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Image formation

Computer Vision Crash Course

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DIGITAL IMAGES

Two important concepts:

- The exact relationship of a digital image to the physical world is determined by the ***acquisition process***

- Any information contained in images (shape, measurements, objects identities) must be computed from 2D numerical arrays

Parameters involved in the acquisition process

Geometric parameters: type of projections, position and orientation of the camera, perspective distortion

Optical parameters: lens type, focal length, field of view, aperture

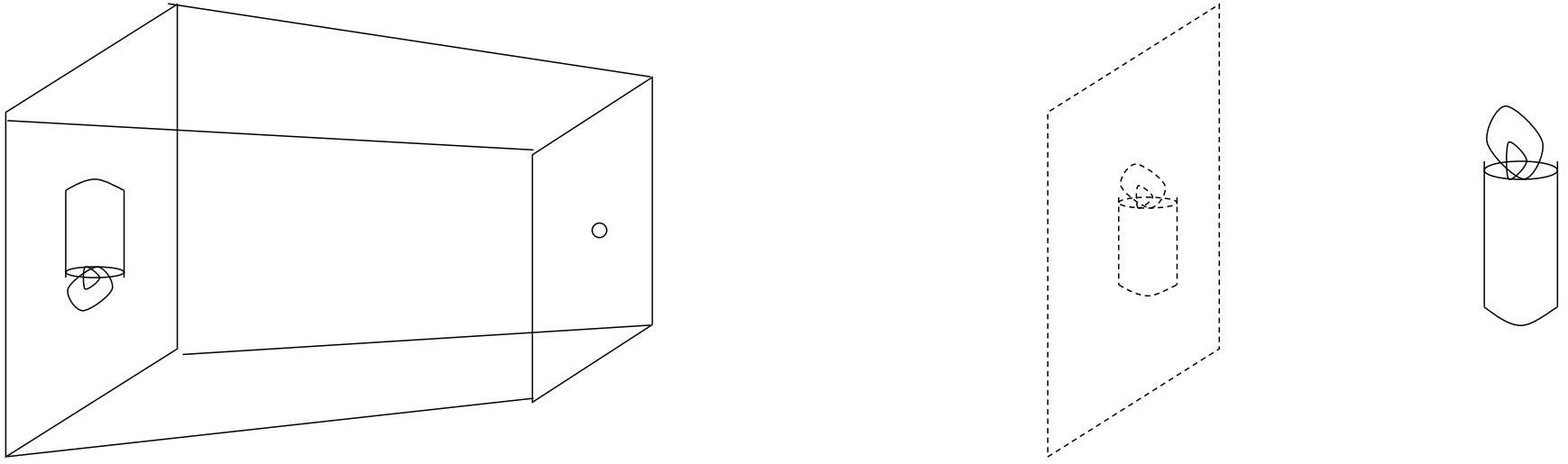
Photometric paramters: type, intensity, direction of illumination; reflectance properties of surfaces, sensors' structure;...

