Image Formation

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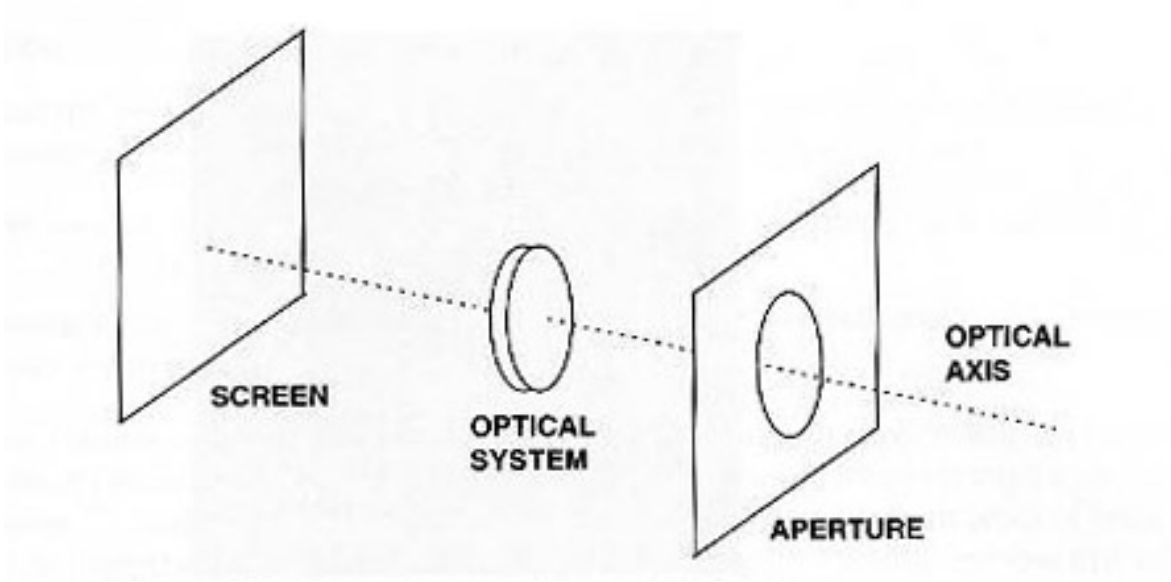
COMP 4900C
Winter 2008

Image Formation

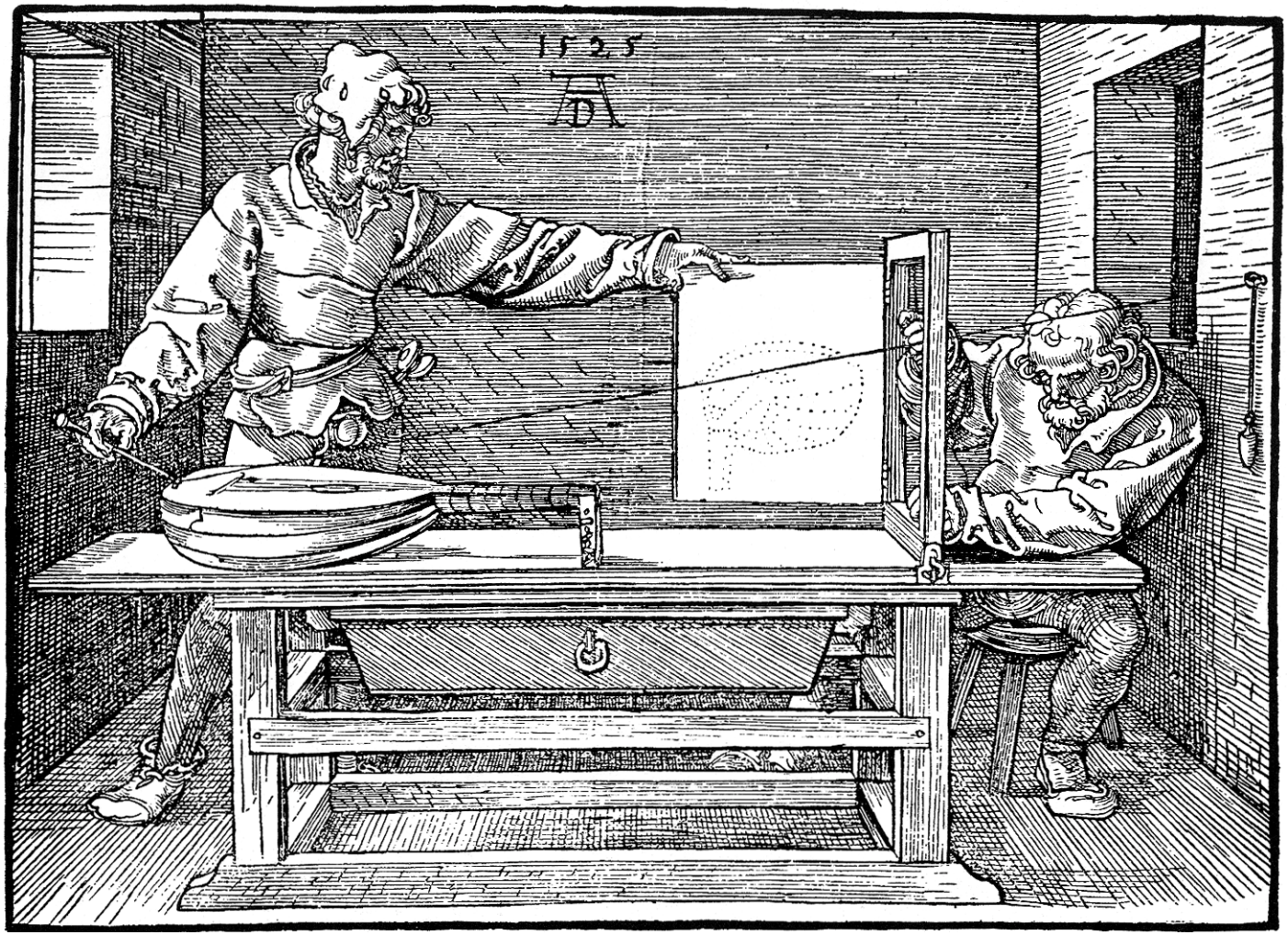
- The physics of image formation.
- Geometric models of cameras.

