Cameras

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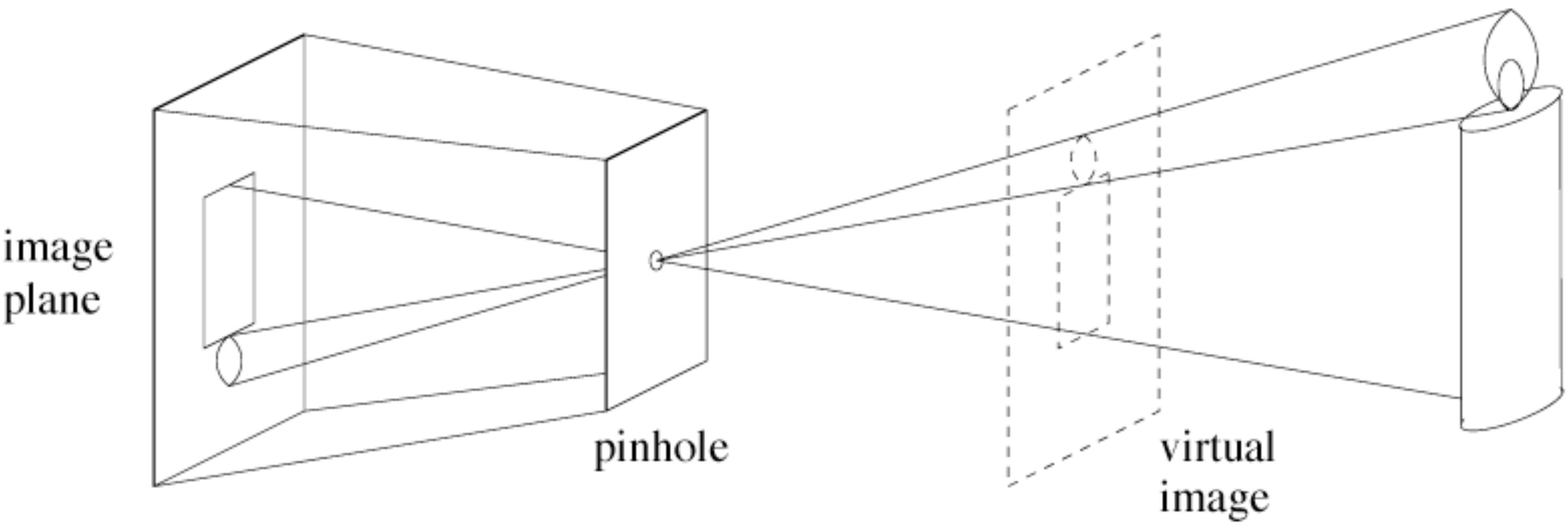
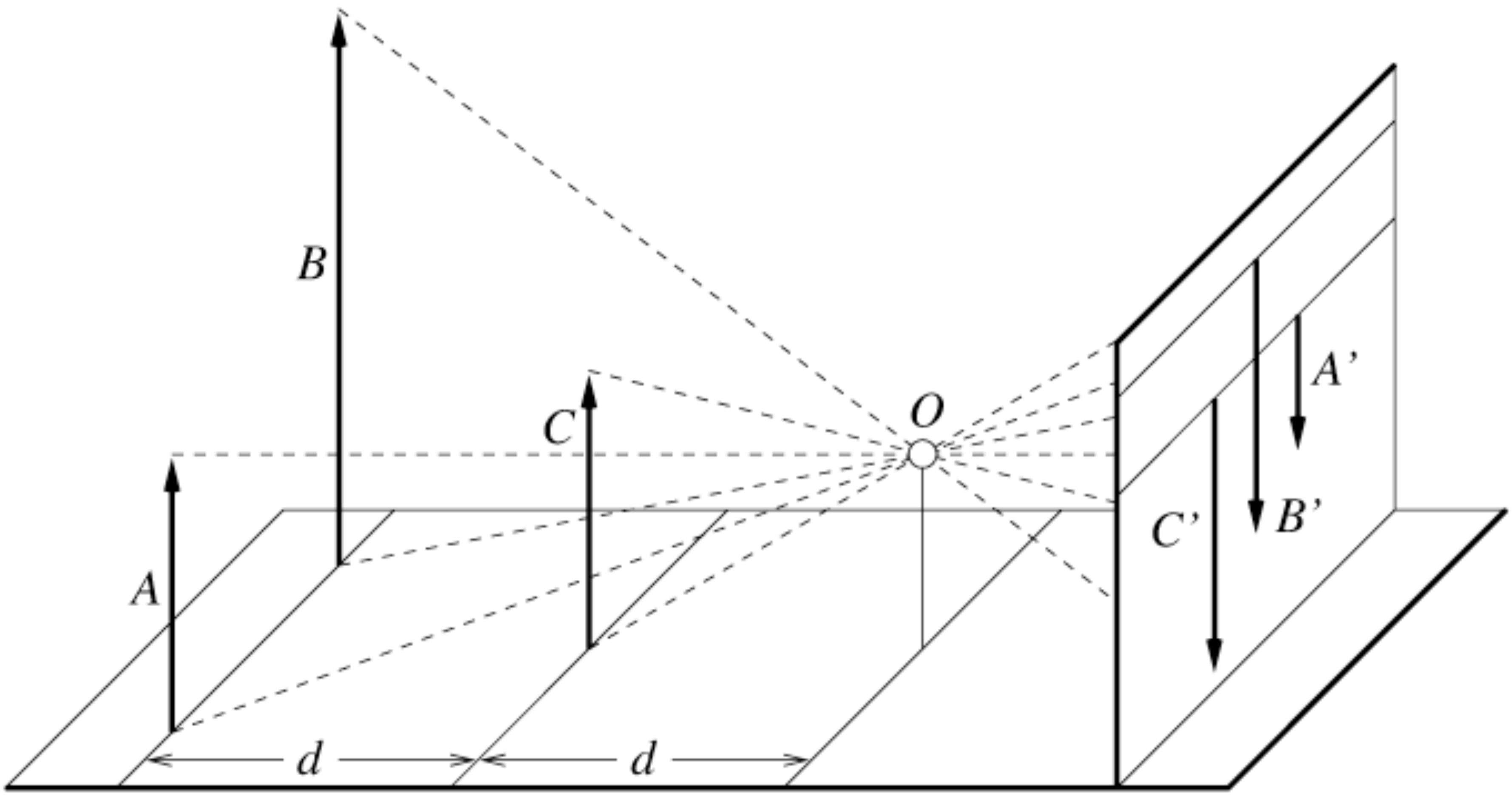
Cameras

