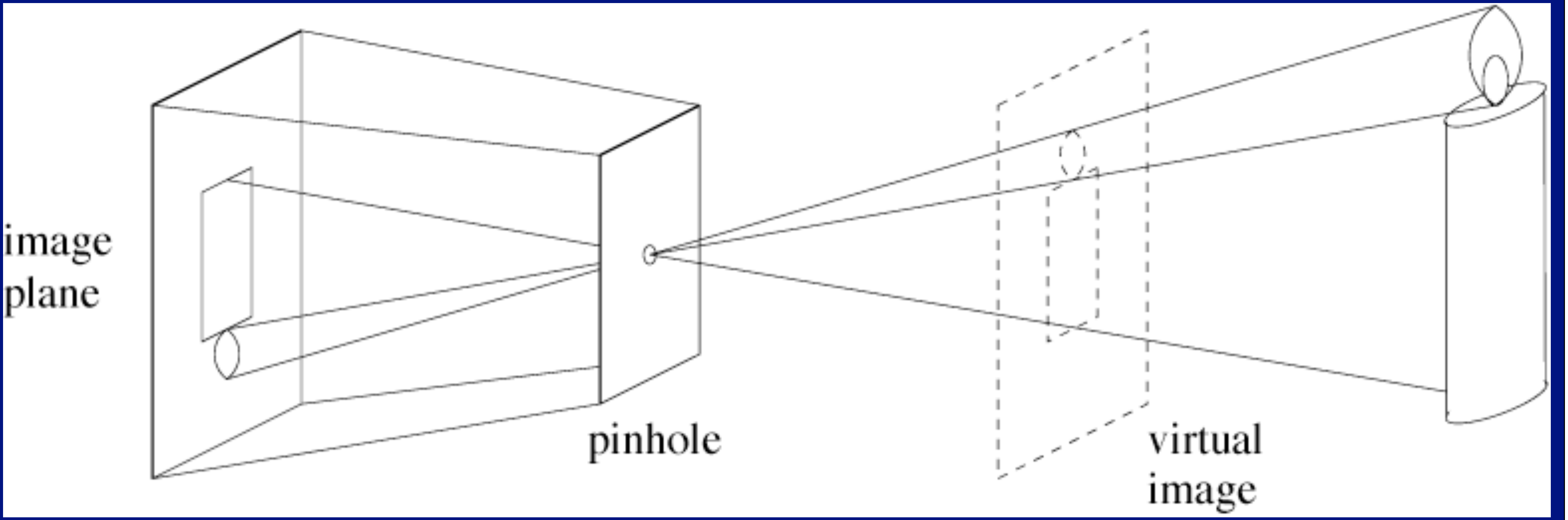
Cameras

D.A. Forsyth

Cameras

- First photograph due to Niepce
- First on record, 1822
- Key abstraction
  - Pinhole camera