Elements of an imaging device

Light rays coming from outside world and falling on the photoreceptors in the retina.

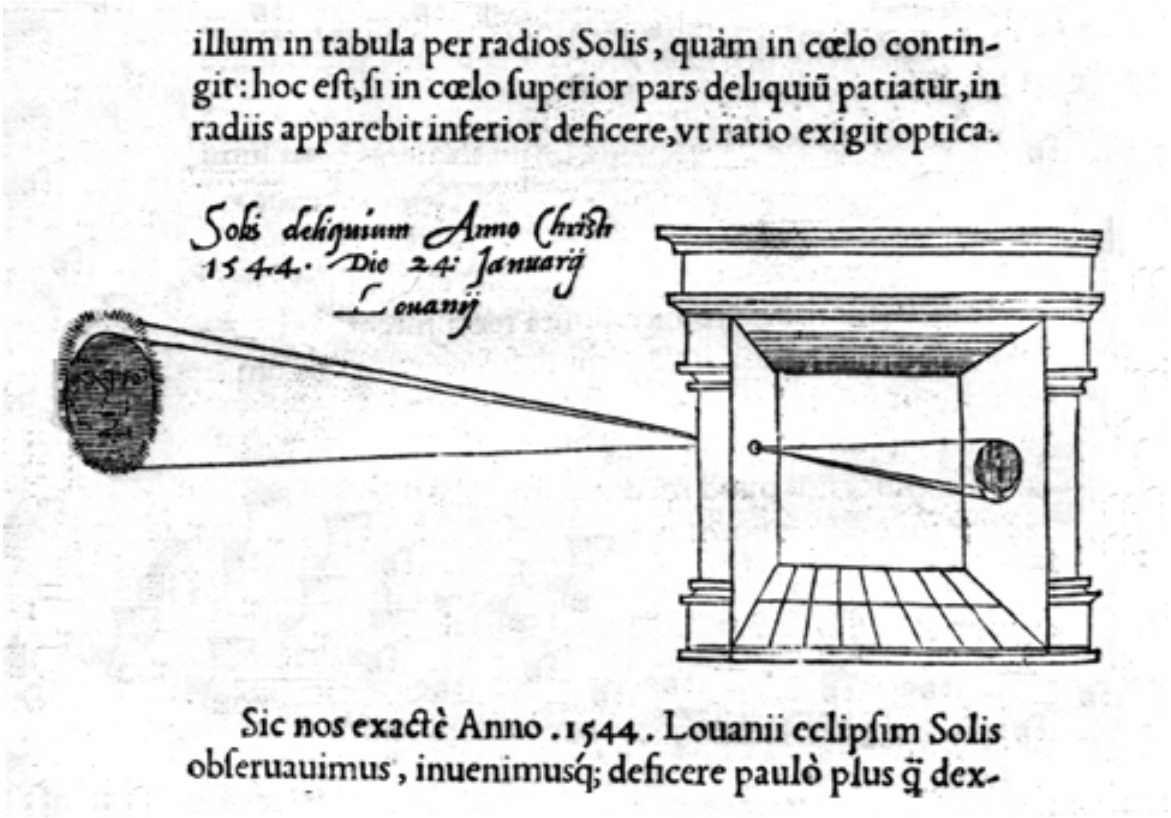


Perspective Projection



Draughtsman Drawing a Lute, Albrecht Dürer, 1525

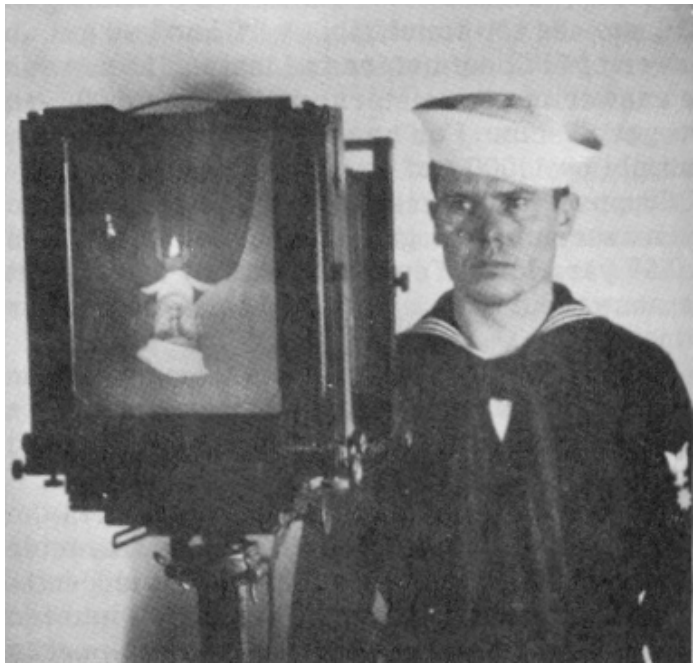
Camera Obscura



Camera Obscura, Reinerus Gemma Frisius, 1544

Camera Obscura: Latin ‘dark chamber’