Spatial and temporal resolution

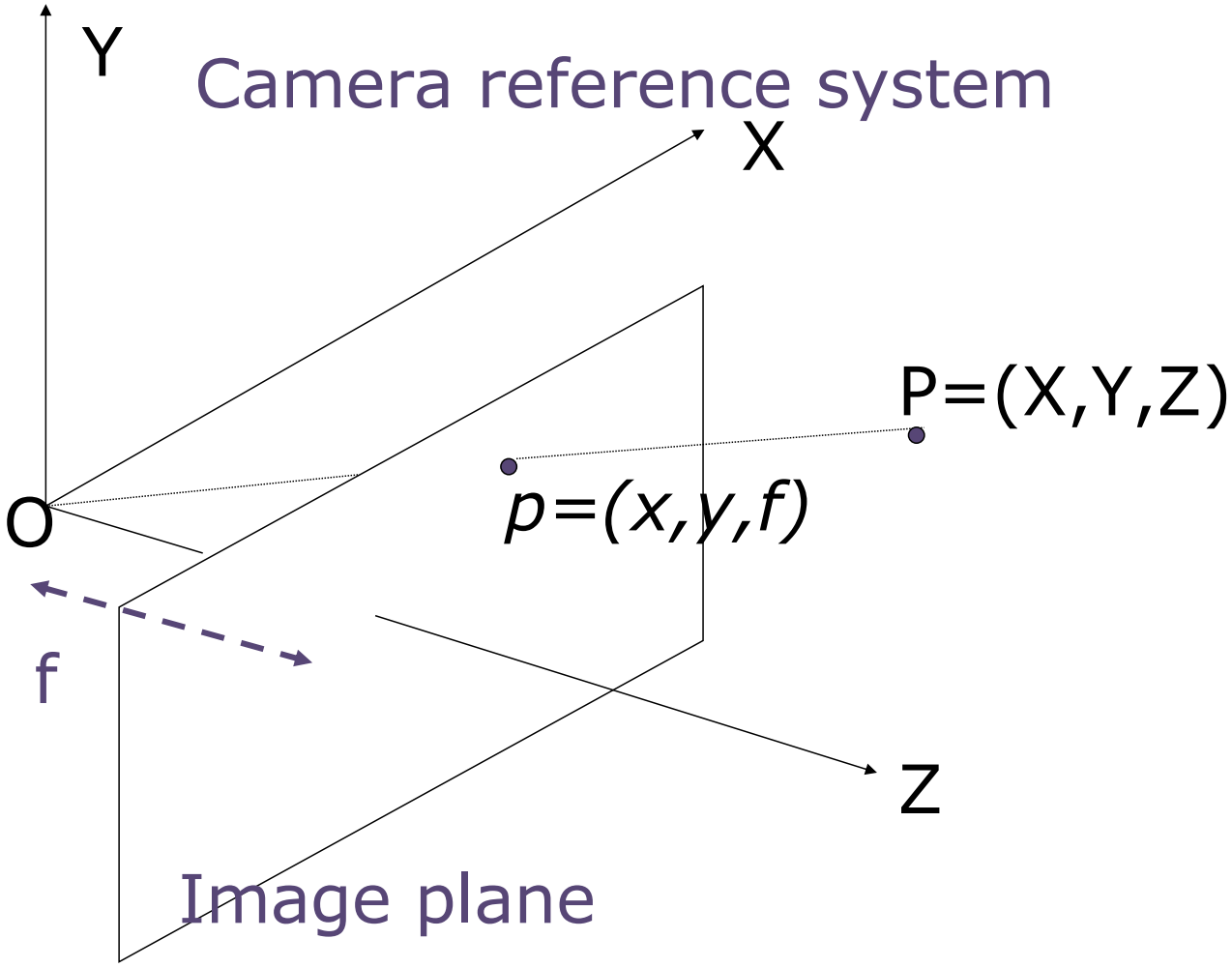
Quantization of intensity scale

THE GEOMETRY OF IMAGE FORMATION

Camera obscura



GEOMETRY: PERSPECTIVE OR PINHOLE MODEL

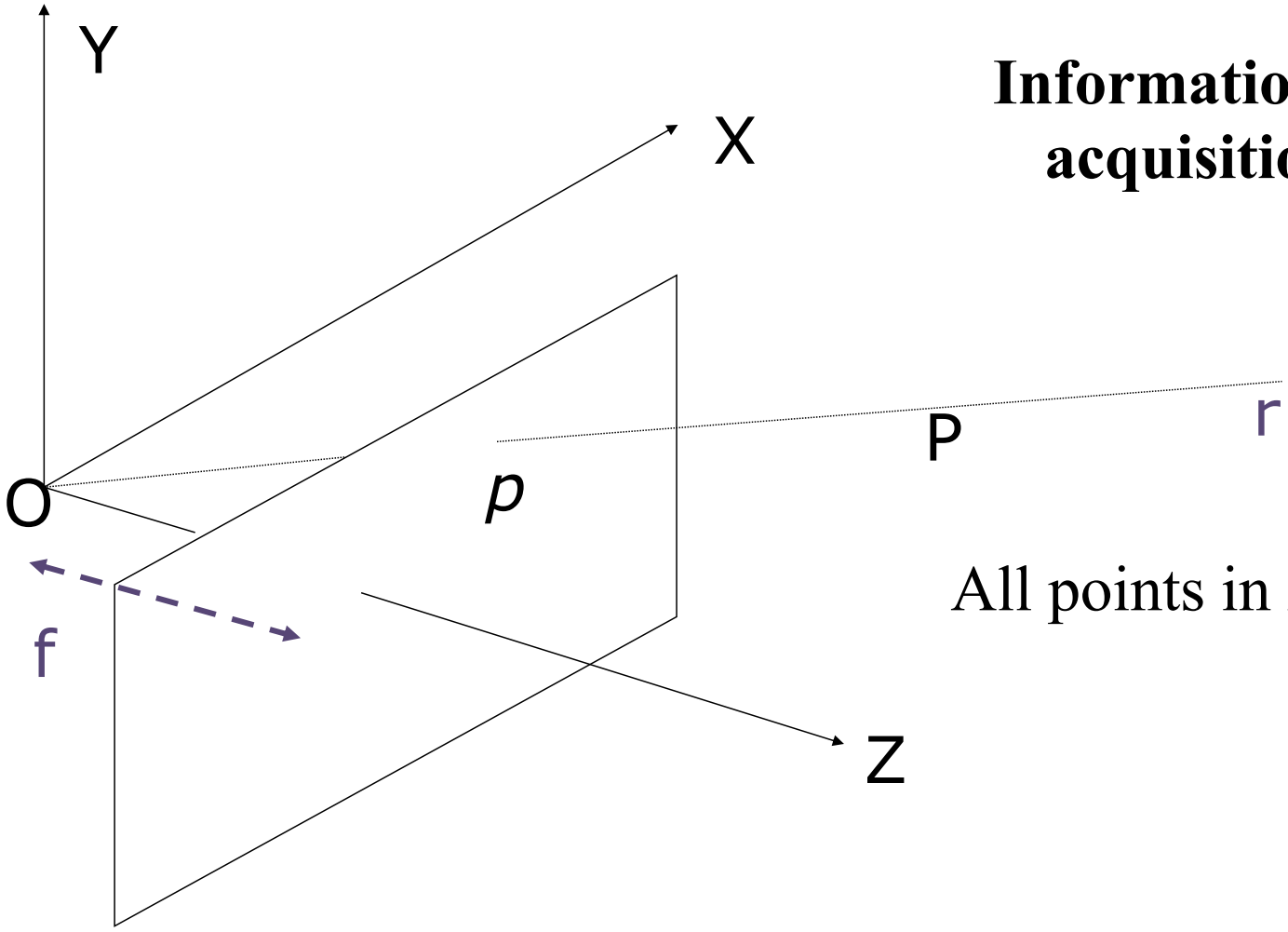


$$x = f\frac{X}{Z}$$

$$y = f\frac{Y}{Z}$$

f focal length

GEOMETRY: PERSPECTIVE OR PINHOLE MODEL