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

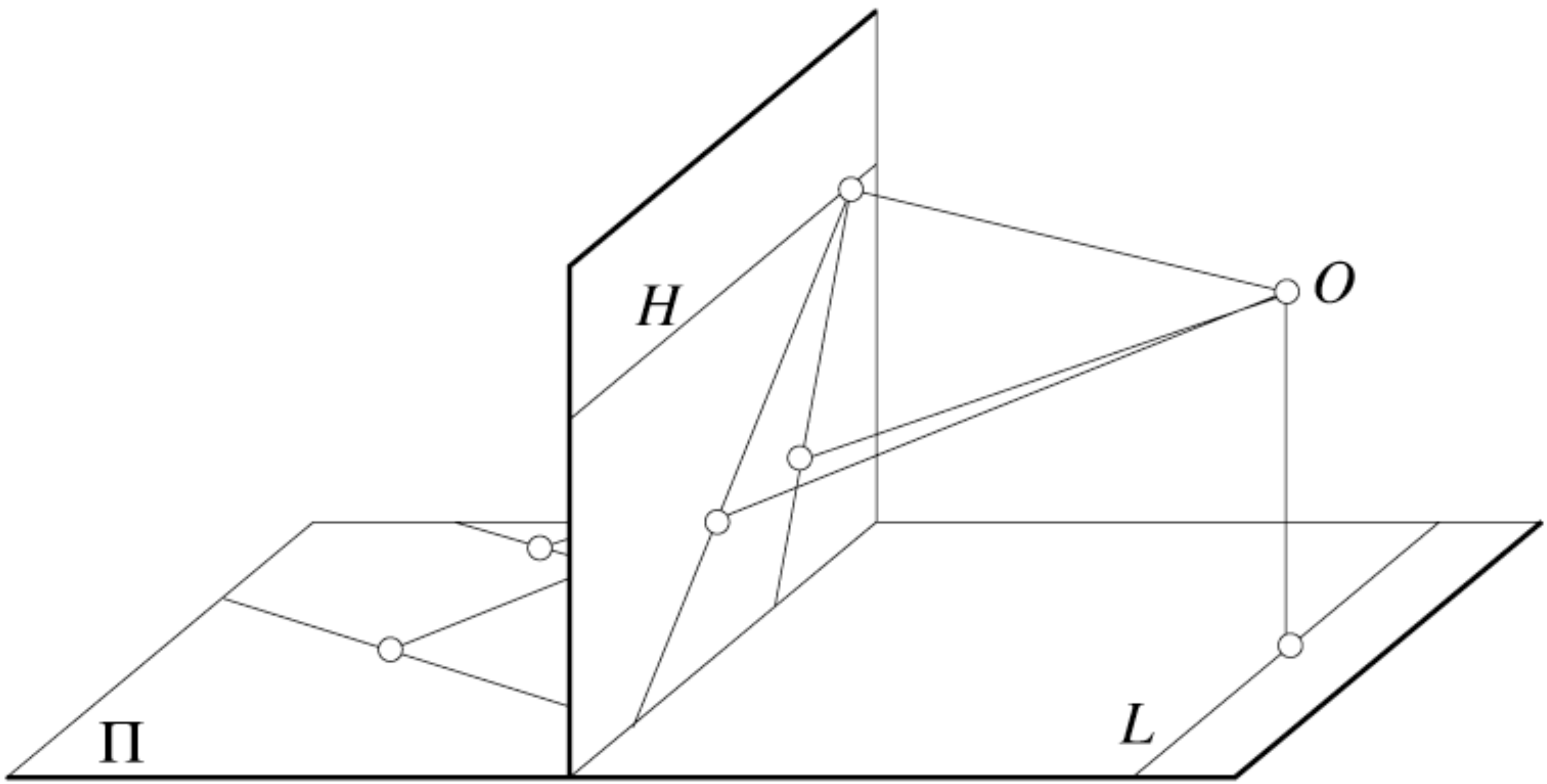
Pinhole camera



Distant objects are smaller in a pinhole camera



