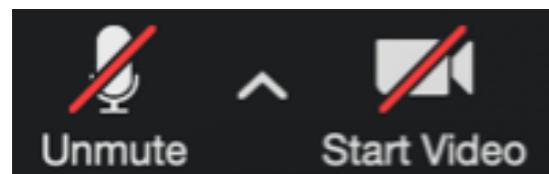




AEROSP 584 - Navigation and Guidance: From Perception to Control



Lectures start at
10:30am EST

Vasileios Tzoumas

Lecture 16



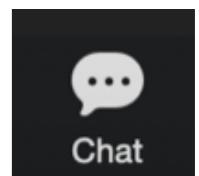
Based on slides made by Luca Carlone @



To ask questions:



Raise Hand

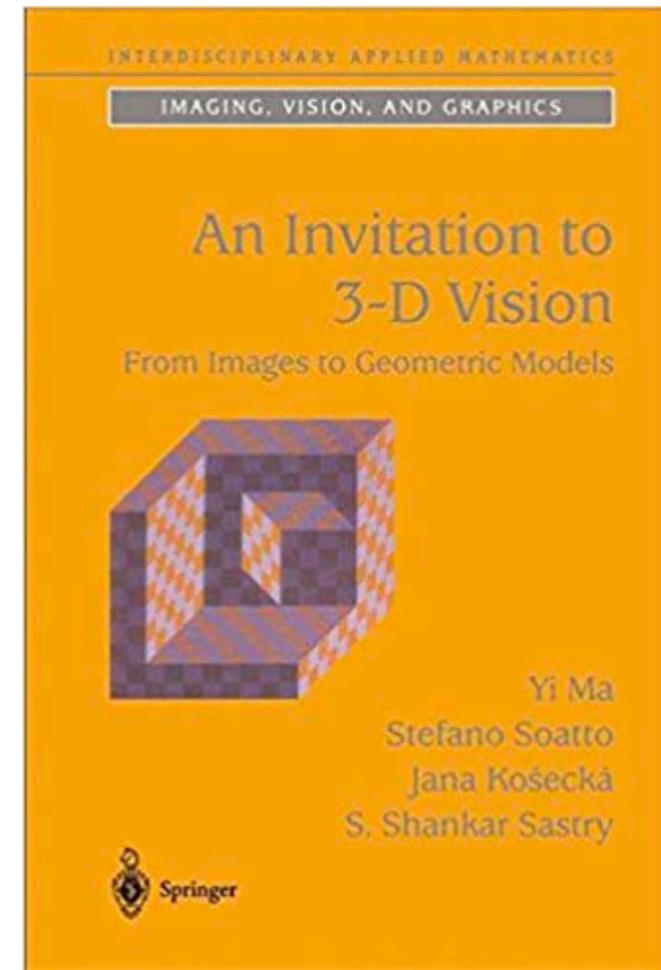


or

Chat

Today

- Image Formation
- Pinhole Camera Model

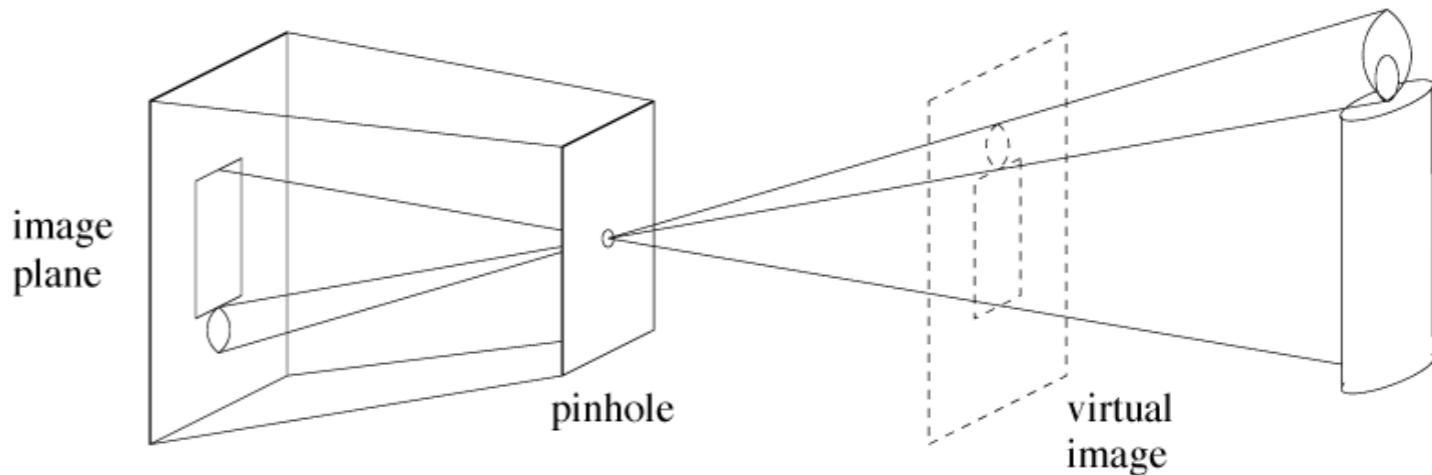


Chapter 3

Image Formation

Image Formation

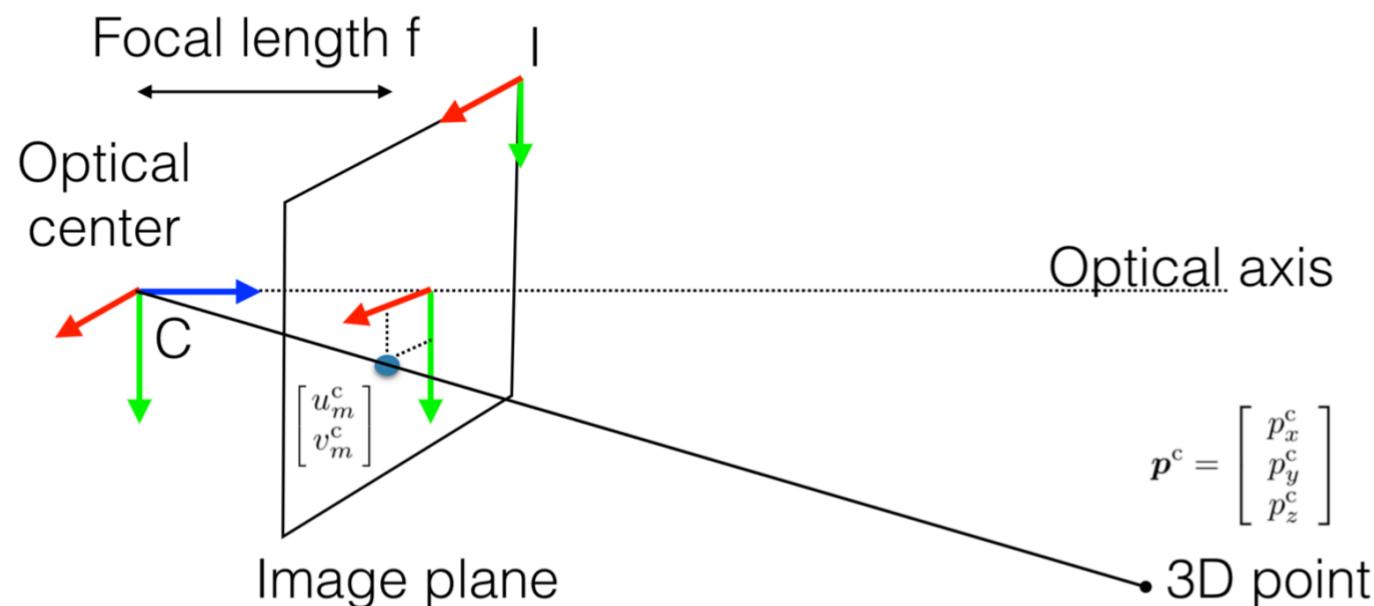