Photographic Camera

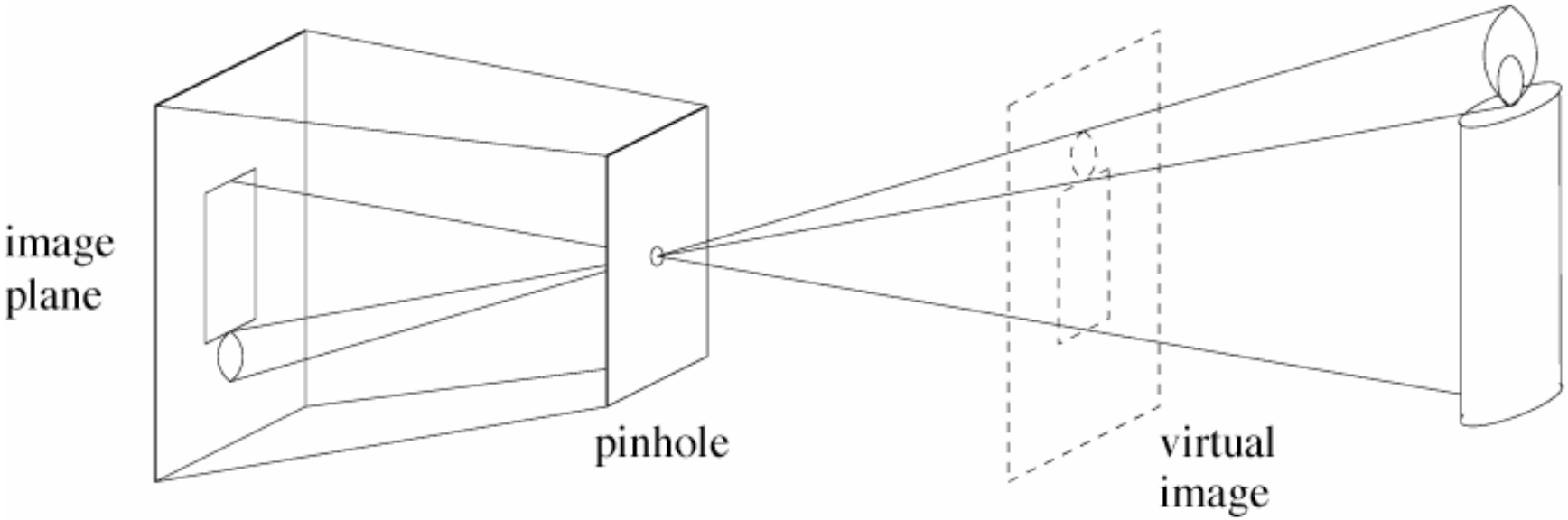


Photographic camera: Joseph Nicéphore Niepce, 1816

First Photograph

First photograph on record, *la table servie,* obtained by Niepce in 1822.

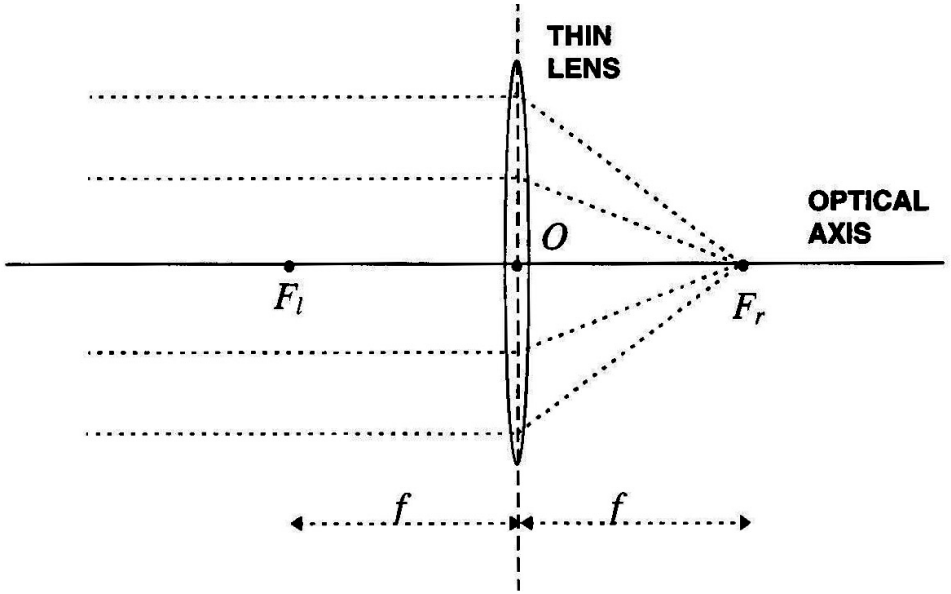
Pinhole Camera



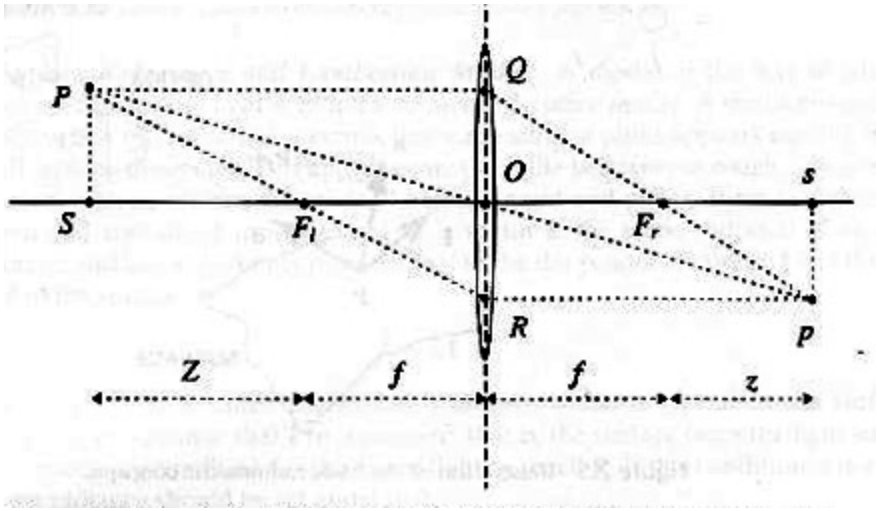
Camera with Lens - Thin Lens Model

Basic properties

1. Any ray entering the lens parallel to the axis on one side goes through the focus on the other side.
2. Any ray entering the lens from the focus on one side emerges parallel to the axis on the other side.