Parallel lines meet in a pinhole camera

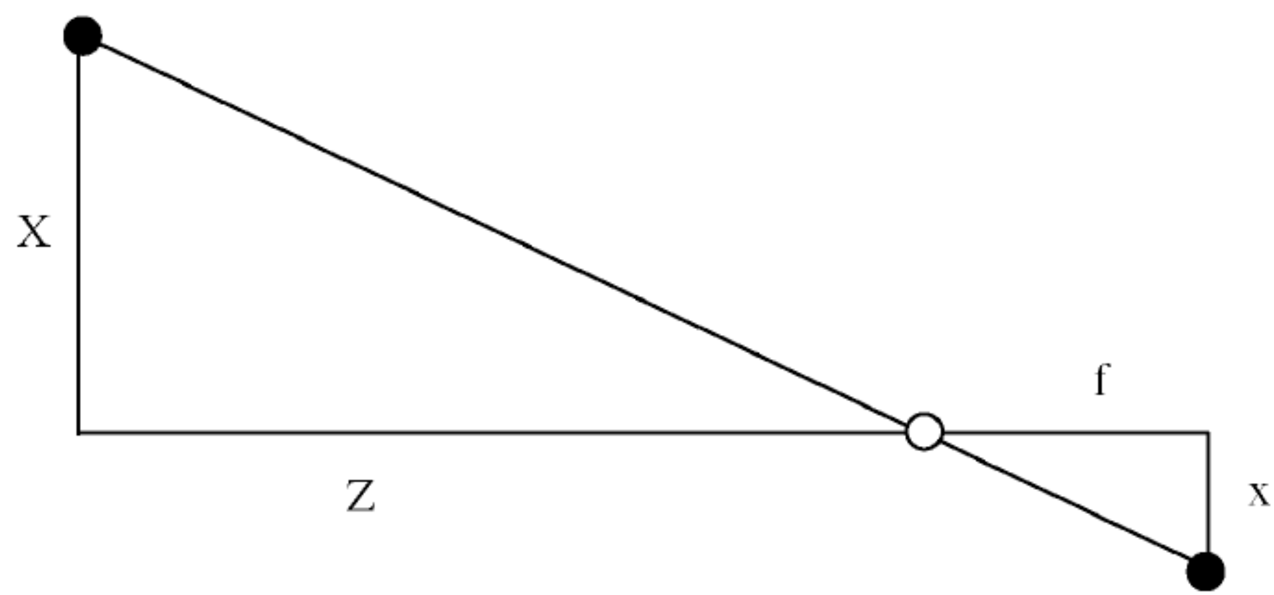


Vanishing points

- 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

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