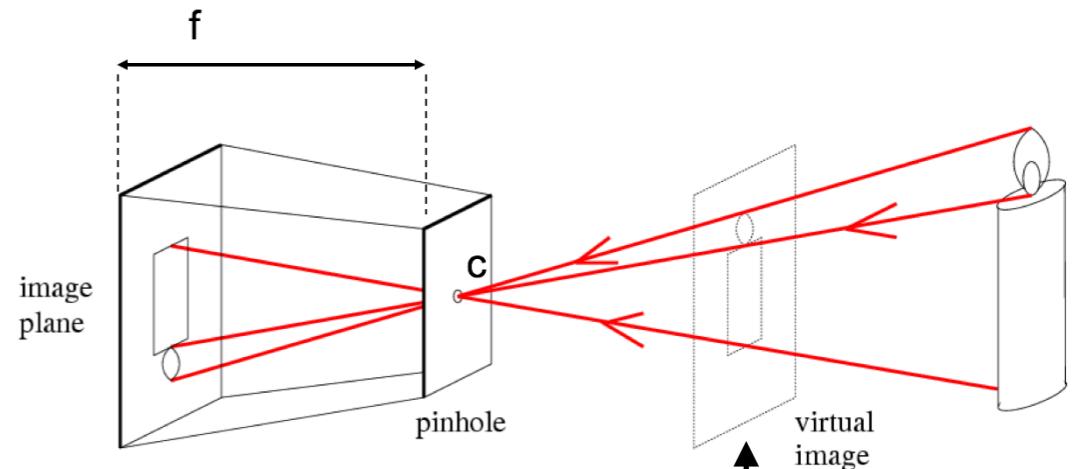
- How to capture a 3D scene on a 2D image?
- **Camera obscura**
(Latin: “dark room”):
 - optical device that projects 3D scene to a surface
 - box with a hole on one side
 - known for several centuries:
 - Mo Ti, Chinese philosopher
(5th Century B.C.)
 - Leonardo da Vinci
(1452-1519)



Frisius (1544)

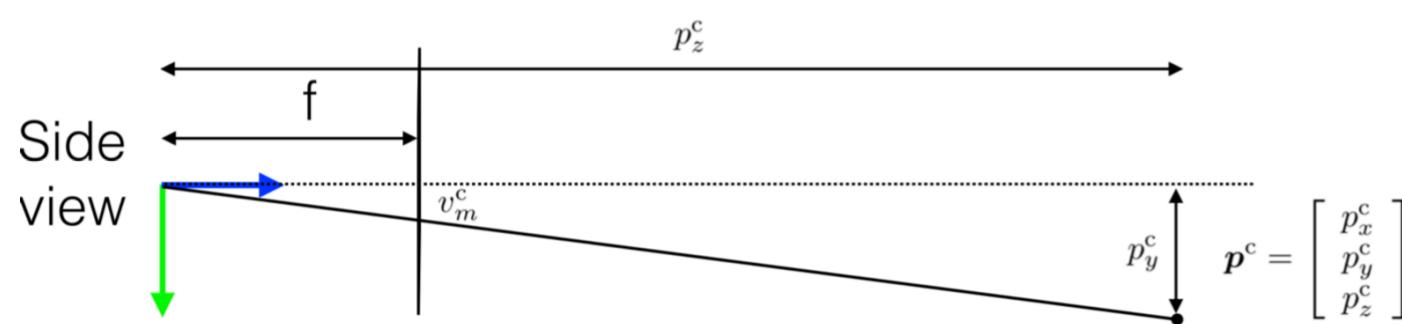
Geometry: Pinhole Camera Model

- How to compute the 2D projection (pixel) of a given 3D point?



