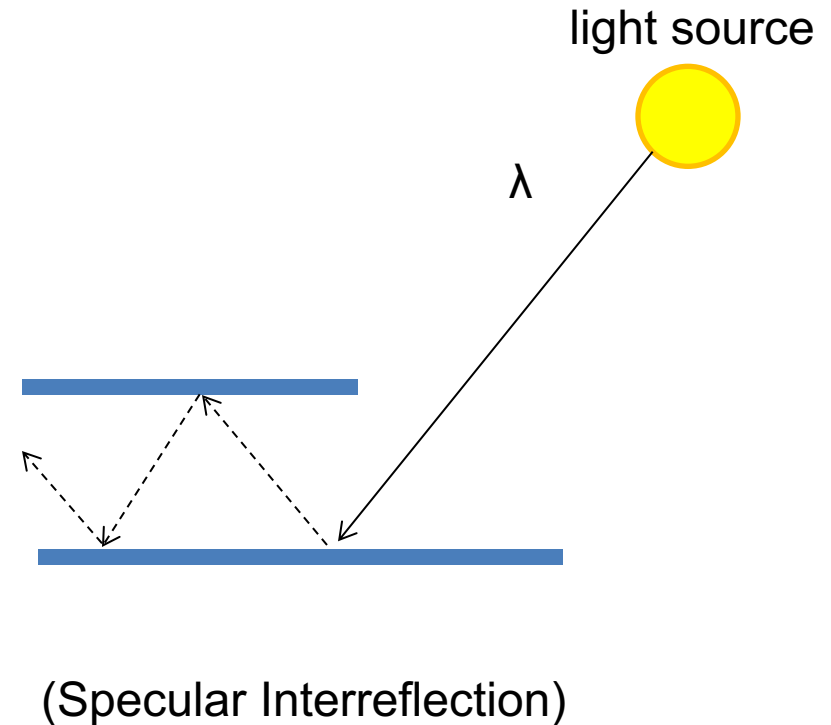
A photon's life choices

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



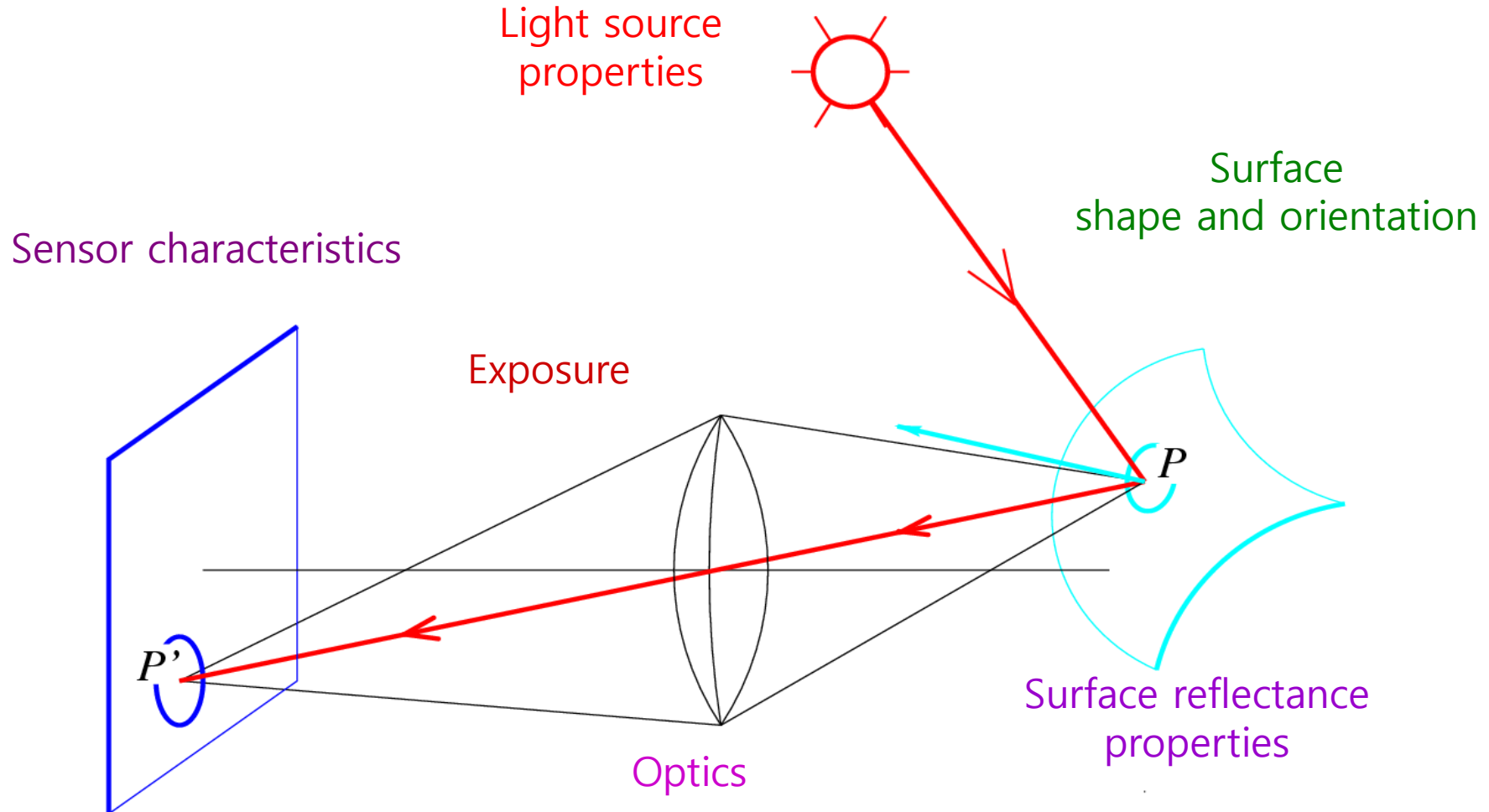
A photon's life choices

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



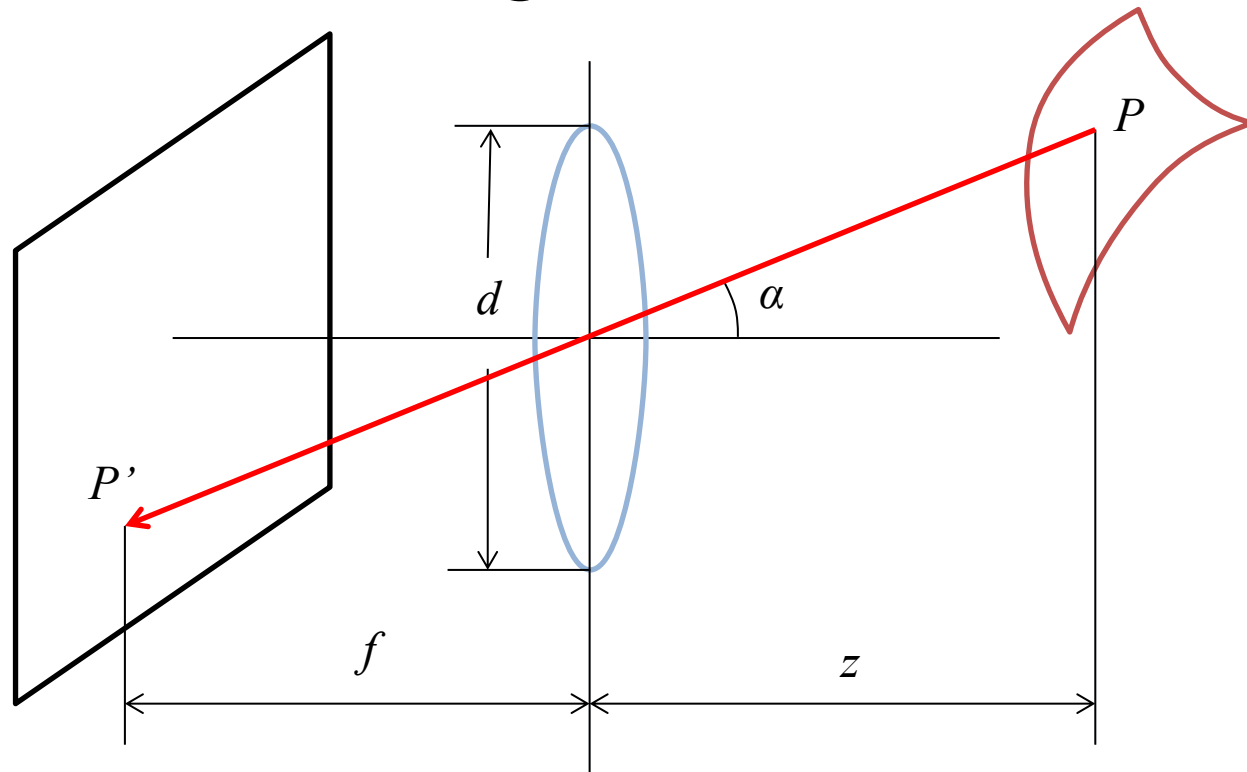
2.1.2 획득과 표현

■ Image formation



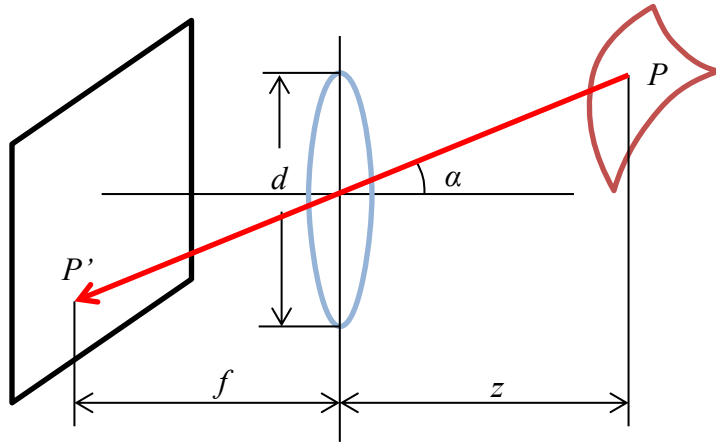
Fundamental radiometric relation