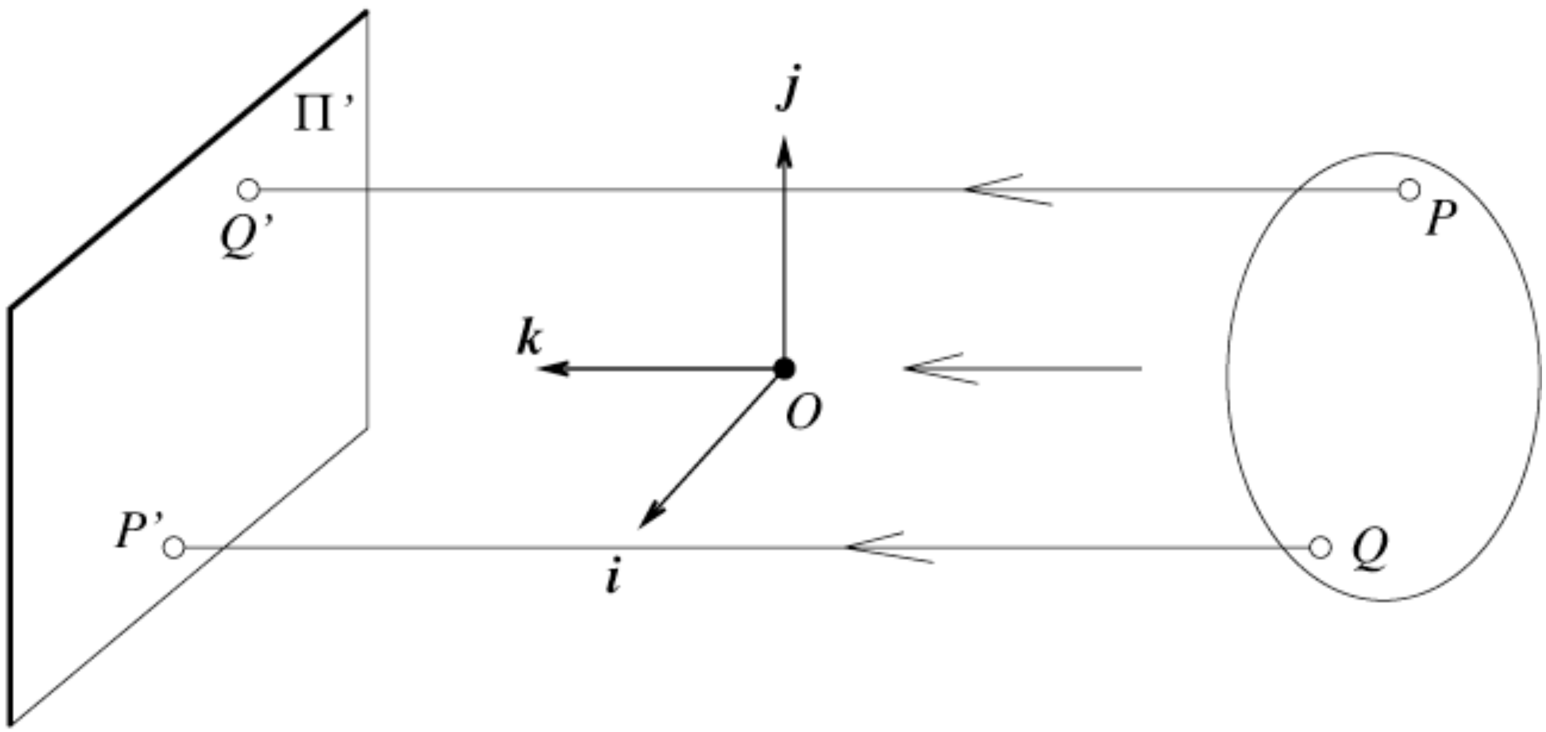
- Turn previous expression into HC's
  - HC's for 3D point are (X,Y,Z,T)
  - HC's for point in image are (U,V,W)