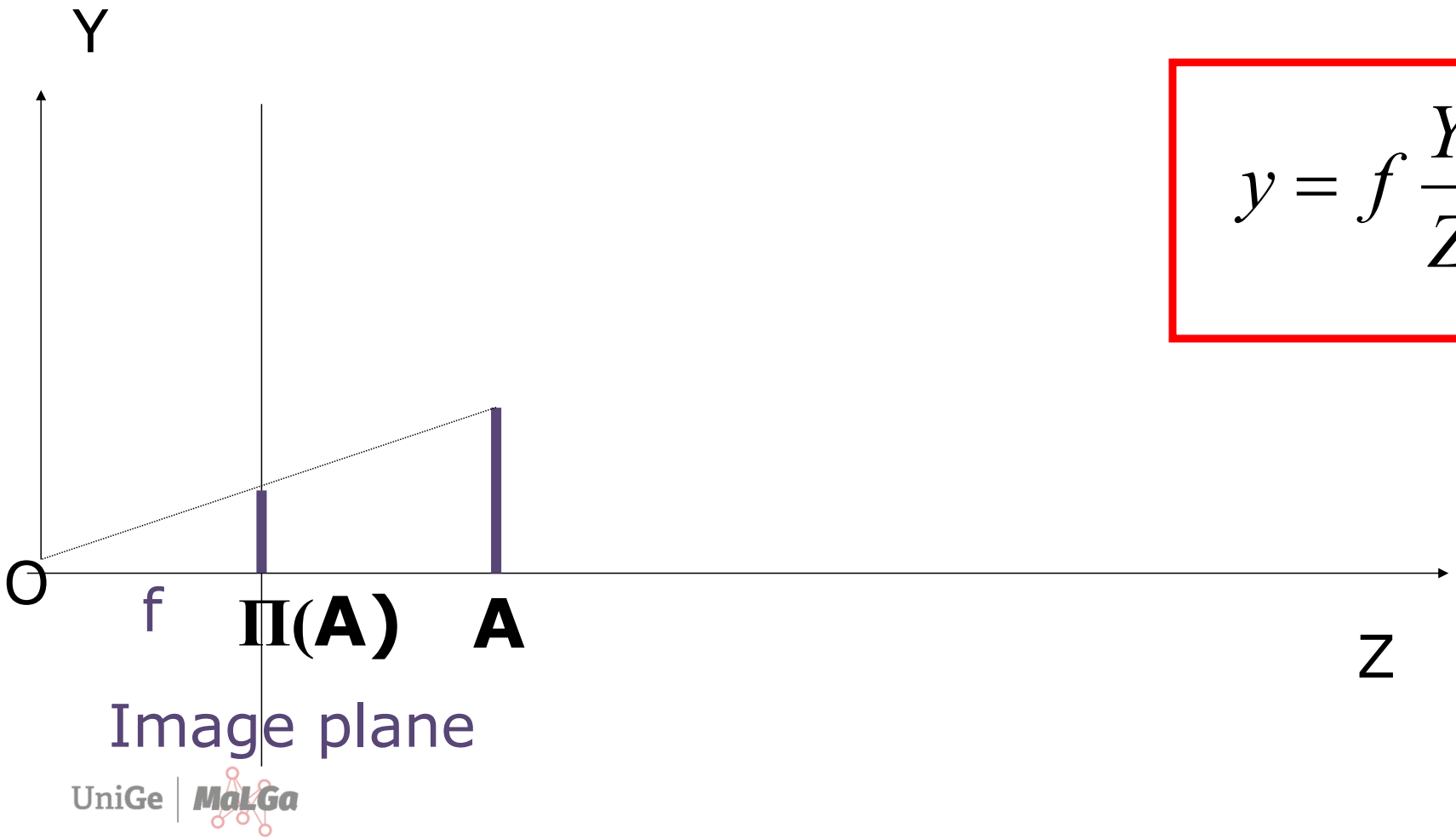


Information loss of the acquisition process

All points in *r* are projected in *p*

GEOMETRY: PERSPECTIVE OR PINHOLE MODEL

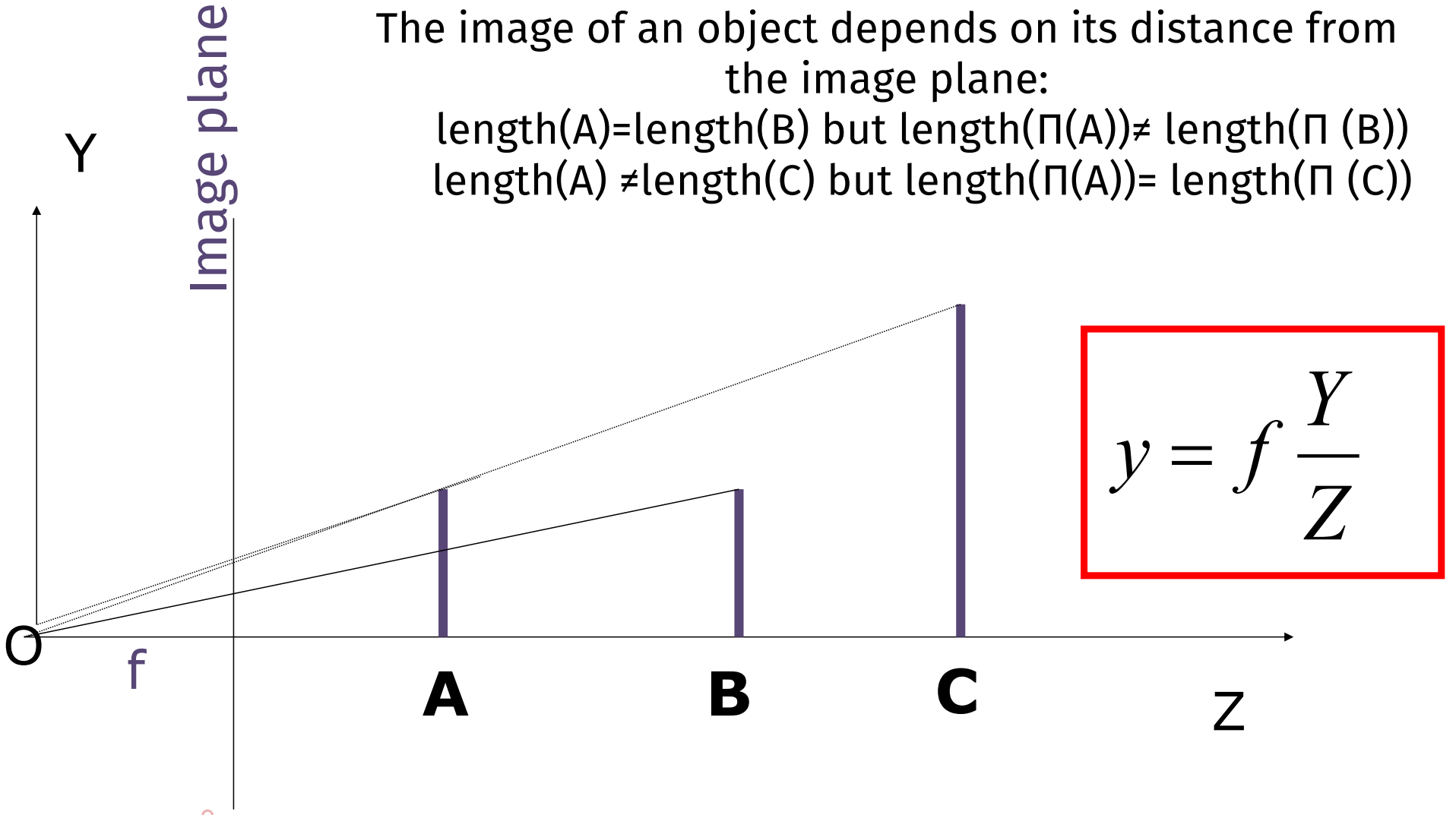
Perspective projection does not preserve distances: $\text{length}(\Pi(A)) \neq \text{length}(A)$