- 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

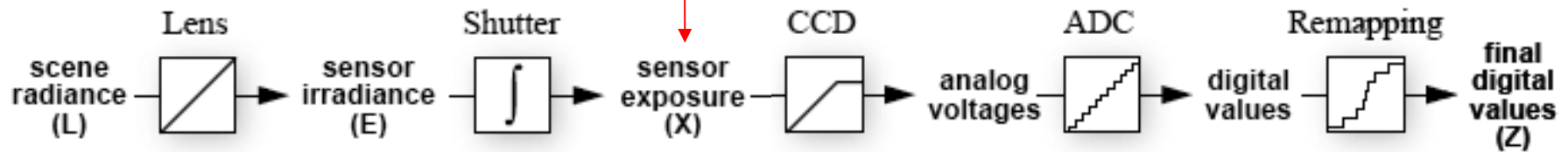


$$E = \left[\frac{\pi}{4} \left(\frac{d}{f} \right)^2 \cos^4 \alpha \right] L$$

- 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

$$X = E \cdot \Delta t$$



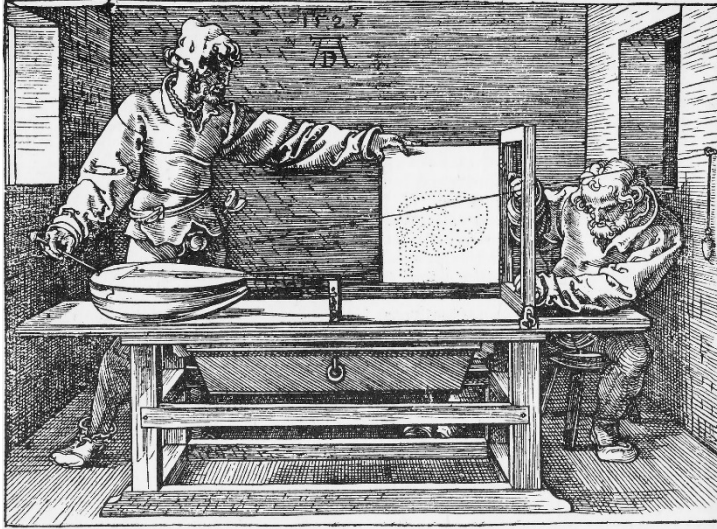
$$E = \left[\frac{\pi}{4} \left(\frac{d}{f} \right)^2 \cos^4 \alpha \right] L$$

$$Z = f(E \cdot \Delta t)$$

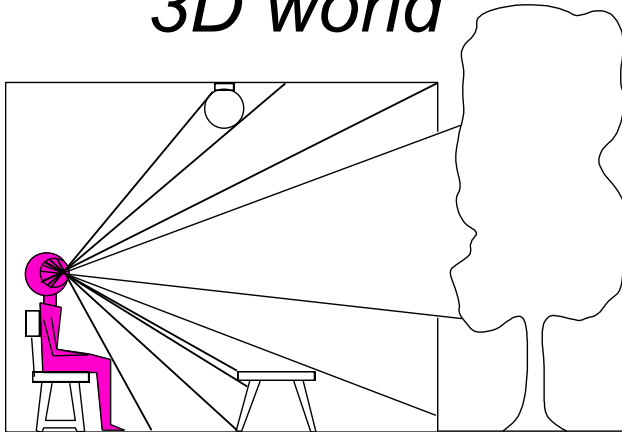
- Camera response function: the mapping f from irradiance to pixel values
 - Useful if we want to estimate material properties
 - Enables us to create high dynamic range images
 - For more info: P. E. Debevec and J. Malik, [*Recovering High Dynamic Range Radiance Maps from Photographs*](#), SIGGRAPH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