f = focal length
 c = center of the camera

Frontal
pinhole
model

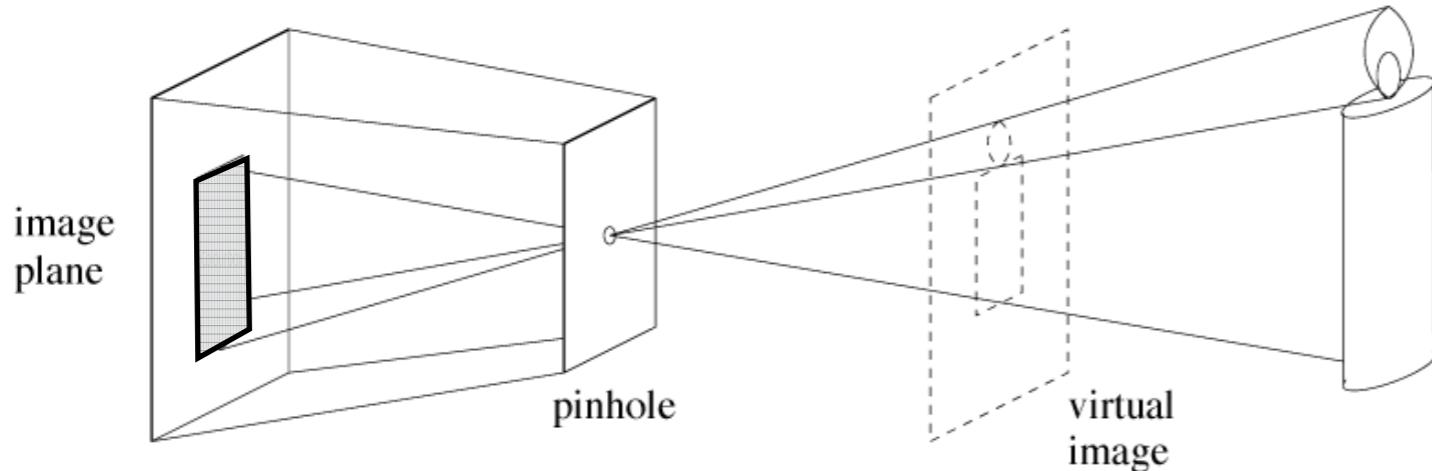


$$p^c = \begin{bmatrix} p_x^c \\ p_y^c \\ p_z^c \end{bmatrix}$$

Let's do
some math

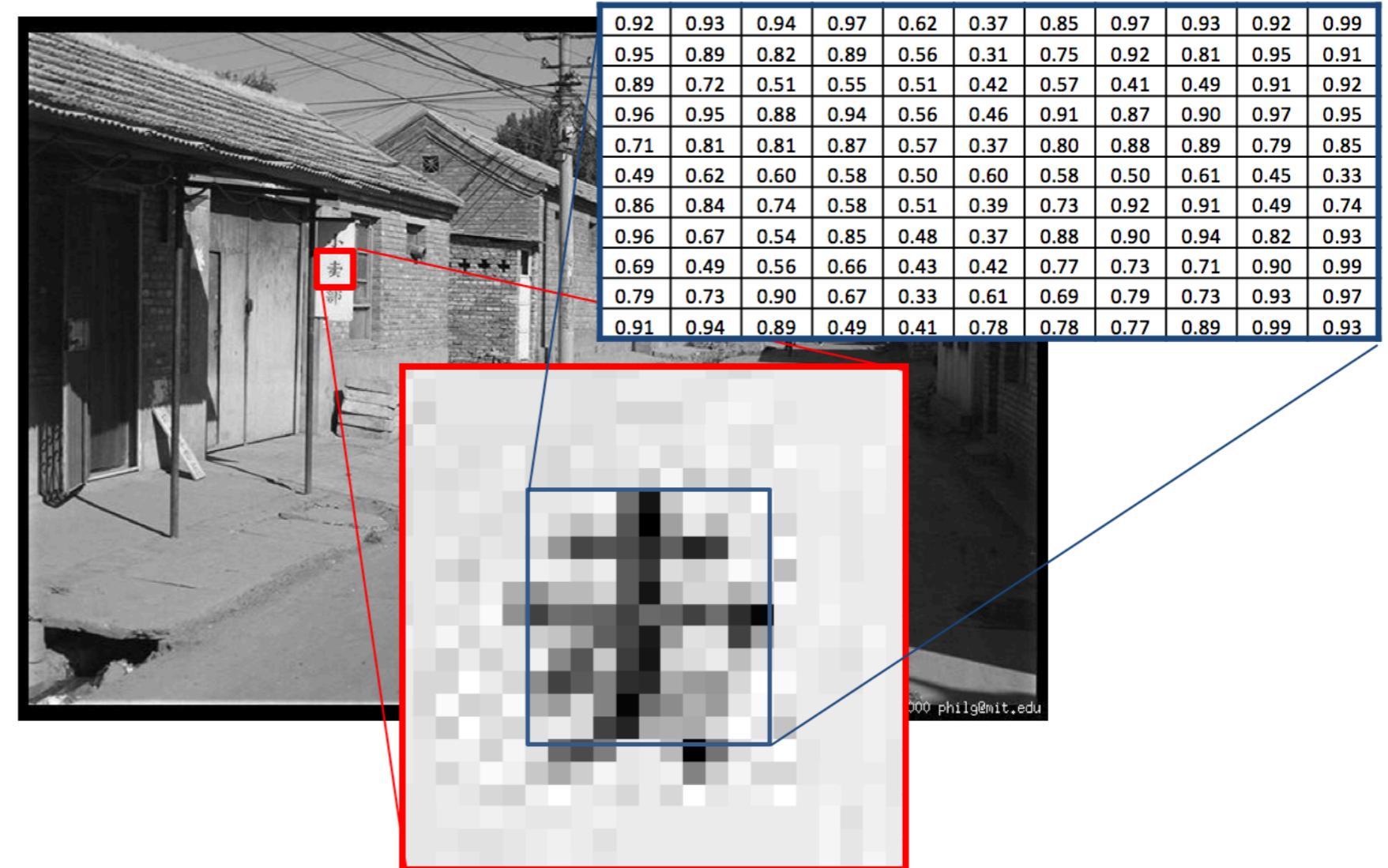
Figure 11.1: Pinhole Model.