$$y = f\frac{Y}{Z}$$

GEOMETRY: PERSPECTIVE OR PINHOLE MODEL

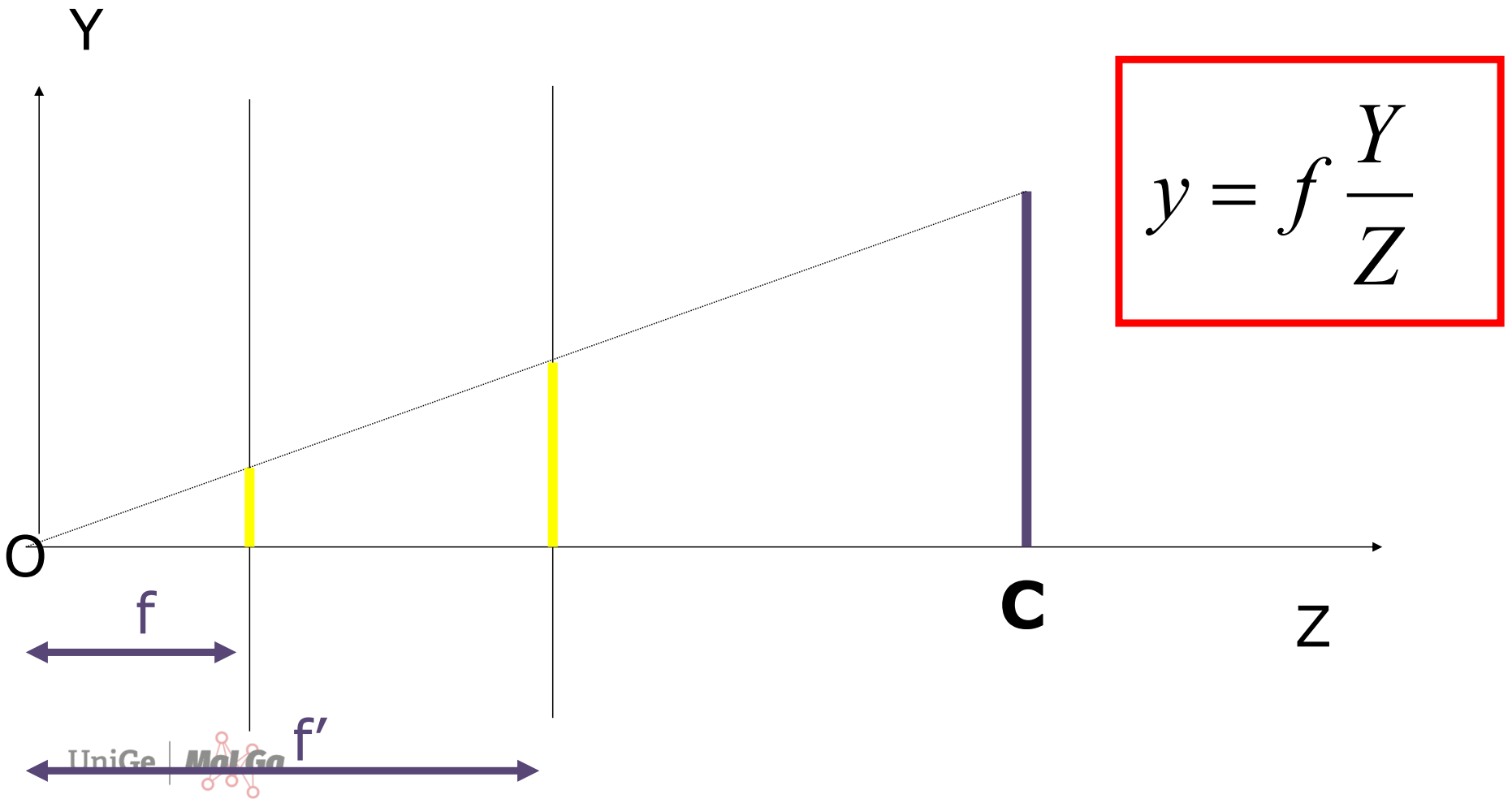
The image of an object depends on its distance from the image plane:
length(A)=length(B) but length(Π(A))≠ length(Π (B))
length(A) ≠length(C) but length(Π(A))= length(Π (C))