2.1.2 획득과 표현

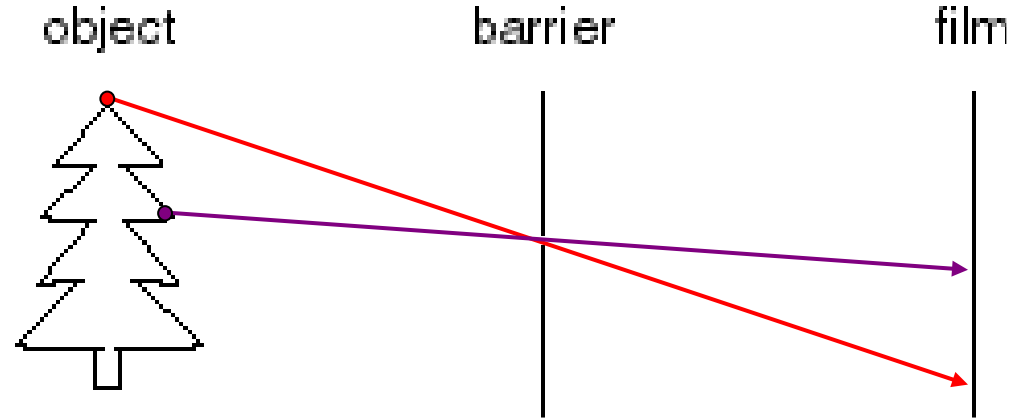
■ Perspective projection



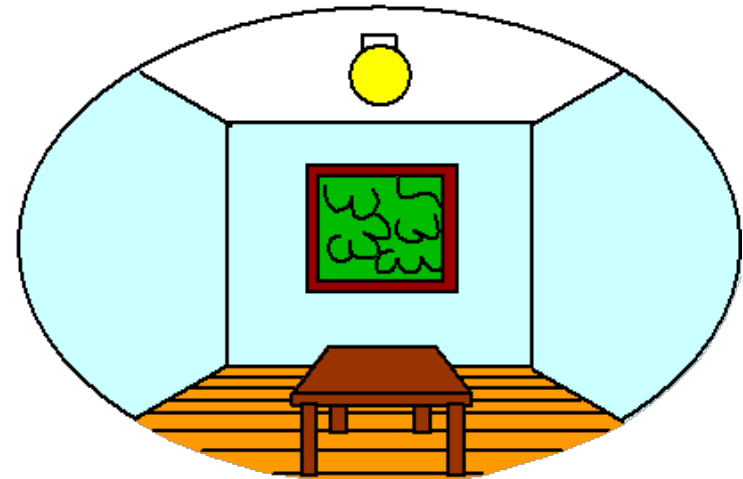
3D world



Point of observation

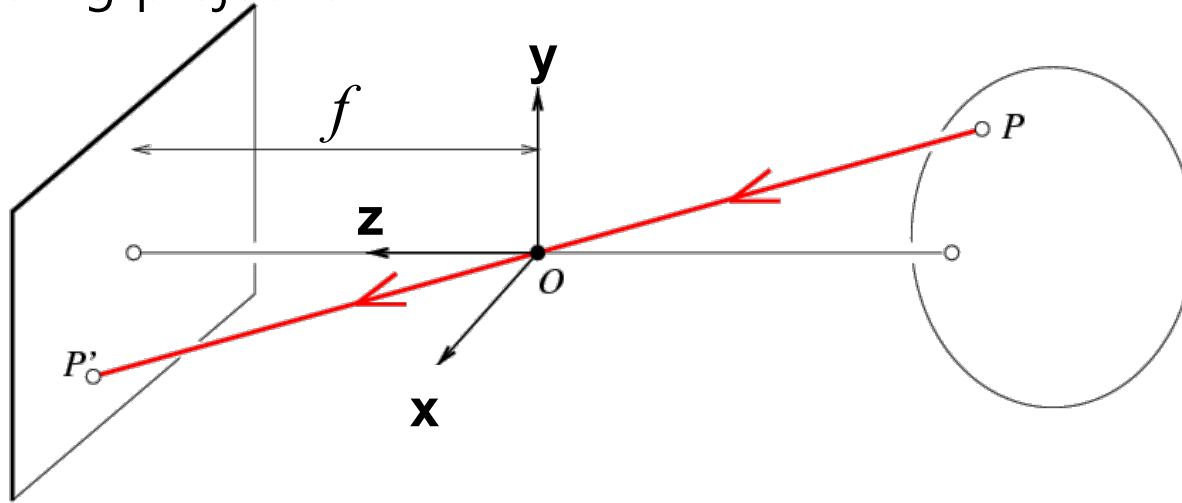


2D image



2.1.2 획득과 표현

■ Modeling projection



- 3차원 공간상에서의 P 는 2차원 영상 평면(image plane)에서 P' 으로 투영됨
- P 와 P' 의 상관관계를 나타낼 수 있는 방법 필요
 - Optical center (O) 가 3차원 공간상의 원점
 - Projection equations