Digital Photography



2D array of
“light sensors”

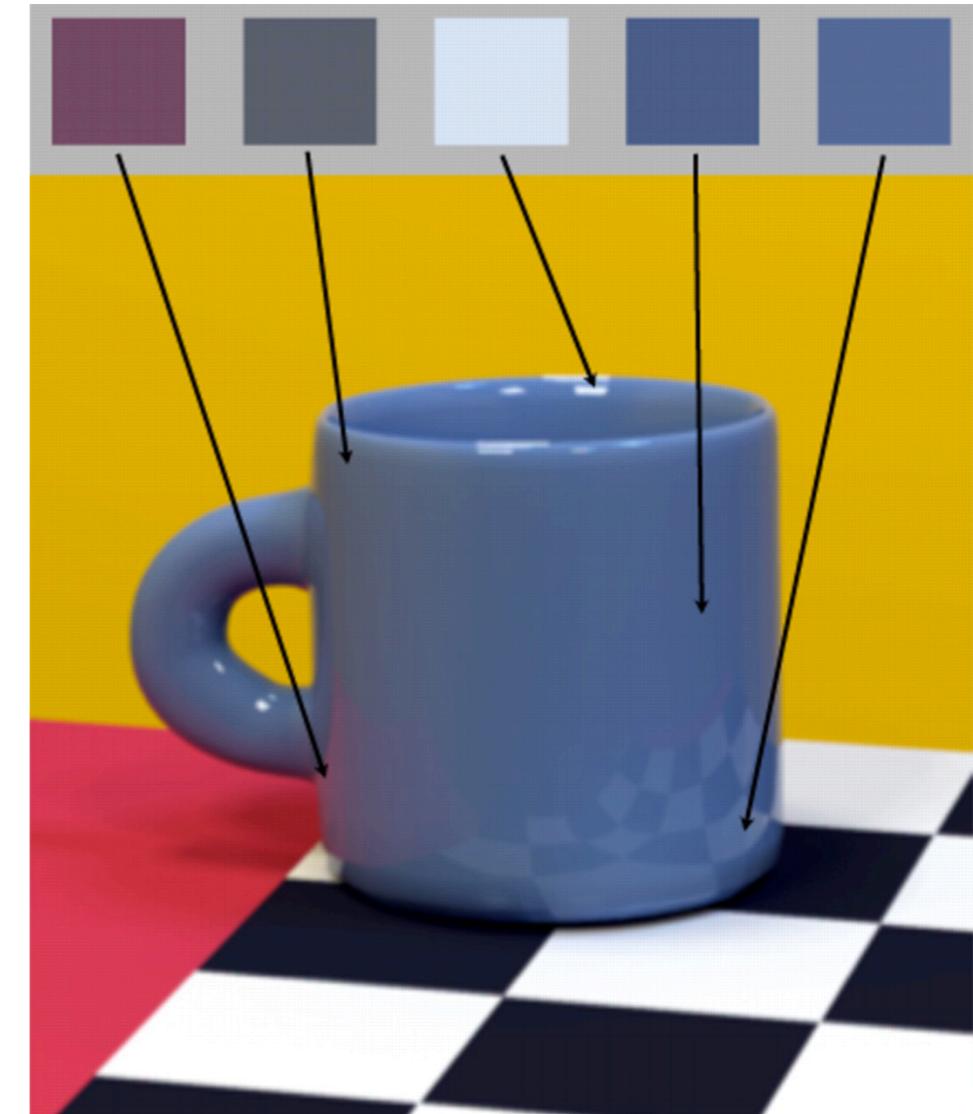
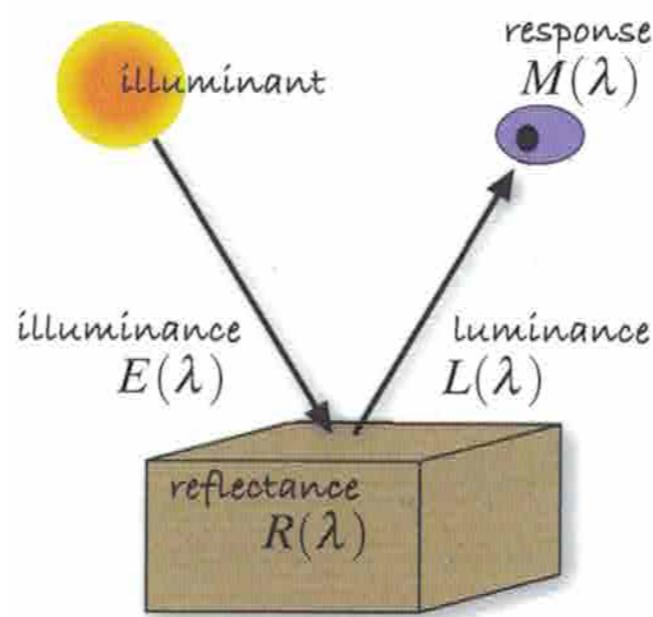
- CCD (charge-coupled device, 1960)
- CMOS (complementary metal-oxide semiconductor, 1963)