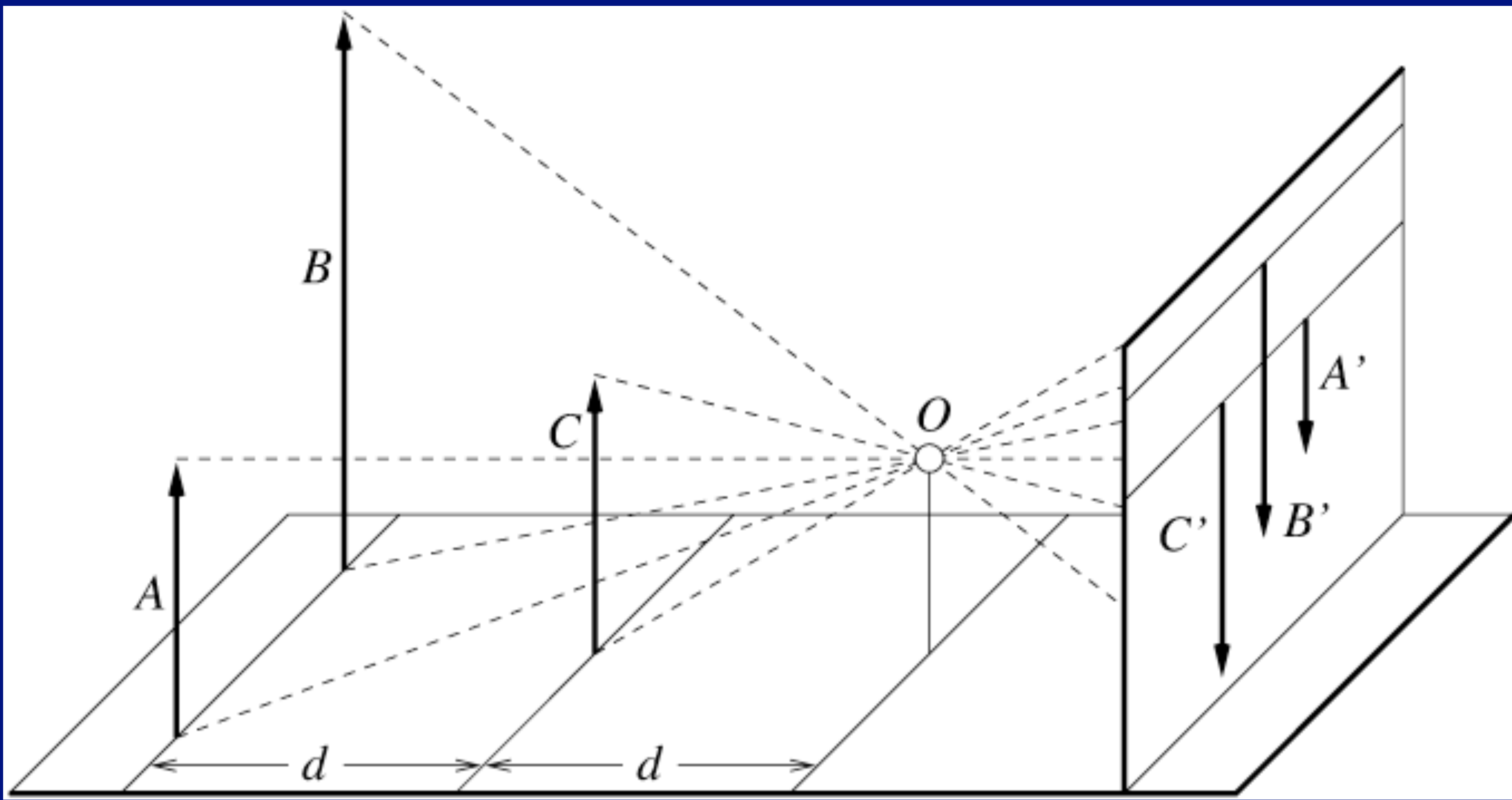
Pinhole camera



Freestanding room-sized camera obscura outside Hanes Art Center at the University of North Carolina at Chapel Hill. Picture taken by User:Seth Ilys on 23 April 2005 and released into the public domain.

A photo of the Camera Obscura in San Francisco. This Camera Obscura is located at the Cliff House on the Pacific ocean. Credit to Jacob Appelbaum of http://www.appelbaum.net.

Distant objects are smaller in a pinhole camera



Vanishing points

- Each set of parallel lines meets at a different point
  - The vanishing point for this direction
- Coplanar sets of parallel lines have a horizon
  - The vanishing points lie on a line
  - Good way to spot faked images