$$y = f\frac{Y}{Z}$$

GEOMETRY: PERSPECTIVE OR PINHOLE MODEL

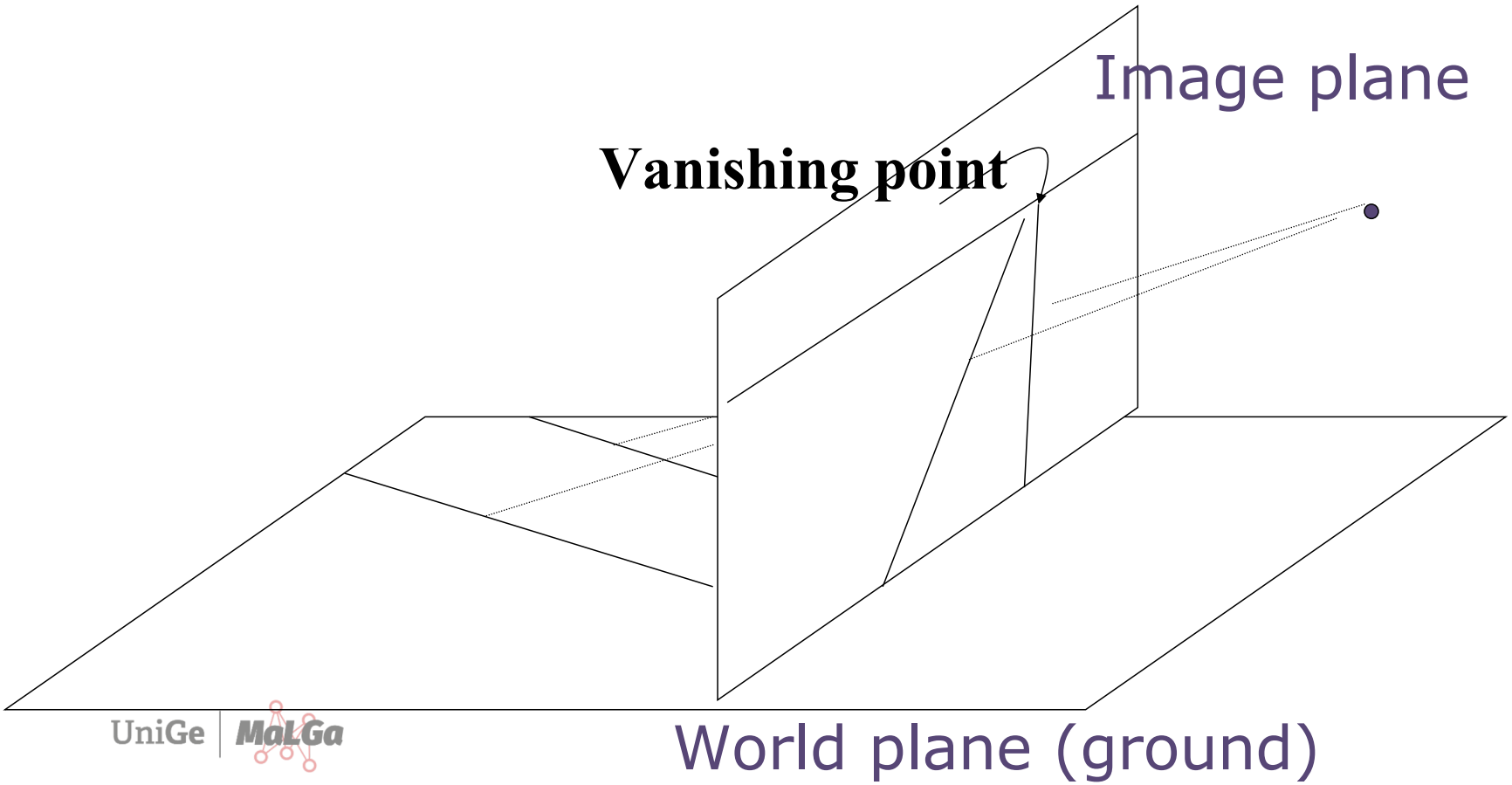
And also depends on the focal length



$$y = f\frac{Y}{Z}$$

GEOMETRY: PERSPECTIVE OR PINHOLE MODEL

Perspective projection does not preserve parallelism



GEOMETRY: PERSPECTIVE OR PINHOLE MODEL

The perspective model preserves lines

(and indeed it does not model distortions)

This property can be shown by drawing a line R in the space and considering the plane passing through R and the optical center

- The intersection of the obtained plane with the image plane is the line *r* the locus of projected points

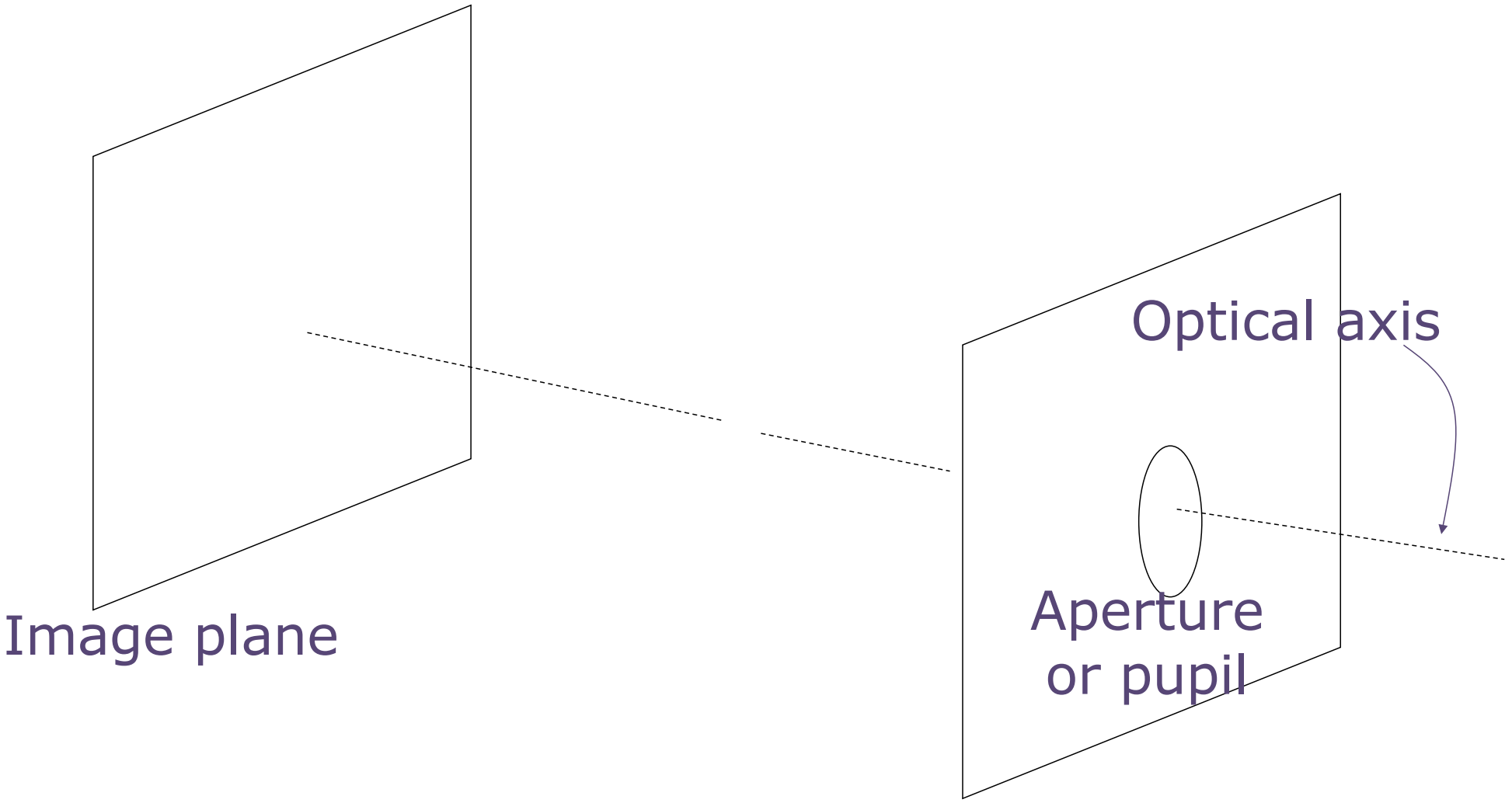
LIMITS OF THE PIN-HOLE MODEL

The pin-hole model is an effective formalization of the geometry of image formation

It is not a practical model:

- It would require very high ***exposure time:*** if a photoreceptor is reached by a small amount of light it needs time (several seconds) to record the information and form the image