Appearance: Light and Colors

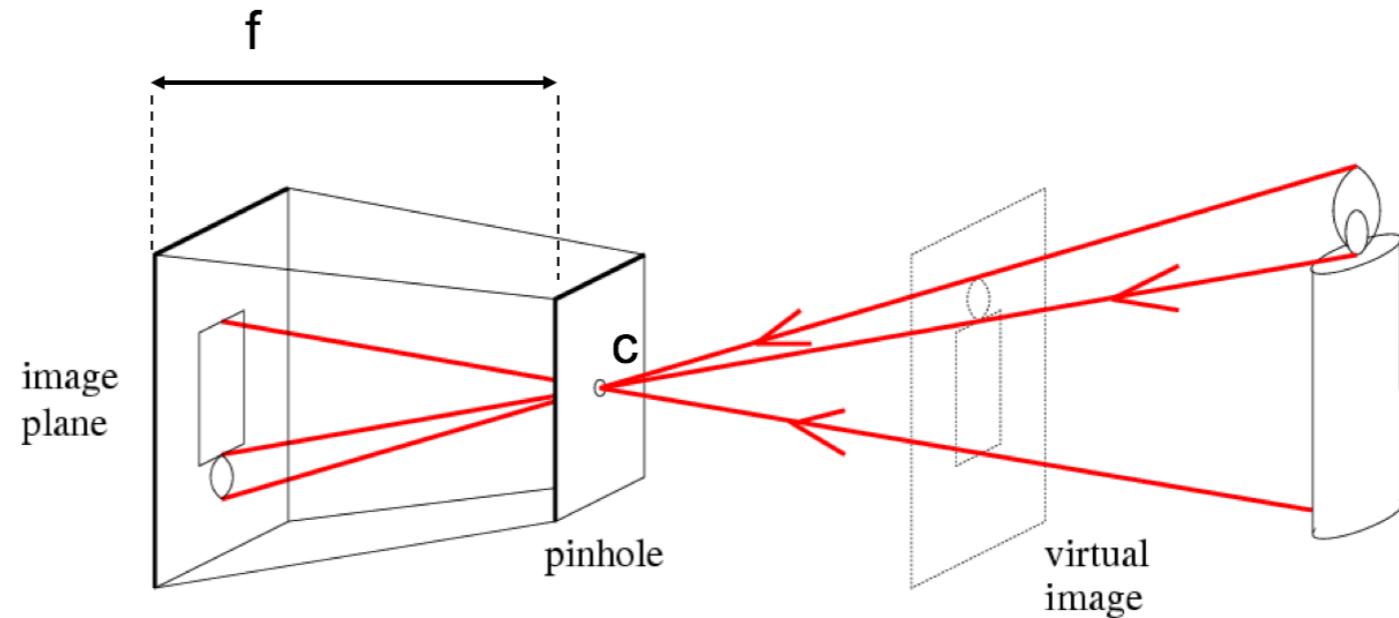


Perceived appearance is the result of (i) geometry, (ii) illumination, (iii) material properties