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

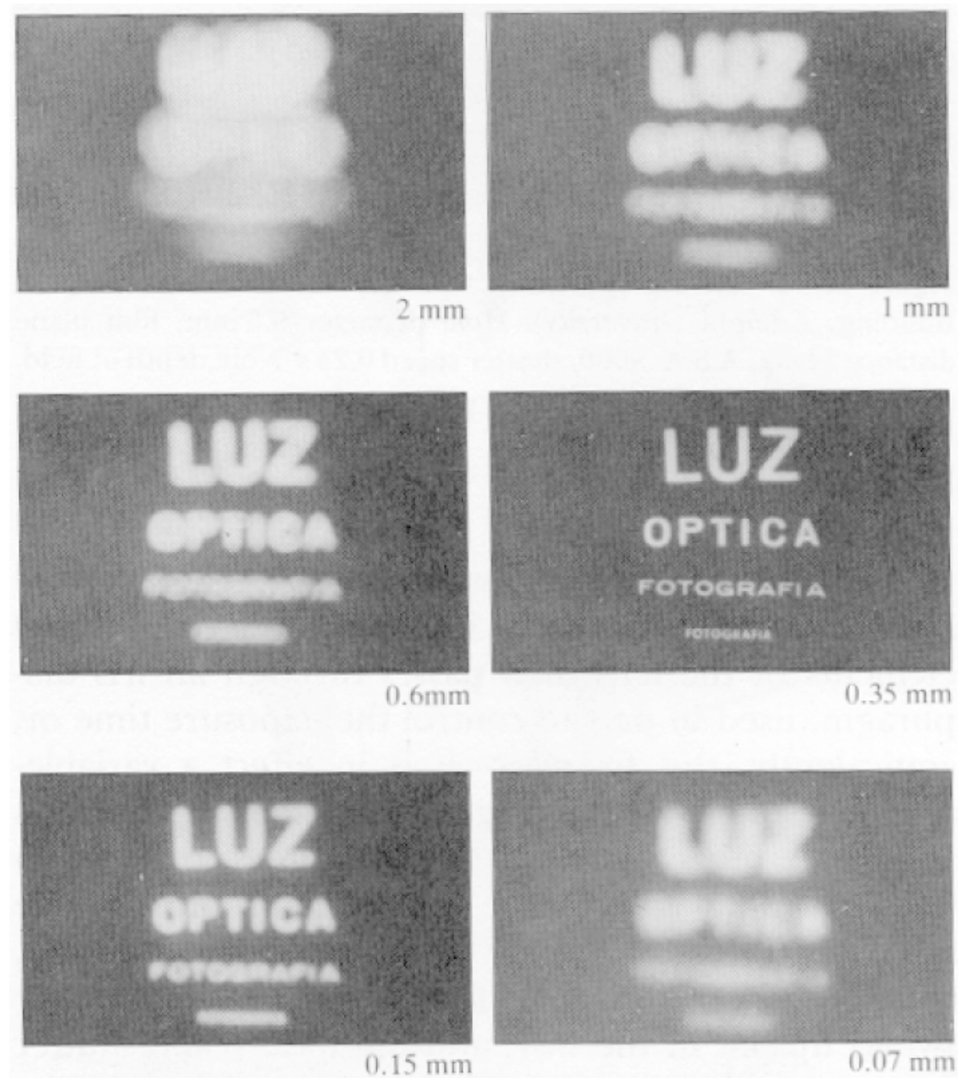
- In Homogeneous coordinates, can write a matrix