OPTICS



OPTICS

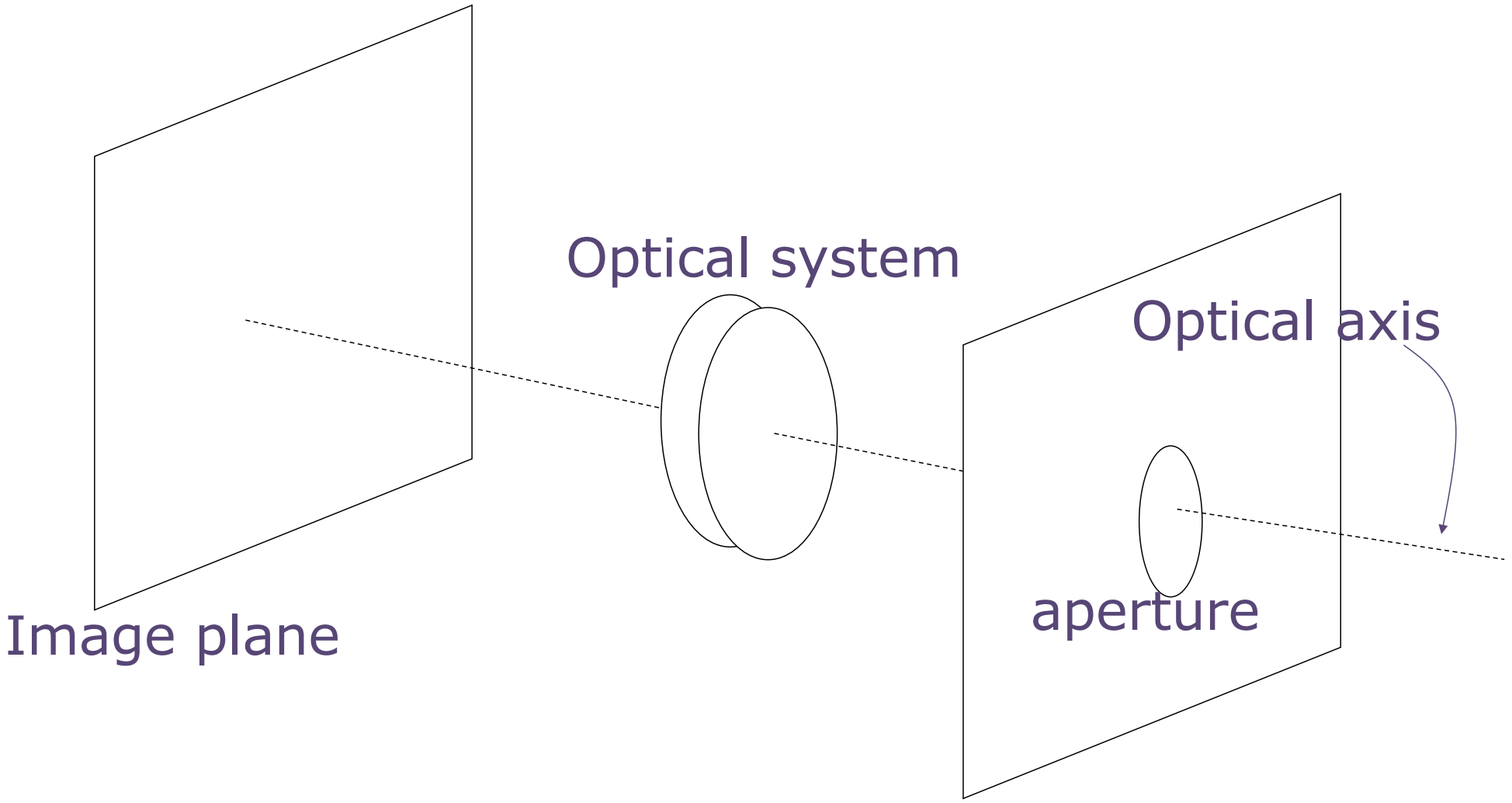
A single point of a scene reflects light coming from possibly many directions

- many rays reflected by the same point may enter the camera

To obtain *sharp* images all rays coming from a single scene point P must converge into a single image point p (P is *in focus*)

- Reduce the aperture to a point (*pin-hole)*
- Introduce an optical system (lens + aperture, ..) designed to make all rays coming from the same 3D point converge into a single 2D point

OPTICS

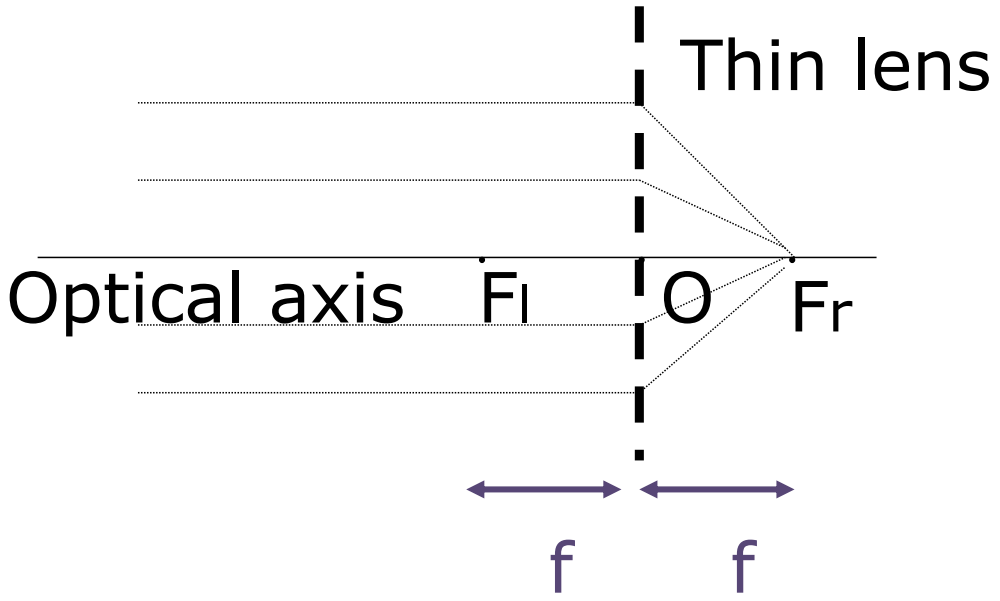


OPTICS: THIN LENS model

A useful approximation is the **thin** lens model

Real acquisition systems (artificial or biological) use more complex optics composed by more than one lens