Fundamental Equation of Thin Lenses



$$\frac{1}{\hat{Z}}+\frac{1}{\hat{z}}=\frac{1}{f}$$

$$\hat{Z}=Z+f \qquad \hat{z}=z+f$$

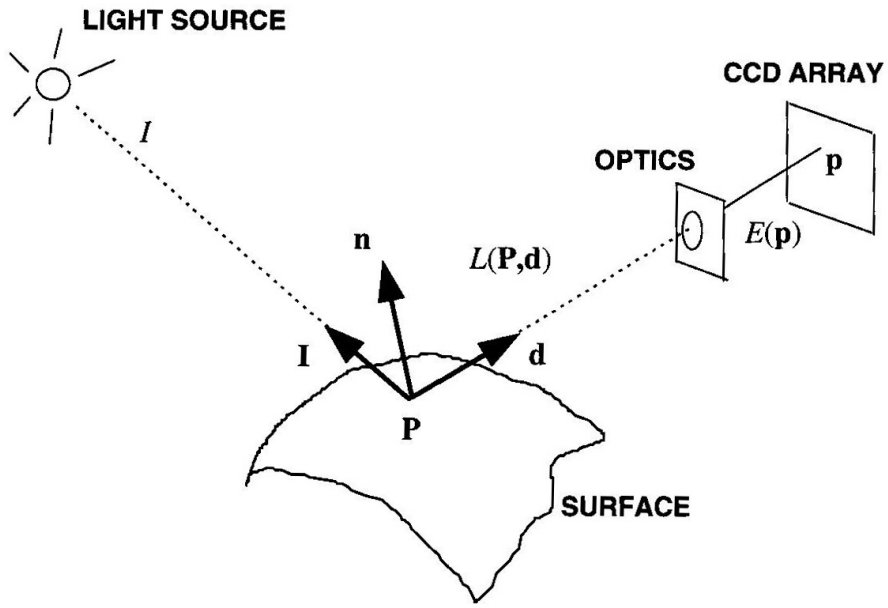
Similar triangles: $PSF_l \sim ORF_l$ and $QOF_r \sim spF_r$

$|PS| = |QO|$ and $|sp| = |OR|$

Basic radiometry

Image Irradiance: the power of light, per unit area and at each point p of the image plane.

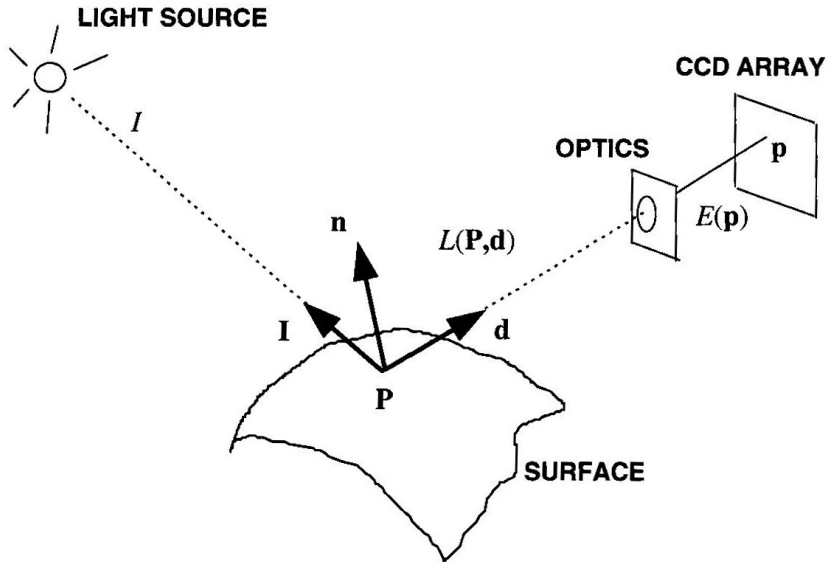
Scene Radiance: the power of the light, per unit area, ideally emitted by each point p of a surface in 3-D space in a given direction.



Surface Reflectance and Lambertian

$$\mathbf{L} = \rho \mathbf{I}^T \mathbf{n}$$

ρ is called surface albedo.



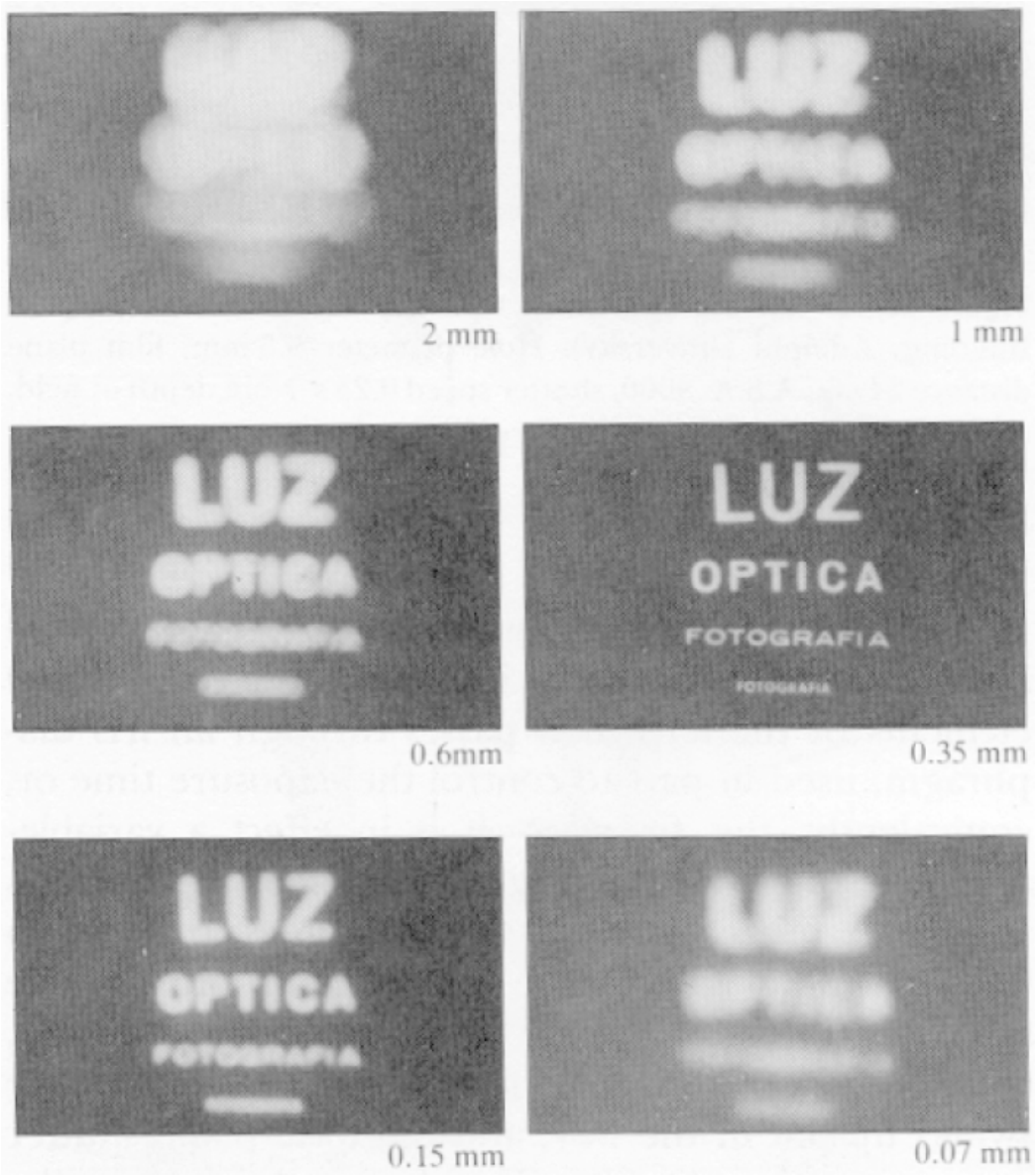
Lambertian model: each surface point appears equally bright from all viewing directions.