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

2.1.2 획득과 표현

■ Perspective projection matrix

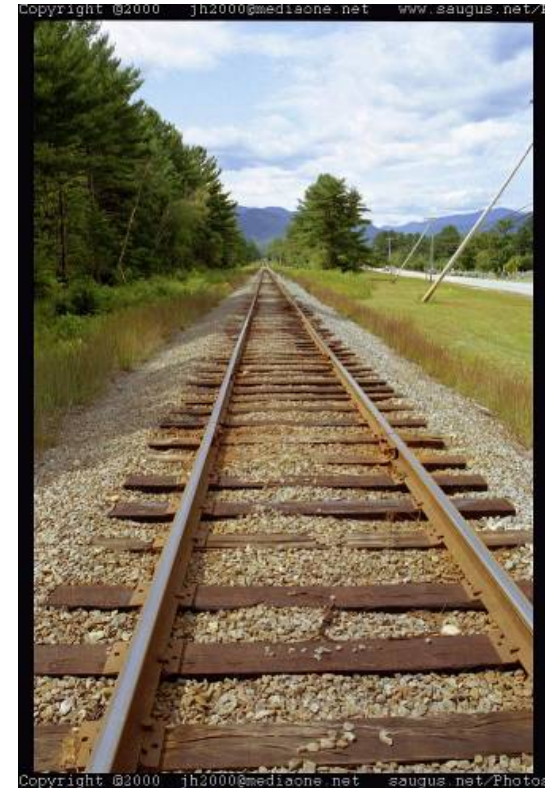
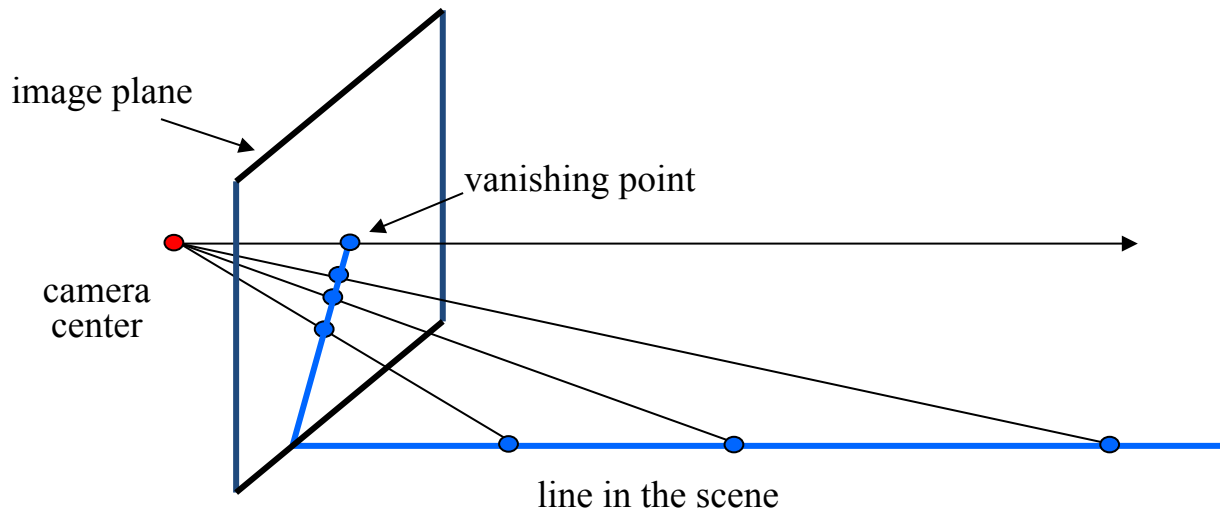
$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1/f & 0 \end{bmatrix} \begin{bmatrix} x \\ y \\ z \\ 1 \end{bmatrix} = \begin{bmatrix} x \\ y \\ z/f \end{bmatrix} \Rightarrow \left(f \frac{x}{z}, f \frac{y}{z} \right)$$

divide by the third coordinate

$$\begin{pmatrix} \text{2D} \\ \text{point} \\ (3 \times 1) \end{pmatrix} = \begin{pmatrix} \text{Camera to} \\ \text{pixel coord.} \\ \text{trans. matrix} \\ (3 \times 3) \end{pmatrix} \begin{pmatrix} \text{Perspective} \\ \text{projection matrix} \\ (3 \times 4) \end{pmatrix} \begin{pmatrix} \text{World to} \\ \text{camera coord.} \\ \text{trans. matrix} \\ (4 \times 4) \end{pmatrix} \begin{pmatrix} \text{3D} \\ \text{point} \\ (4 \times 1) \end{pmatrix}$$