Perspective Projection

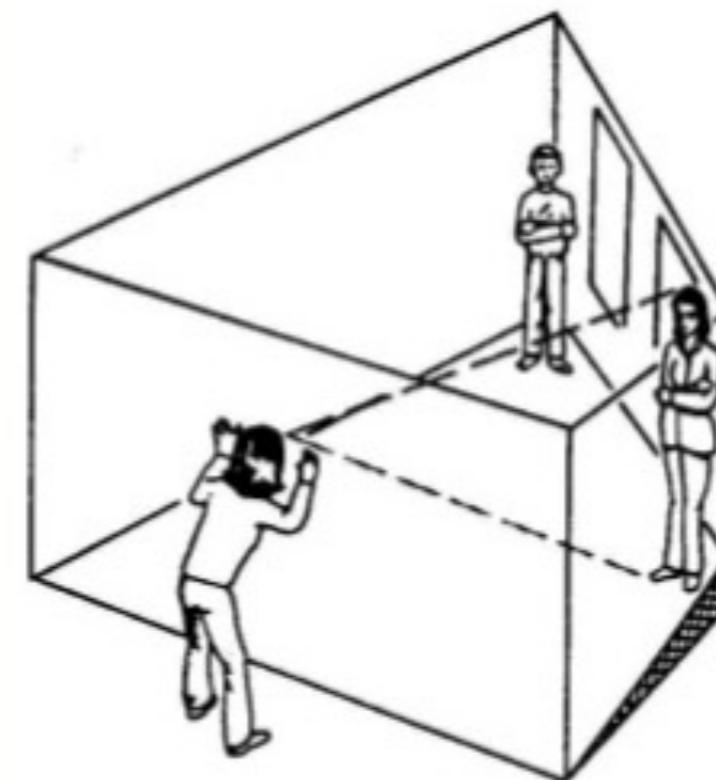
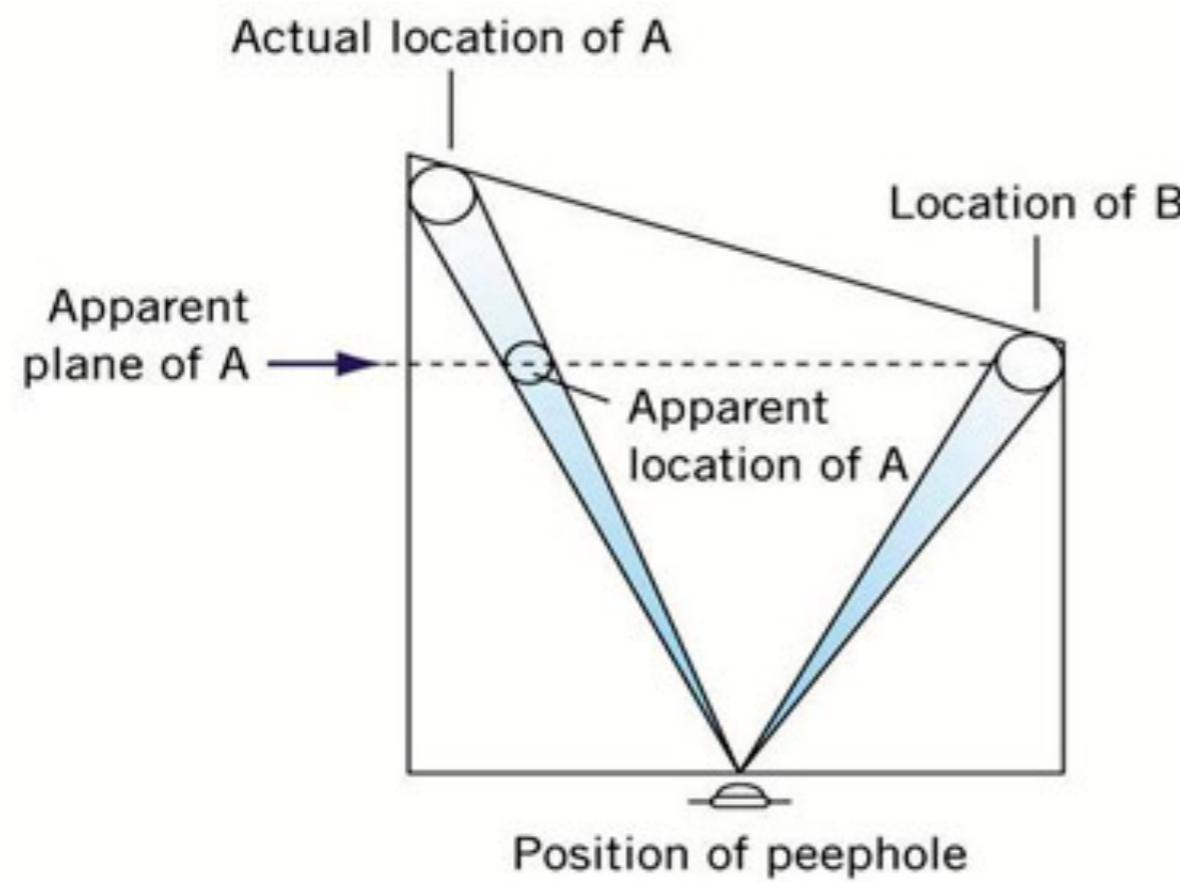
- what is lost?
 - depth?