Why Lenses?

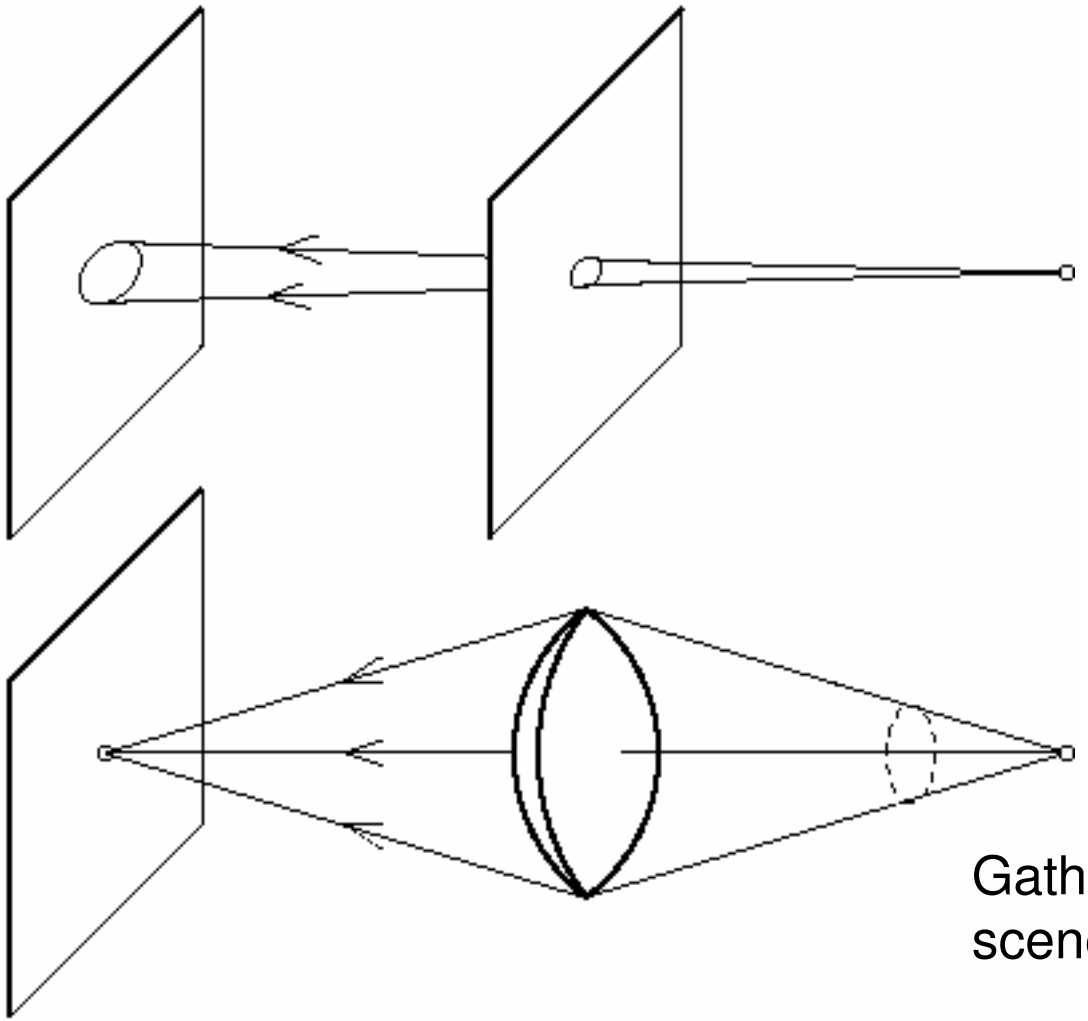
•Pinhole too big - many directions are averaged, blurring the image

•Pinhole too small - diffraction effects blur the image

•Generally, pinhole cameras are *dark*, because a very small set of rays from a particular point hits the screen.