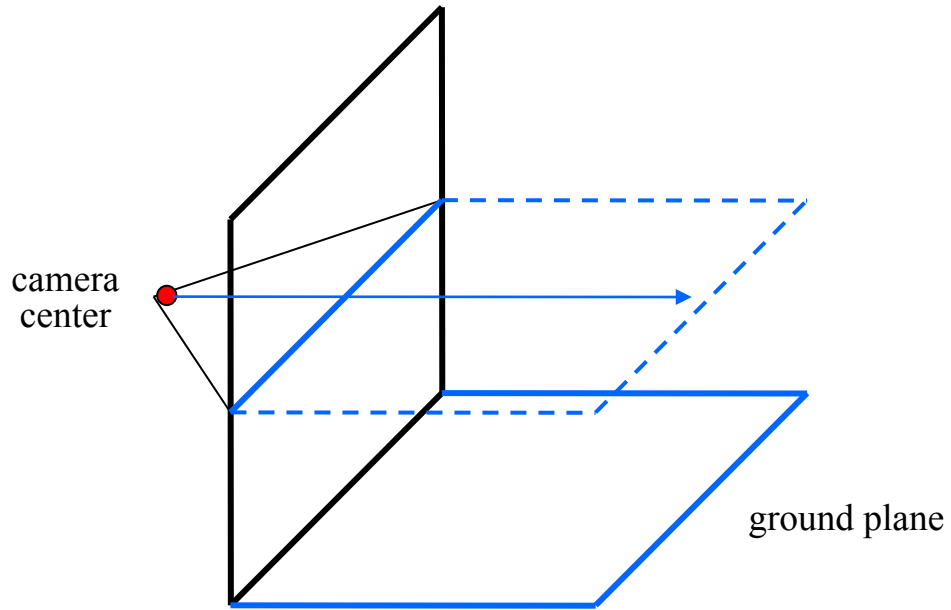
2.1.2 획득과 표현

■ Projection of a line



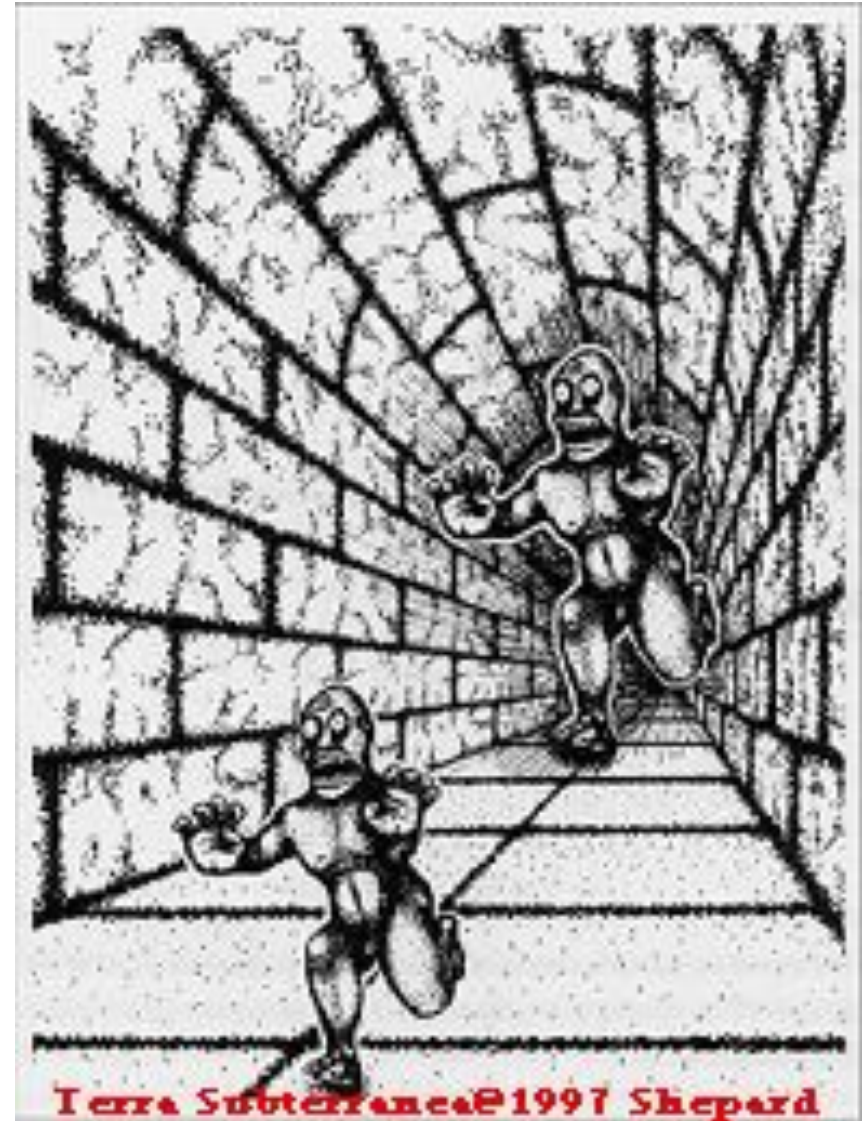
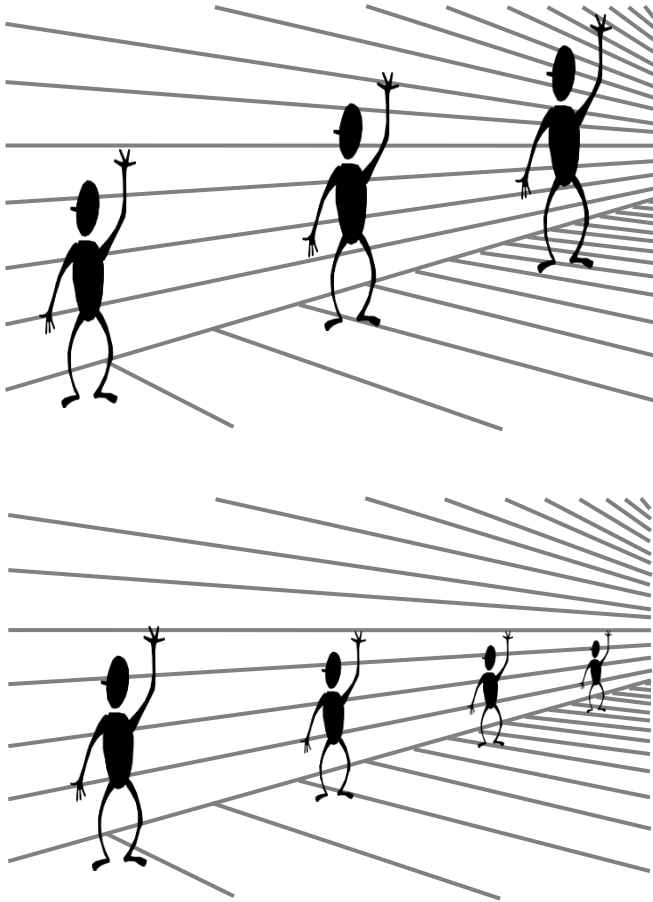
2.1.2 획득과 표현

■ The horizon



2.1.2 획득과 표현

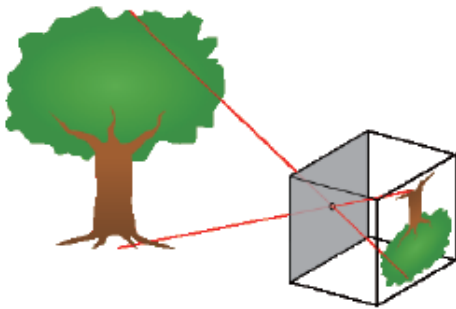
■ The perspective cues



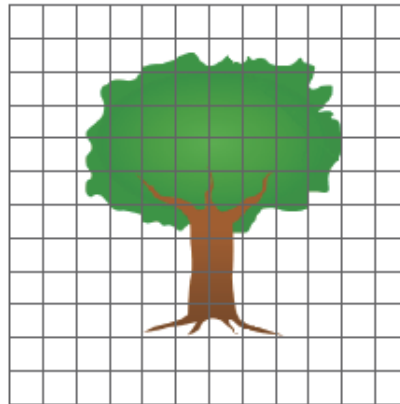
2.1.2 획득과 표현

■ 샘플링과 양자화

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



(a) 핀홀 카메라 모델



(b) 샘플링과 양자화

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

(c) 디지털 영상

그림 2-4 디지털 영상 획득

2.1.2 획득과 표현

■ 영상 좌표계

- 화소 위치는 $\mathbf{x}=(j,i)$ 또는 $\mathbf{x}=(y,x)$ 로 표기
- 영상은 $f(\mathbf{x})$ 또는 $f(j,i)$, $0 \leq j \leq M-1$, $0 \leq i \leq N-1$ 로 표기