f = focal length
 c = center of the camera



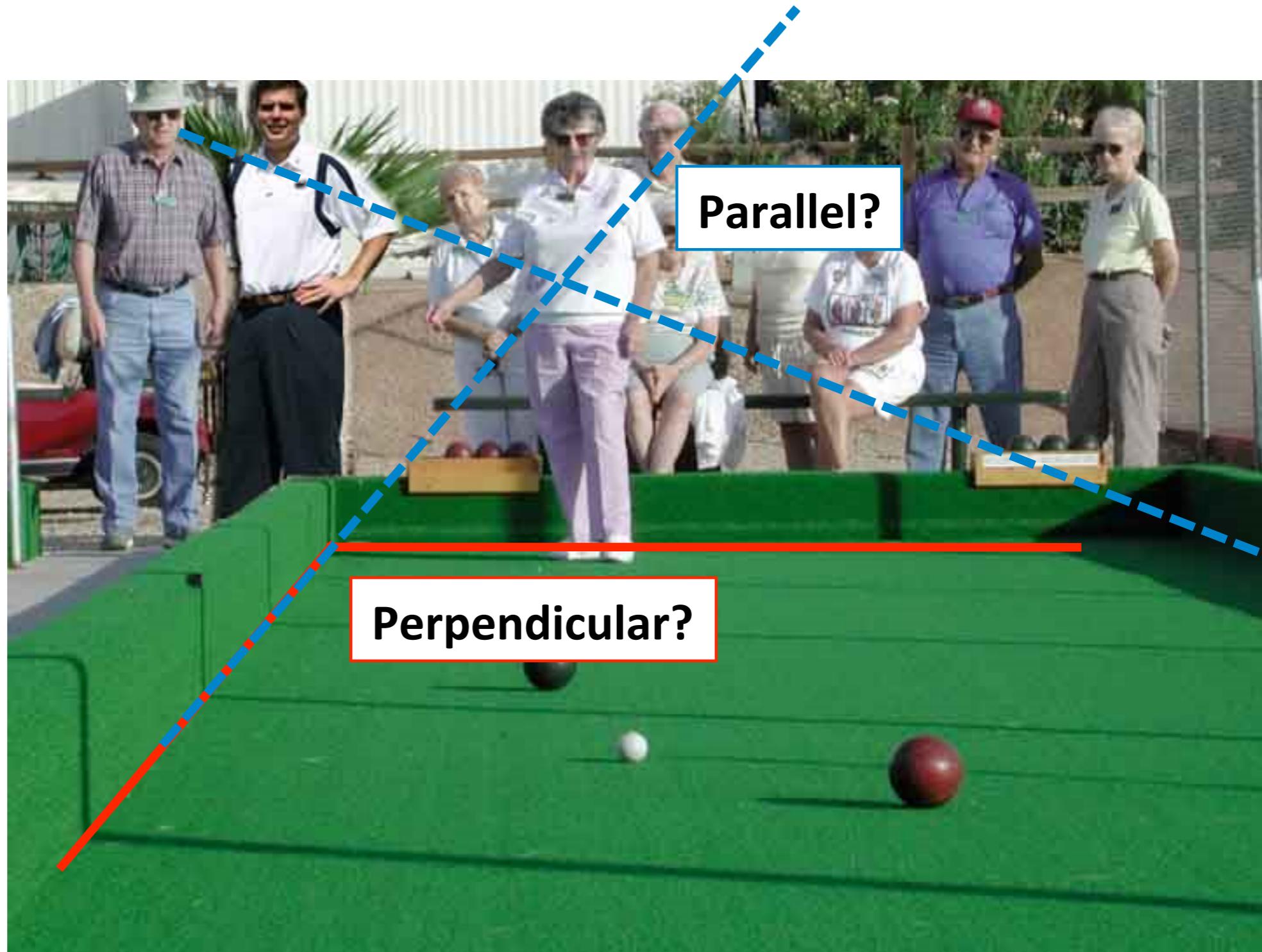
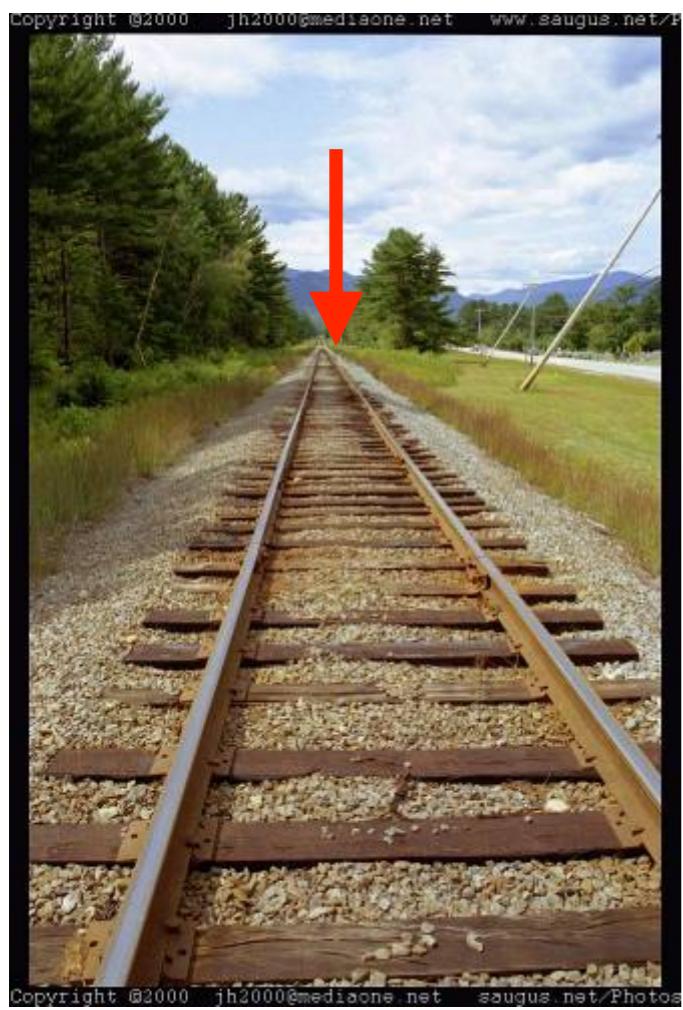
Ames Room