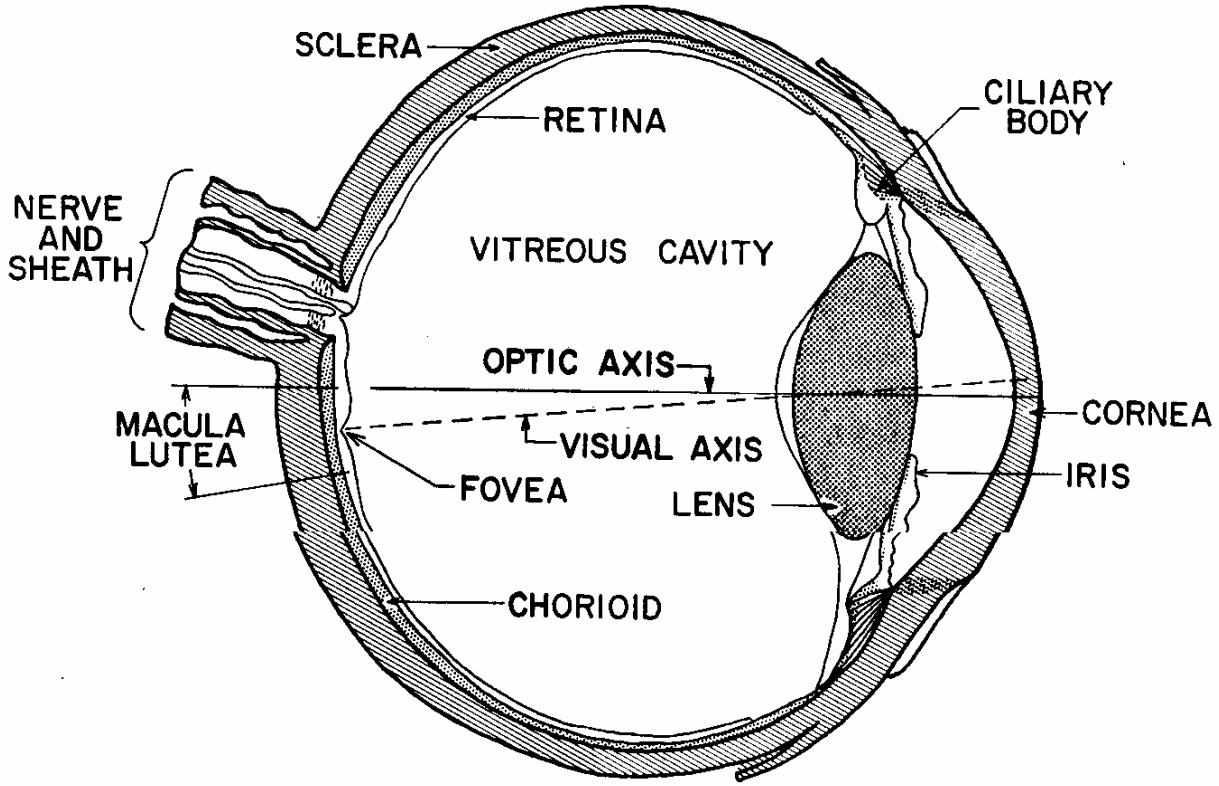


Why Lenses?



Gather more light from each scene point

Human Eye


SCLERA
RETINA
CILIARY BODY
NERVE AND SHEATH
VITREOUS CAVITY
OPTIC AXIS
CORNEA
MACULA LUTEA
VISUAL AXIS
FOVEA
IRIS
LENS
CHORIOID

CCD (Charge-Coupled Device) Cameras

Small solid state cells convert light energy into electrical charge

The image plane acts as a digital memory that can be read row by row by a computer

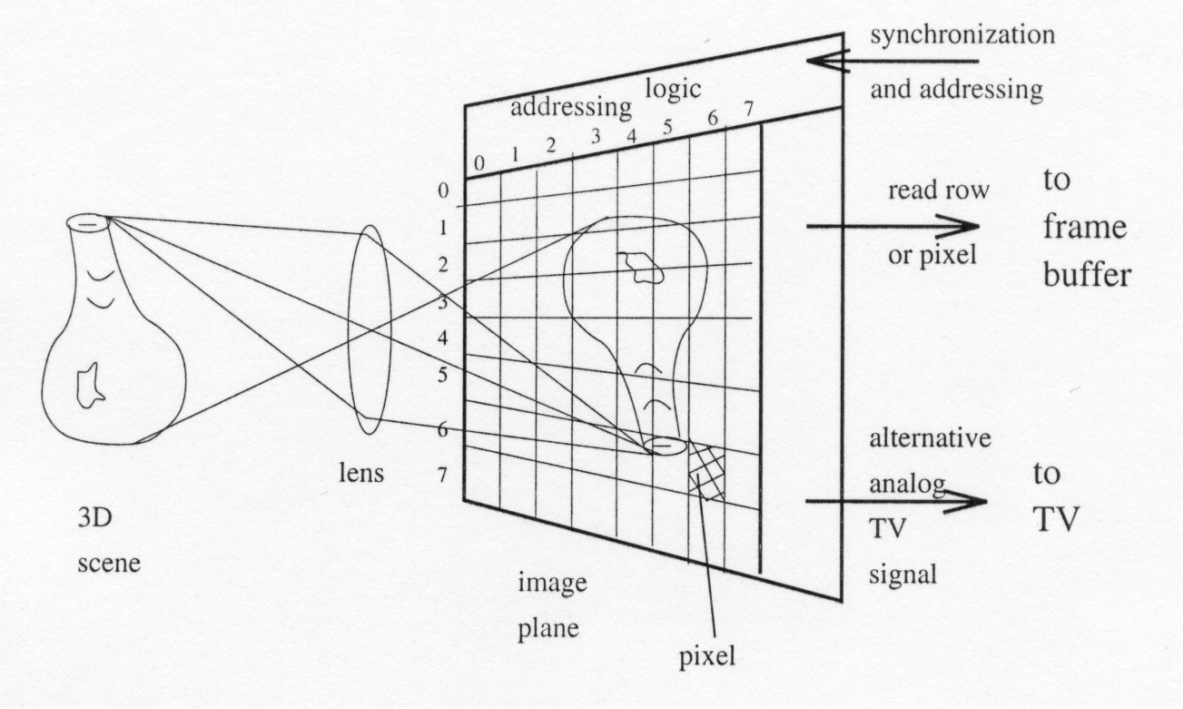
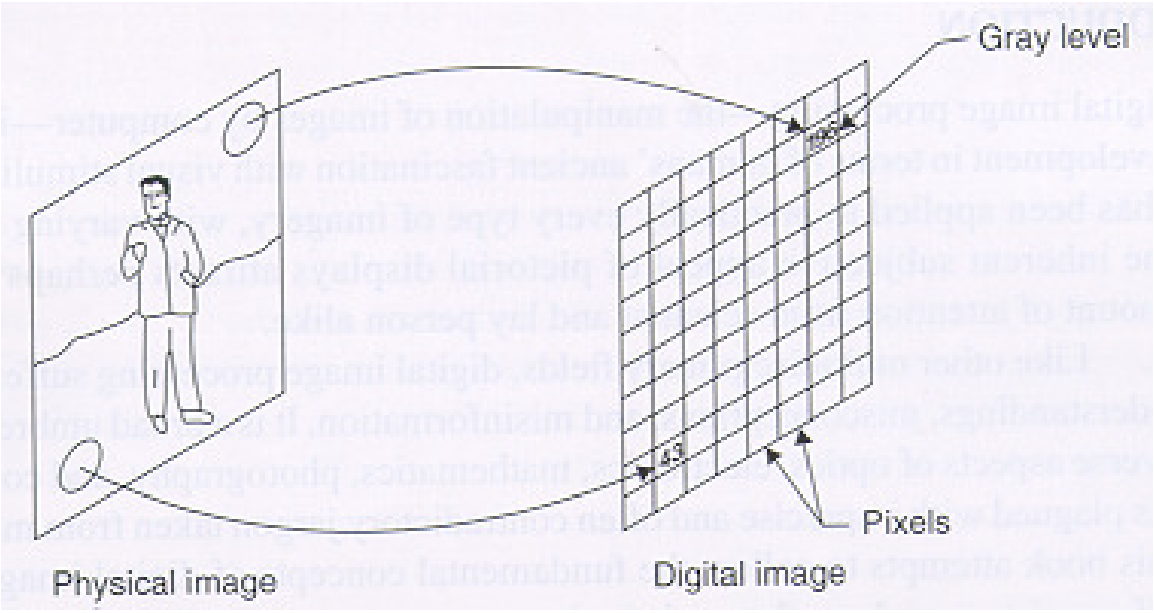