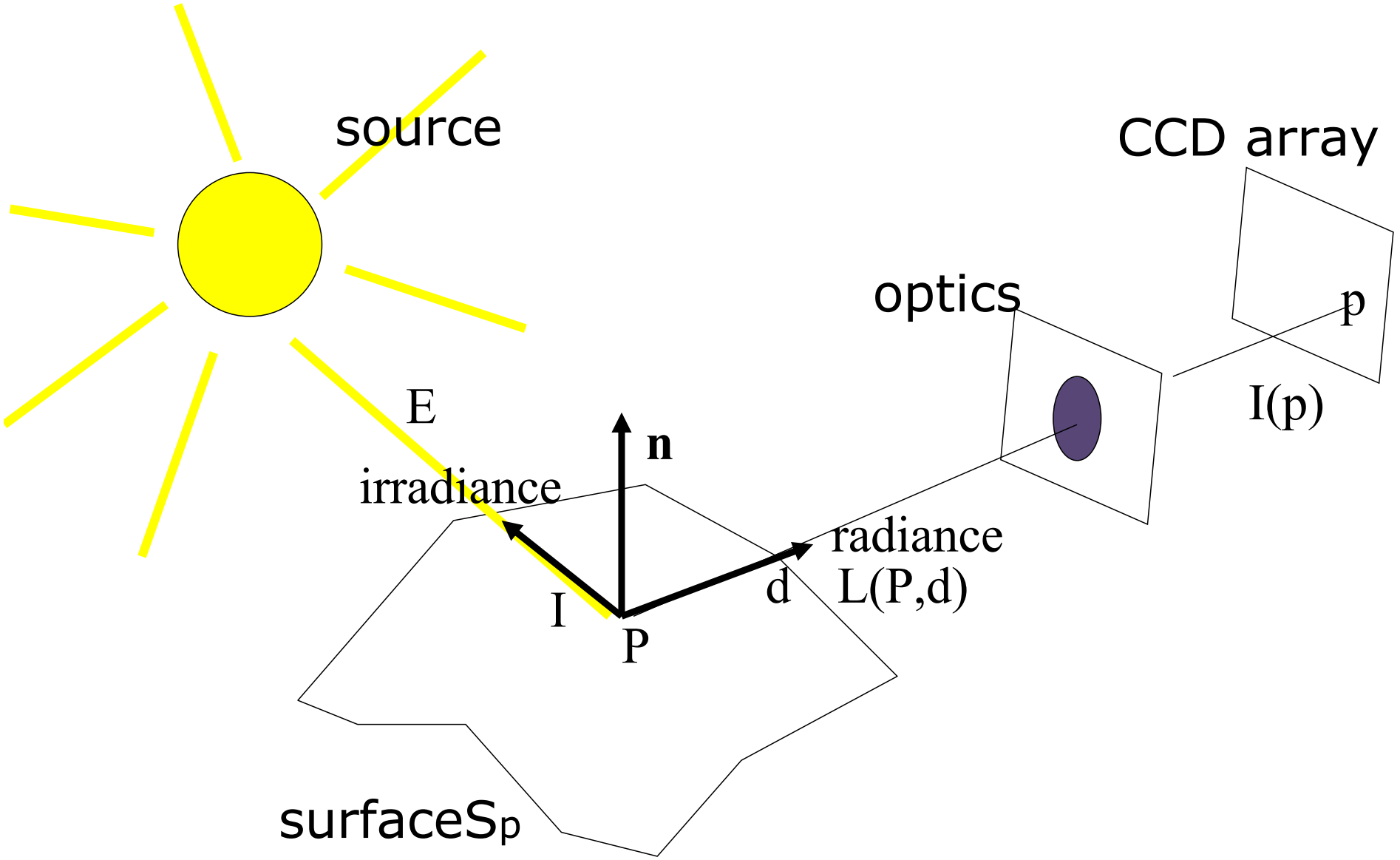
OPTICS: THIN LENS model



Rays parallel to the optical axis are reflected by the lens through a point of the optical axis called a *focus*

Rays passing through the optical center O are not altered.