Railroad tracks "vanishing" into the distance

Source

own work

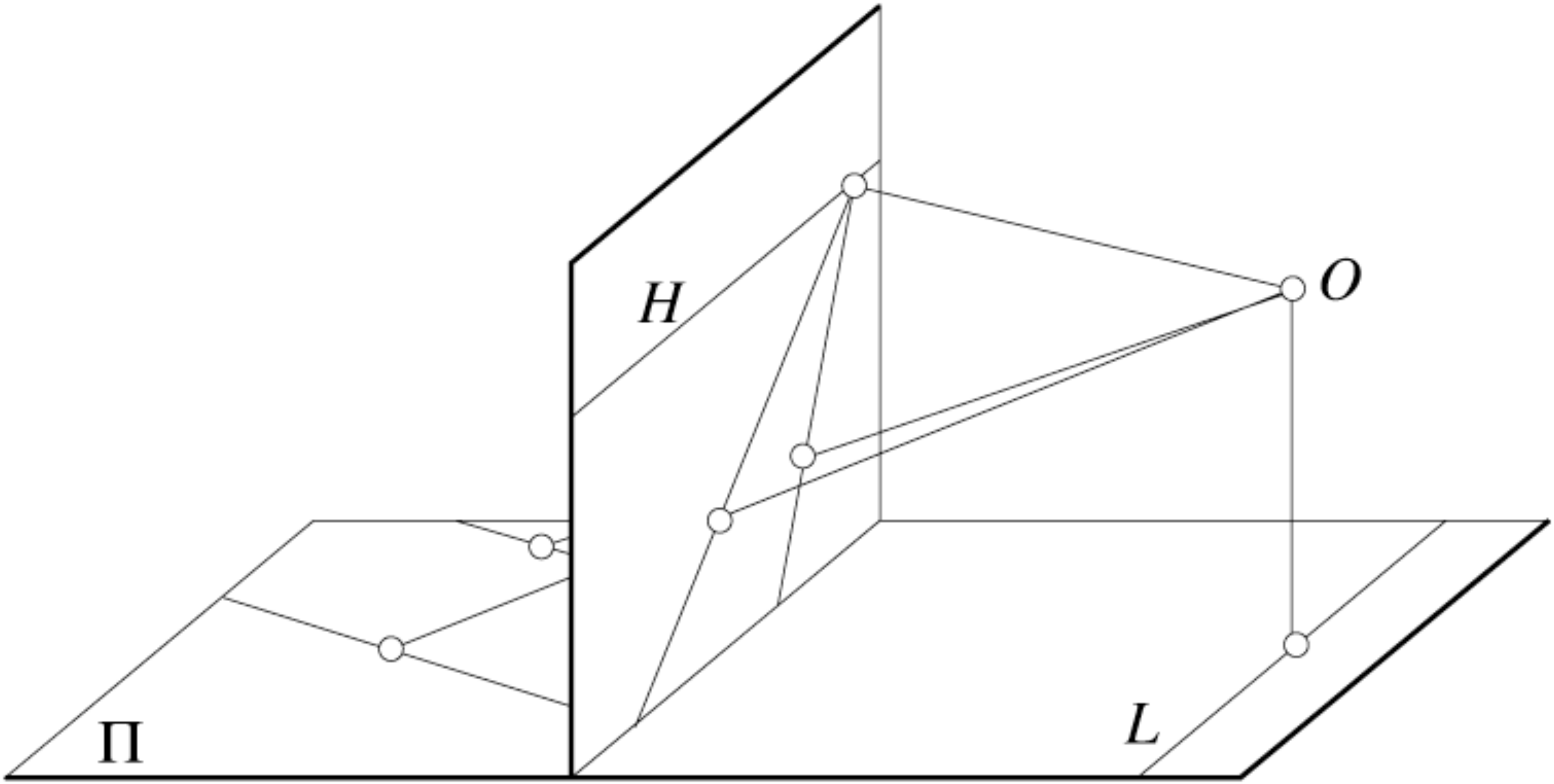
Date

2006-05-23

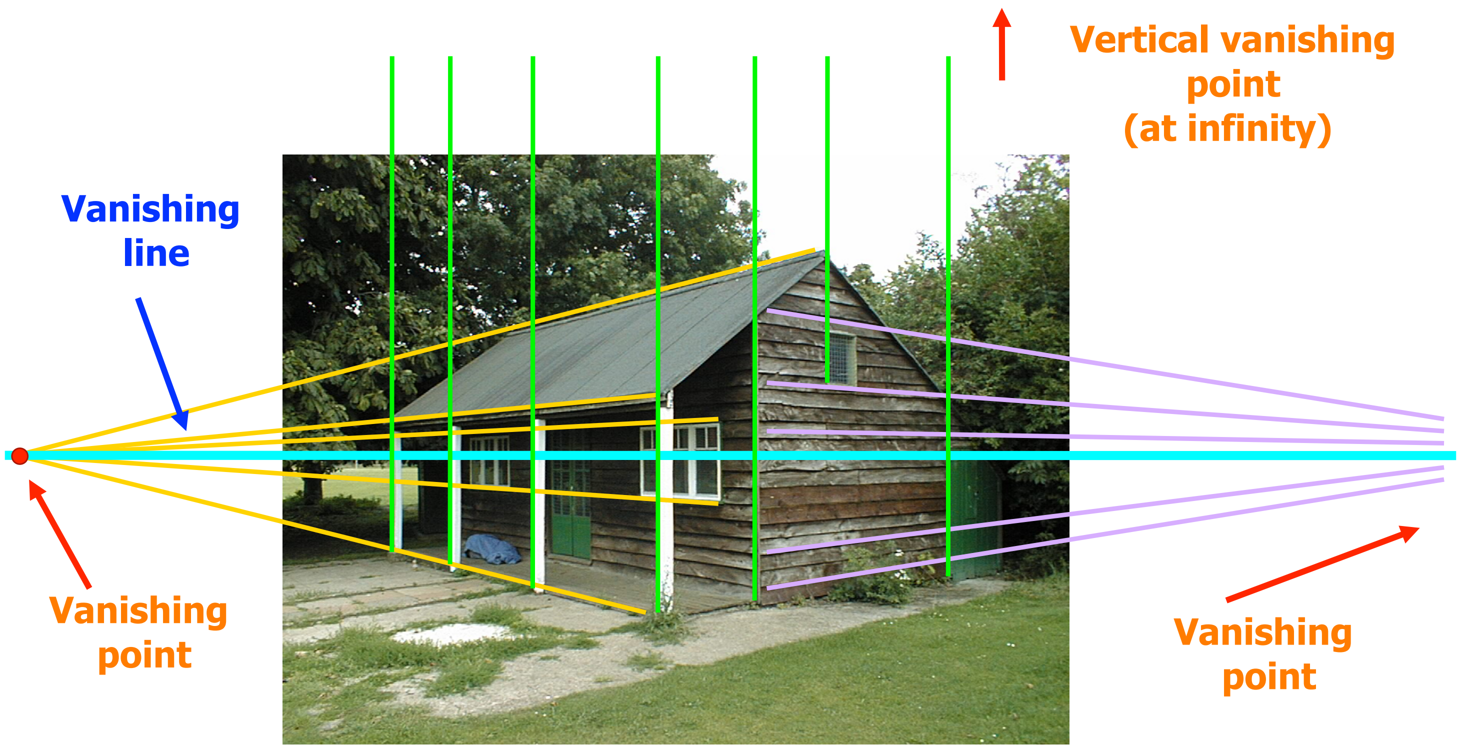
Author

User:MikKBDFJKGeMalak

Parallel lines meet in a pinhole camera



Vanishing points



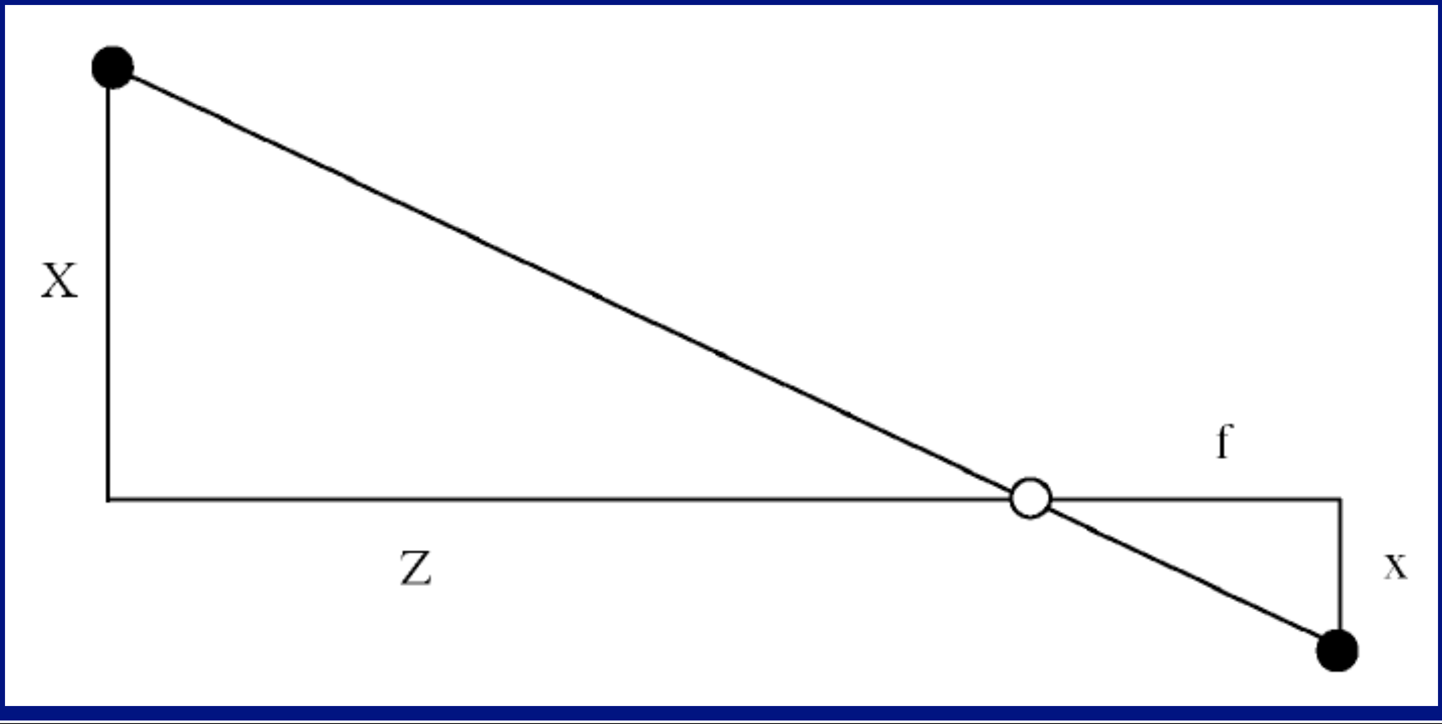
Slide from Efros, Photo from Criminisi

Horizons

Which ball is closer to the viewer?

Projection in Coordinates

- From the drawing, we have X/Z = -x/f
- Generally



Homogeneous coordinates

- Add an extra coordinate and use an equivalence relation
- for 2D
  - three coordinates for point
  - equivalence relation
    k*(X,Y,Z) is the same as (X,Y,Z)
- for 3D
  - four coordinates for point
  - equivalence relation
    k*(X,Y,Z,T) is the same as (X,Y,Z,T)
- Canonical representation
  - by dividing by one coordinate (if it isn't zero).

Homogeneous coordinates

- Why?
  - Possible to represent points "at infinity"
  - Where parallel lines intersect (vanishing points)
  - Where parallel planes intersect (horizons)
  - Possible to write the action of a perspective camera as a matrix

A perspective camera as a matrix

- Turn previous expression into HC's
  - HC's for 3D point are (X,Y,Z,T)
  - HC's for point in image are (U,V,W)