Image Digitization

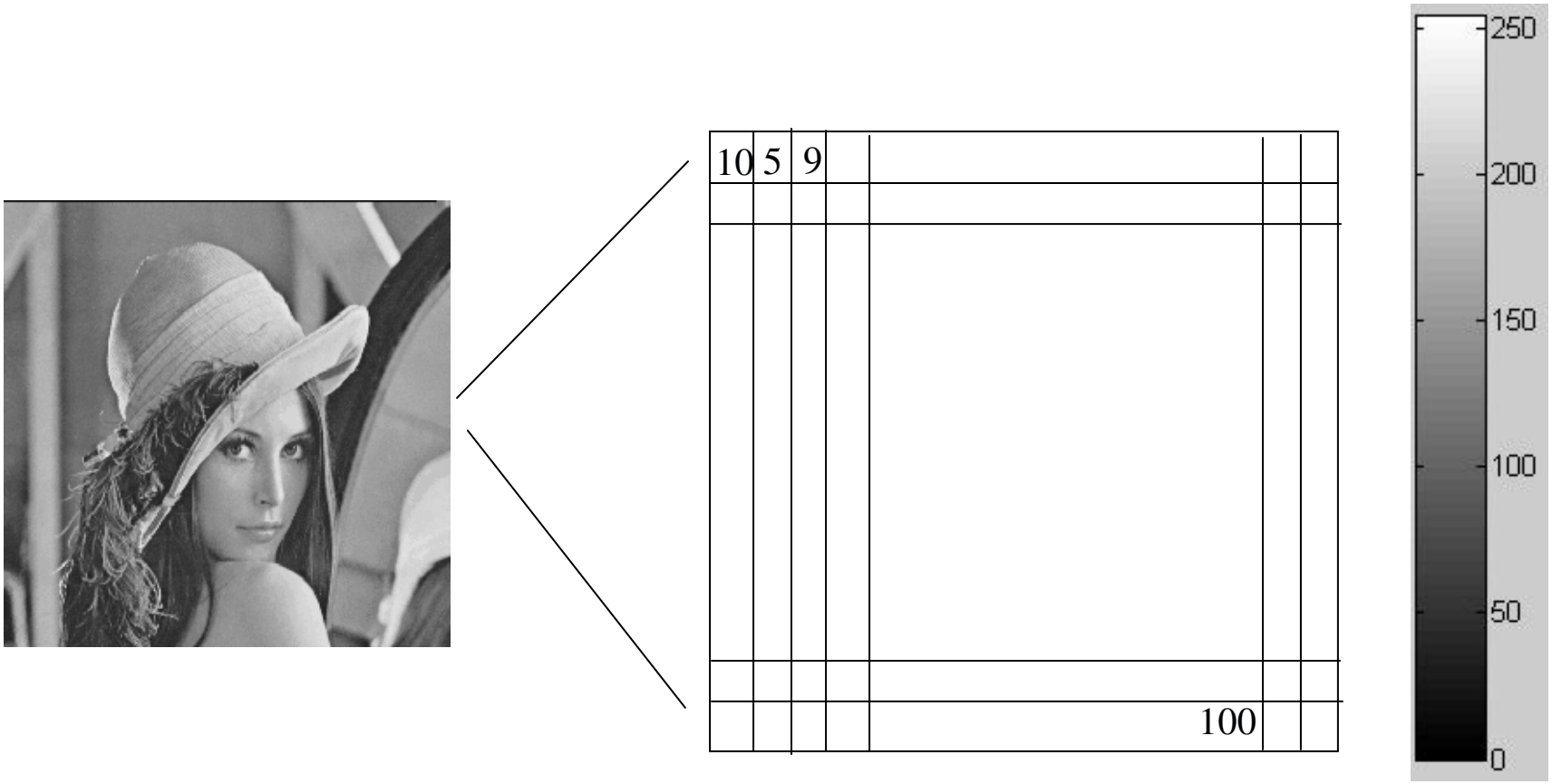


Sampling – measuring the value of an image at a finite number of points.

Quantization – representing the measured value at the sampled point, by an integer.