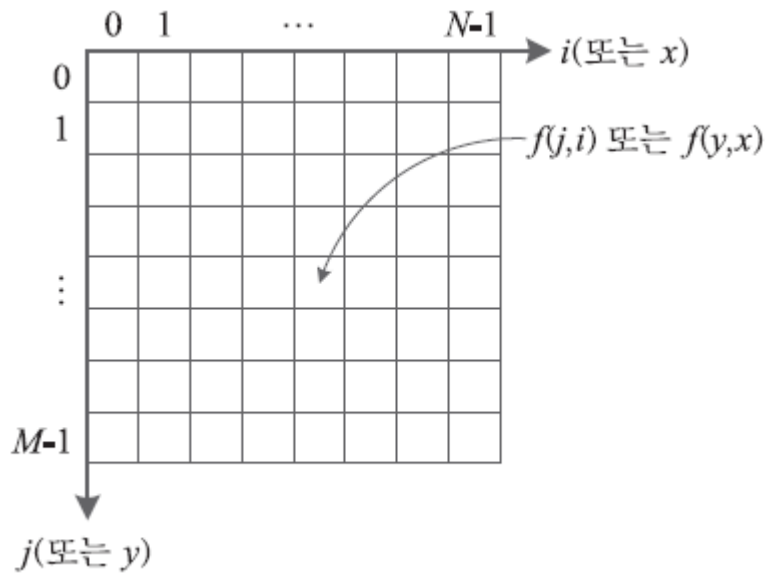
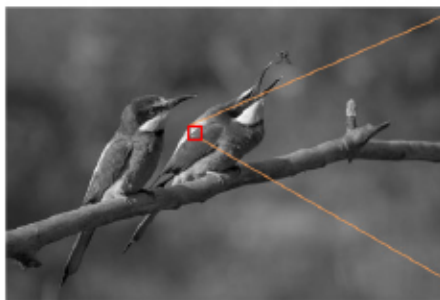


그림 2-5 디지털 영상의 좌표계

- 컬러 영상은 $f_r(x)$, $f_g(x)$, $f_b(x)$ 의 세 채널로 구성

2.1.2 획득과 표현

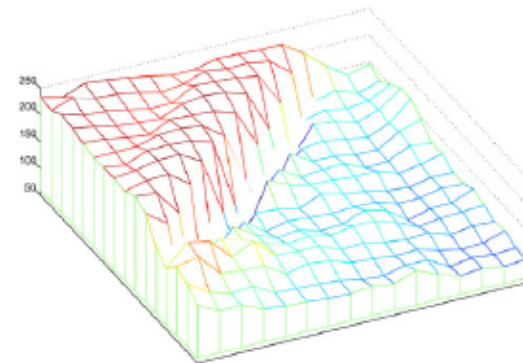
■ 영상 표시 방법



(a) 영상

233	224	239	235	230	224	215	215	226	225	223	223	196	163	136	147
229	244	233	231	223	214	219	233	226	229	222	191	127	137	122	136
243	232	229	223	214	215	237	235	232	226	167	122	131	124	129	151
237	231	223	219	216	234	240	235	223	145	81	136	132	130	134	164
231	229	222	217	235	234	231	218	148	81	121	126	120	112	128	164
225	225	226	237	240	235	206	111	70	142	119	118	111	111	134	147
229	222	239	240	238	225	97	93	145	119	124	125	108	110	129	123
228	234	241	242	220	112	59	153	136	126	126	121	122	108	115	124
225	234	236	208	78	73	125	121	112	130	120	115	107	102	111	111
236	232	185	86	95	139	111	121	116	114	116	116	103	104	112	110
225	197	85	110	160	137	119	124	113	115	132	122	93	105	106	122
183	125	157	169	155	140	130	133	124	133	133	119	102	107	110	112
164	203	195	156	174	138	137	136	119	122	114	108	112	98	104	102
188	196	156	150	150	125	134	129	116	113	108	111	99	91	93	106
176	152	138	142	120	118	117	113	104	102	112	111	90	96	93	94
158	137	138	122	117	114	111	110	113	108	122	107	93	98	90	94

(b) 숫자 배열



(c) 지형

그림 2-6 디지털 영상 표시 방법