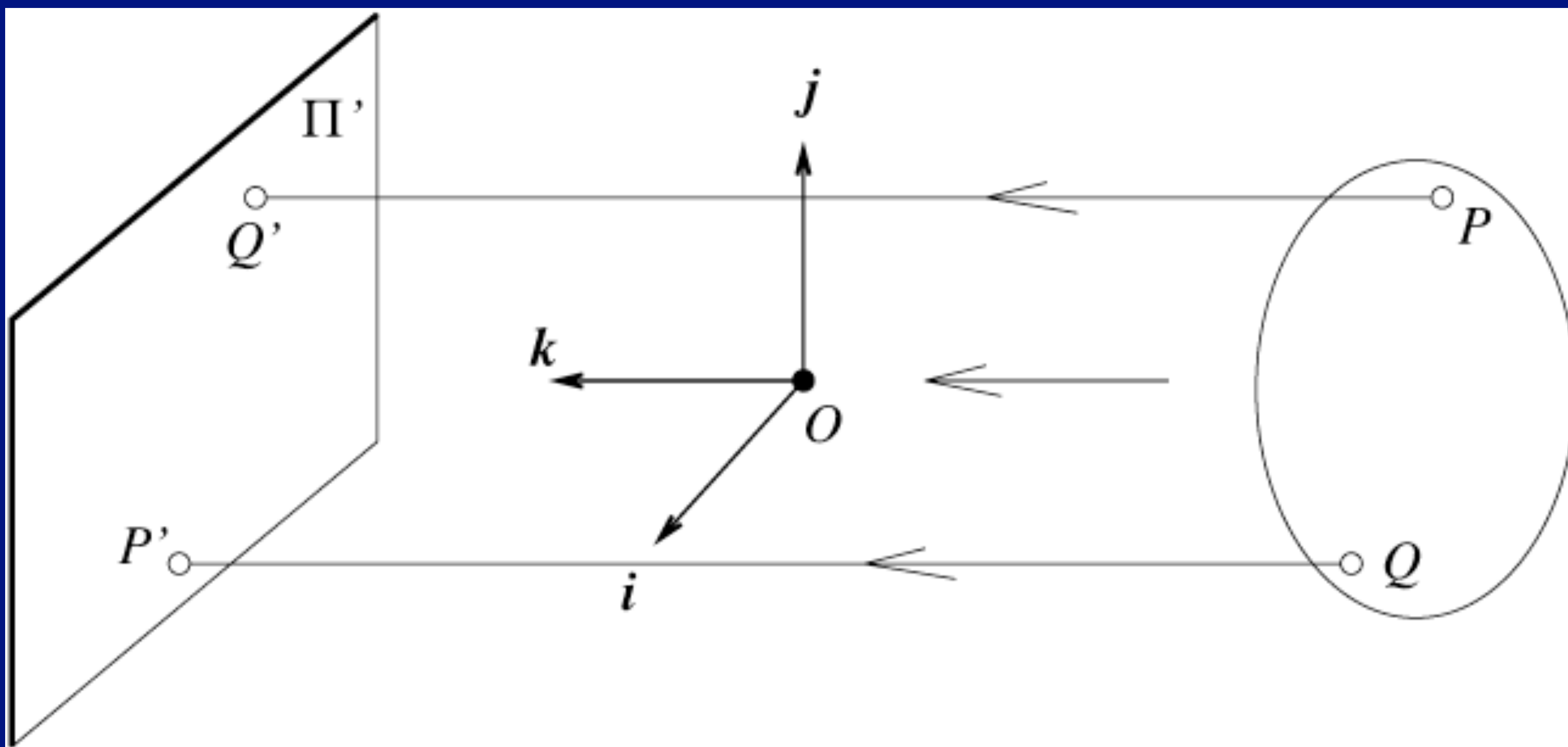
$$\begin{pmatrix} U \\ V \\ W \end{pmatrix} = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & \frac{1}{f} & 0 \end{pmatrix} \begin{pmatrix} X \\ Y \\ Z \\ T \end{pmatrix}$$

Weak perspective

- Issue
  - perspective effects, but not over the scale of individual objects
    - For example, texture elements in picture below
  - collect points into a group at about the same depth, then divide each point by the depth of its group
  - Adv: easy
  - Disadv: wrong

Orthographic projection

- Perspective effects are often not significant
  - eg
    - pictures of people
    - all objects at the same distance



Orthographic projection in HC's

- In conventional coordinates, we just drop z

$$\begin{pmatrix} U \\ V \\ W \end{pmatrix} = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} X \\ Y \\ Z \\ T \end{pmatrix}$$