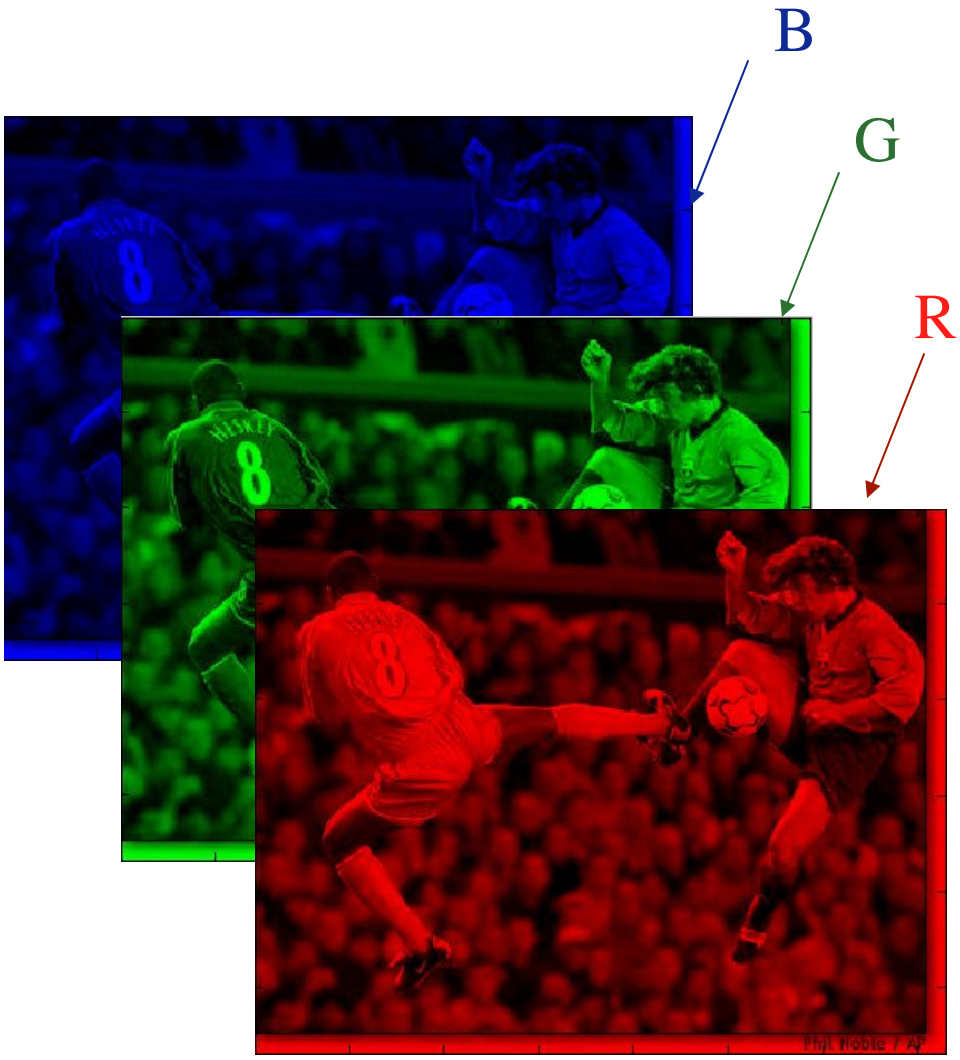
Pixel – picture element, in the range [0,255]

Grayscale Image



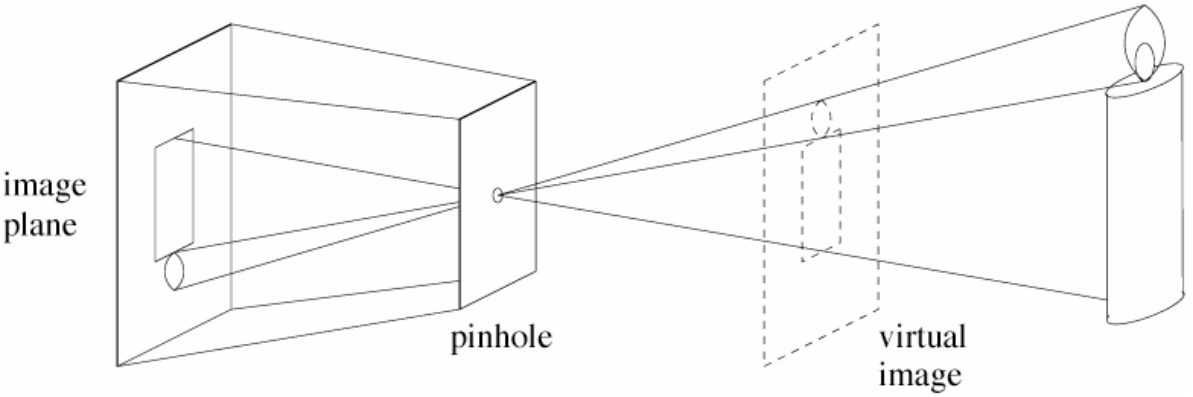
A digital image is represented by an integer array E of m-by-n. E(i,j), a pixel, is an integer in the range [0, 255].

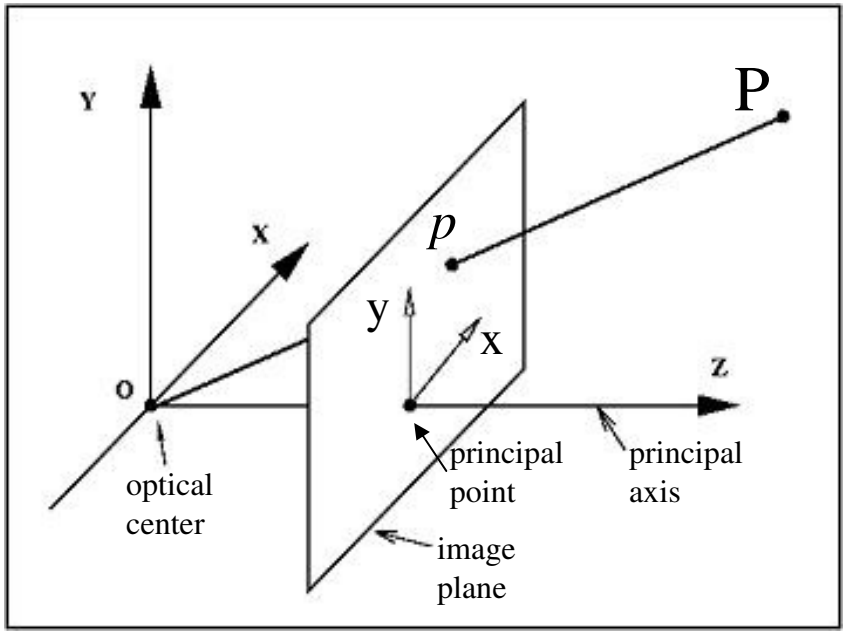
Color Image



Geometric Model of Camera

Perspective projection





$P(X,Y,Z) \longrightarrow p(x,y)$

$$x = f\frac{X}{Z} \quad y = f\frac{Y}{Z}$$