PHOTOMETRY


source
CCD array
optics
p
I(p)
E
irradiance
n
radiance
L(P,d)
d
I
P
surfaceSp

DIGITALIZATION

The digitalization process is formed by two steps

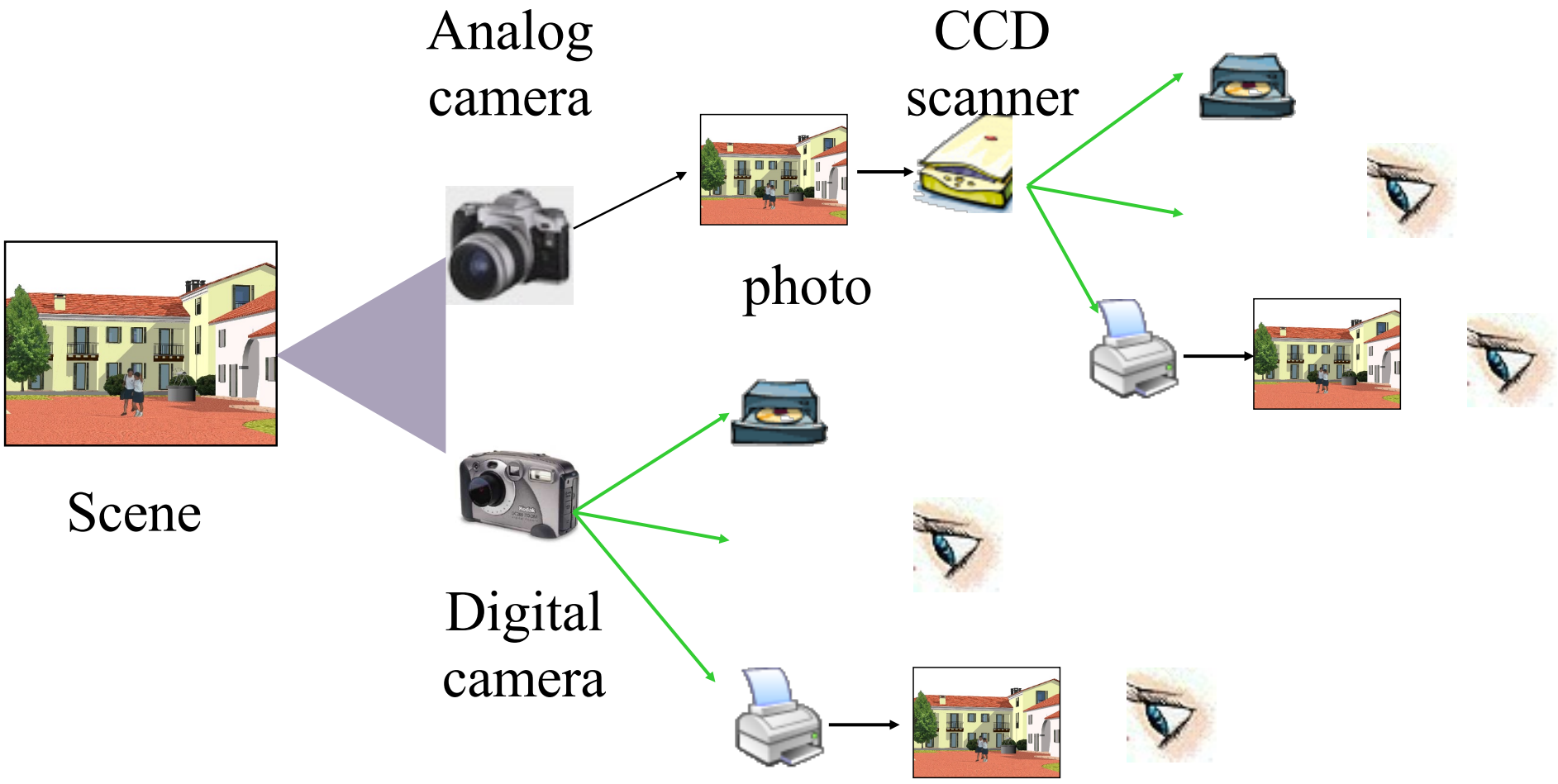
✧*Measurement*

✧*Conversion from analog to digital*

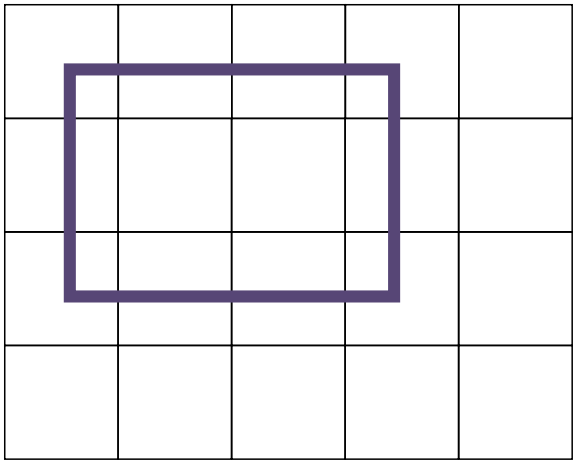
In the first step the physical quantity to be represented (eg light) is measured by an appropriate device that converts it into an electrical continuous signal

In the second step the electrical signal is converted into a digital signal

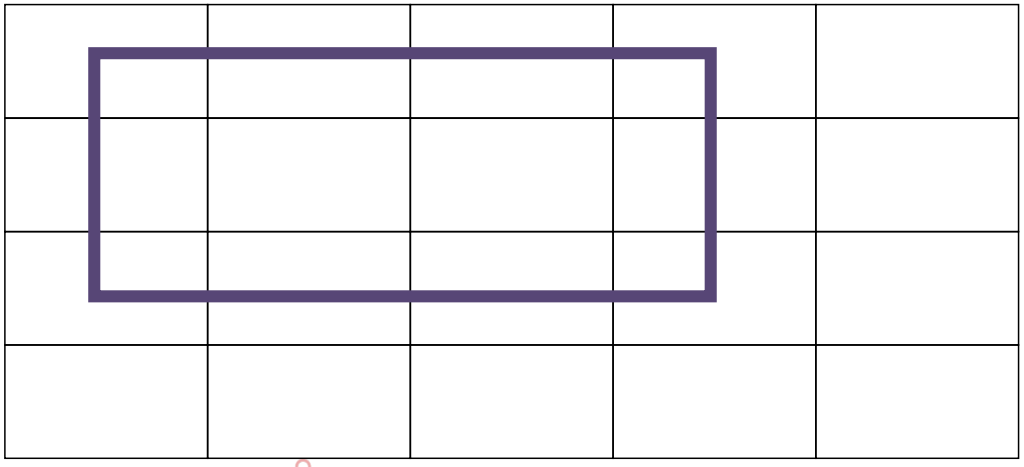
DIGITALIZATION



ASPECT RATIO

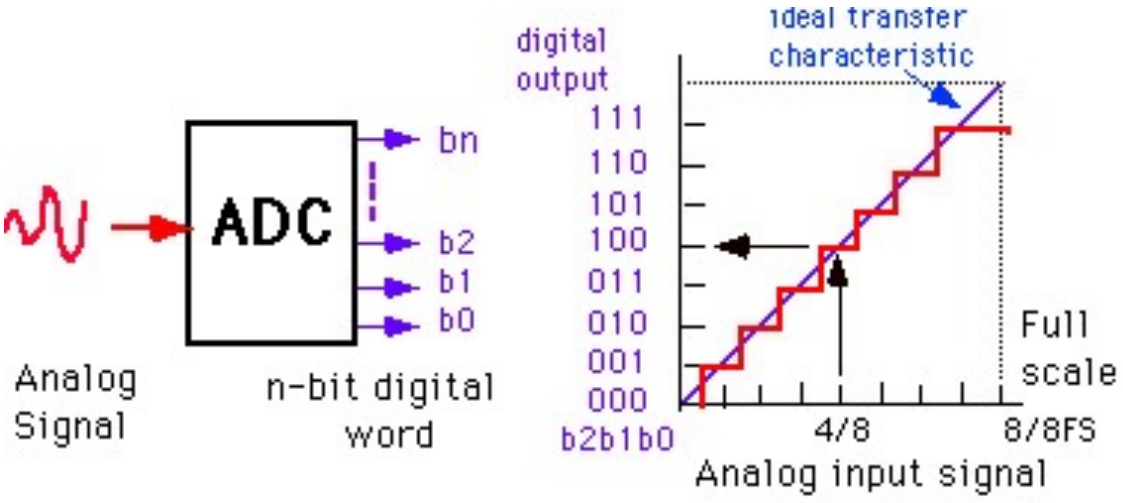


CCD aspect ratio does not necessarily correspond to image aspect ratio



QUANTIZATION

Quantization of intensity scale: number of bits associated with the digital encoding



QUANTIZATION

1 bit

8 bit (1 byte)

16 bit (2 byte)

24 bit (true color)

Numer of bits (B)	Depth (2^B) i	Max value	Memory occupacy [512x512 uncompressed image]
1	2	1	32 Kb
8 (unsigned char)	256	255	(512x512x8)bit = 256 Kb
16 (int)	65536	65535	(512x512x16)bit = 512 Kb
24 (color: 3 int)	16 10^6	255 (per color)	(512x512x8)x3 bit = 768 Kb
32 (long int,float)	4 10^9	2^{32}-1	(512x512x32) bit=1 Mb

Wrap up – day 1

Today we have introduced the main ingredient of computer vision: digital images

- Pixel content
- Histogram representations
- Operations on images
- The image formation process

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