Pinhole Problems

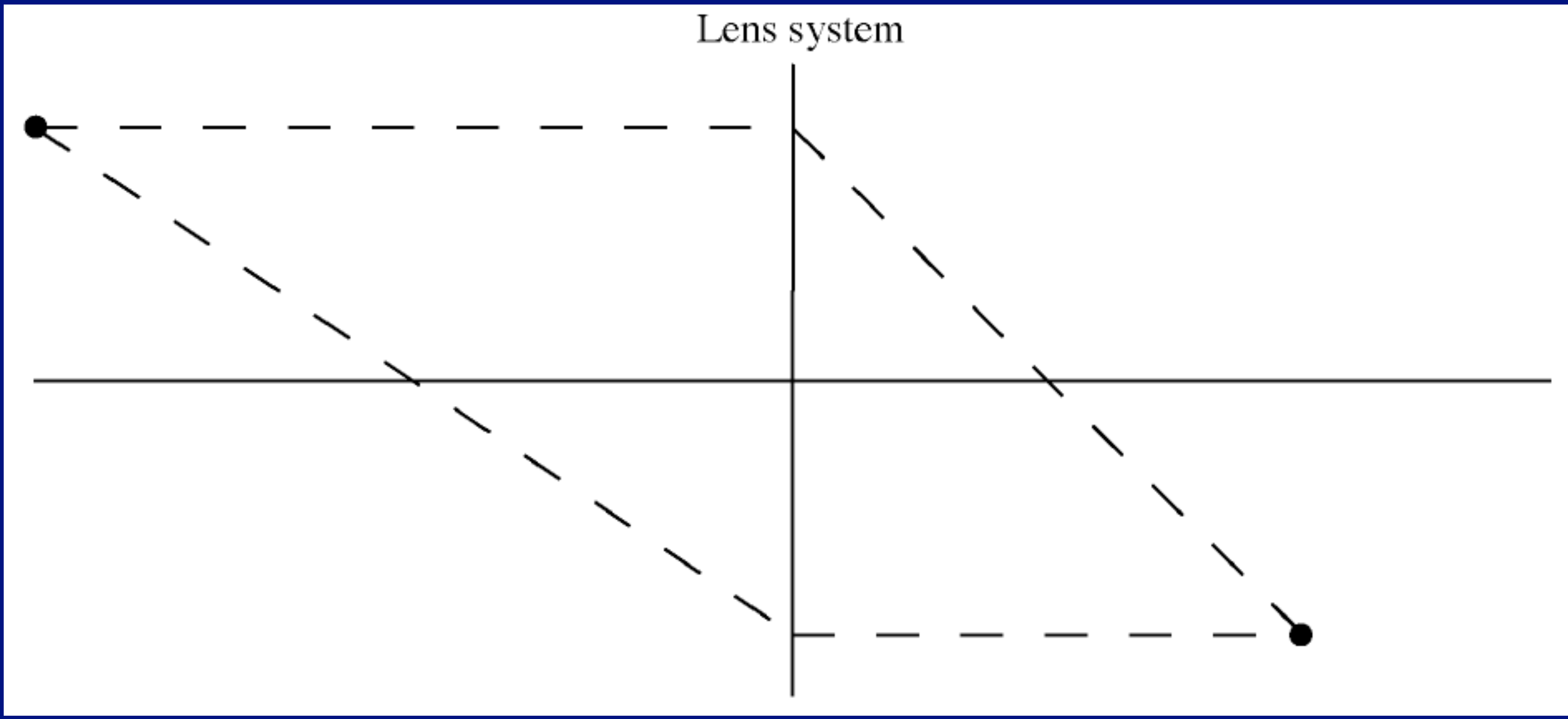
Pinhole too big: brighter, but blurred

Pinhole right size: crisp, but dark

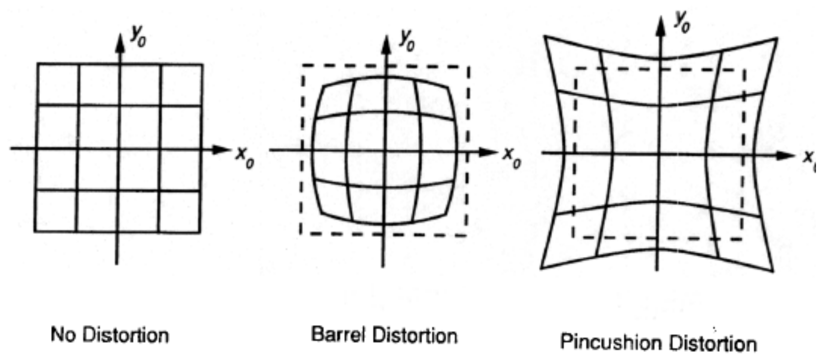
Pinhole too small: diffraction effects blur, dark

Lens Systems

- Collect light from a large range of directions



Lens distortion



Corrected Barrel Distortion

Image from Martin Habbecke

Crucial points

- Cameras project 3D to 2D
  - distort flat patches
  - distortion can be represented by matrices in homogenous coordinates
  - models:
    - perspective camera
    - orthographic camera
- Lenses
  - make images brighter by focusing light
  - can distort images