Ames, 1946

Perspective Projection

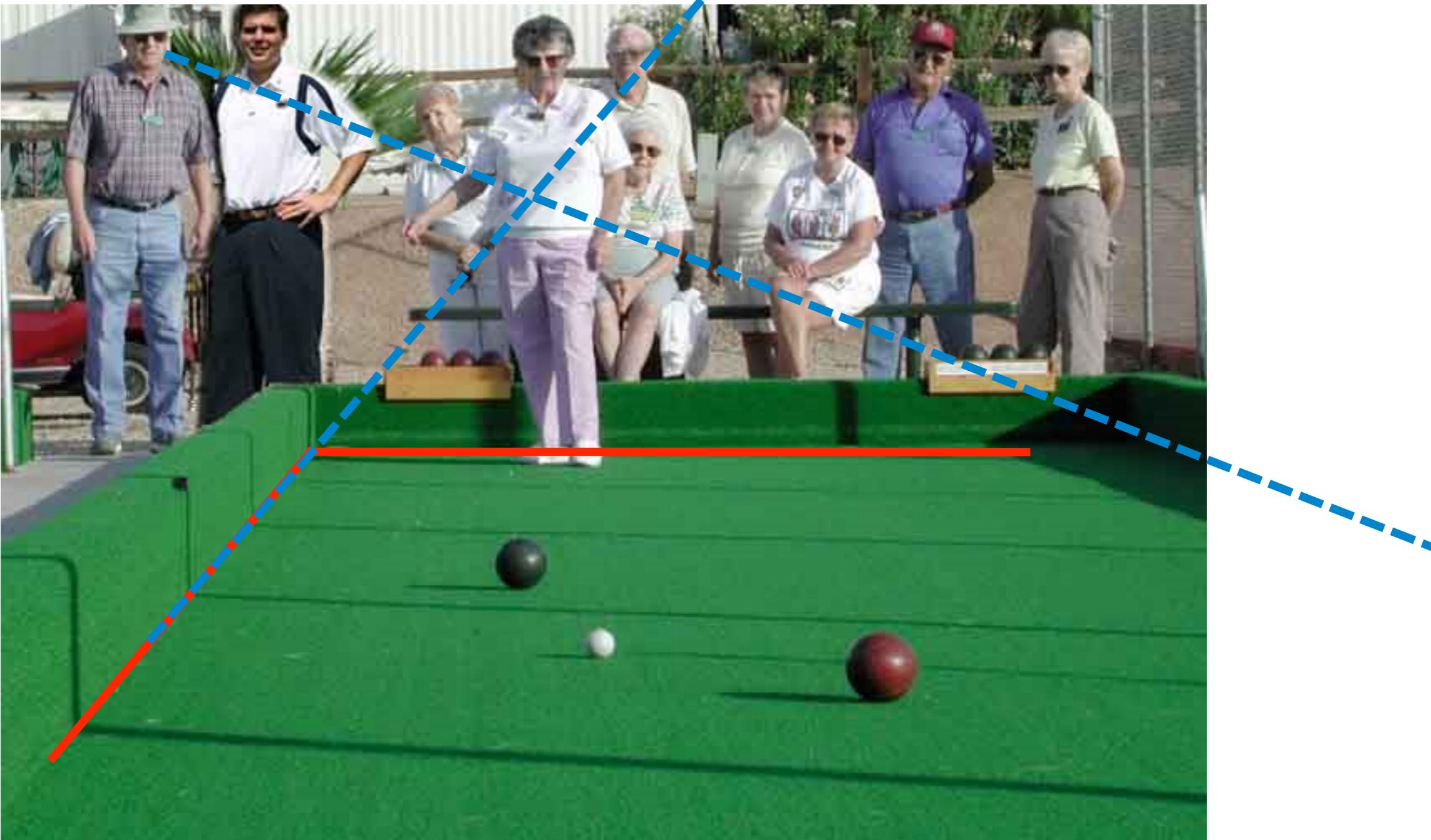
- what is lost?
 - depth?
 - length?
 - angles?



Parallel lines which intersect ...

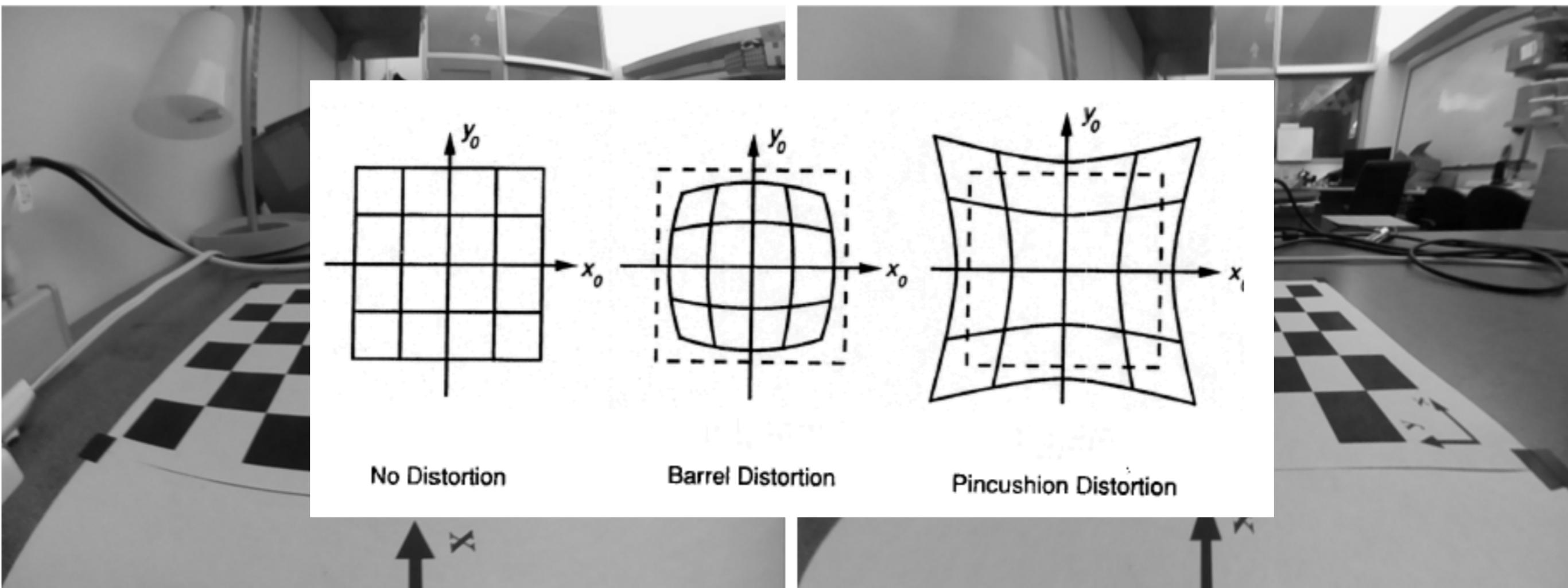
Perspective Projection

- what is preserved?
 - straight lines remain straight



The final Touch: Adding a Lens

- Pinhole model is based on the geometry of the **camera obscura**
- In practice: add a **lens** in front of the aperture to capture more light
- Pinhole model holds, but **distortion** may appear due lens imperfections



- distortion can be described mathematically using **distortion parameters**
- can be estimated during calibration and compensated for (**undistortion**)