Pinhole Problems

Pinhole too big: brighter, but blurred

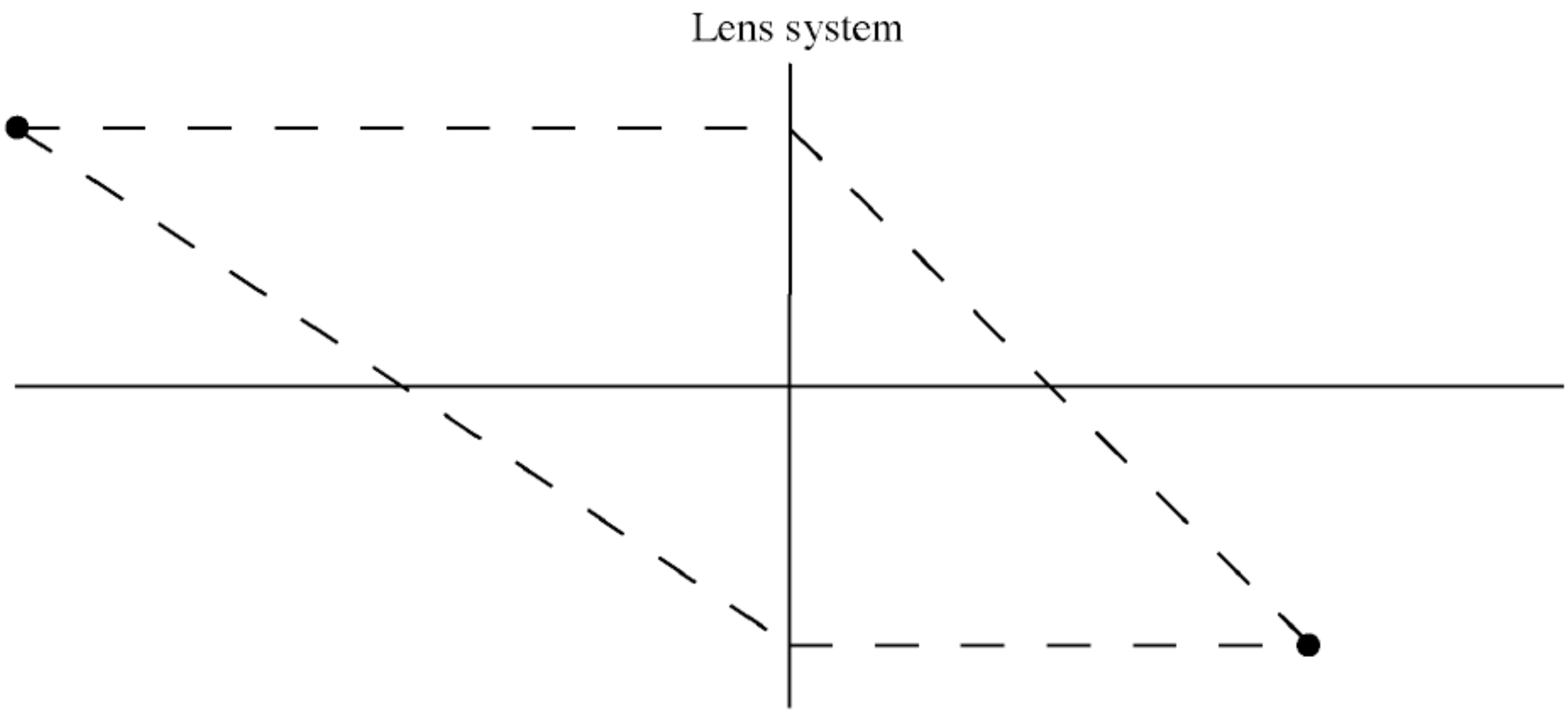
Pinhole right size: crisp, but dark

Pinhole too small: diffraction effects blur, dark



Lens Systems

- Collect light from a large range of directions



Lens Systems

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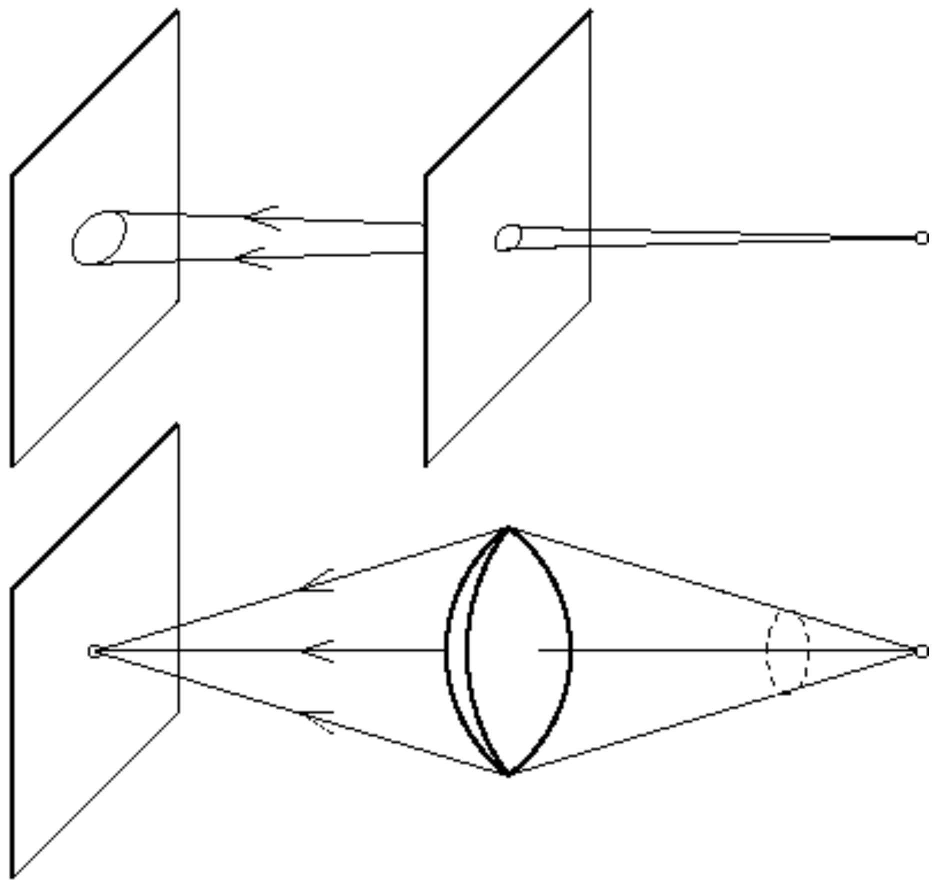
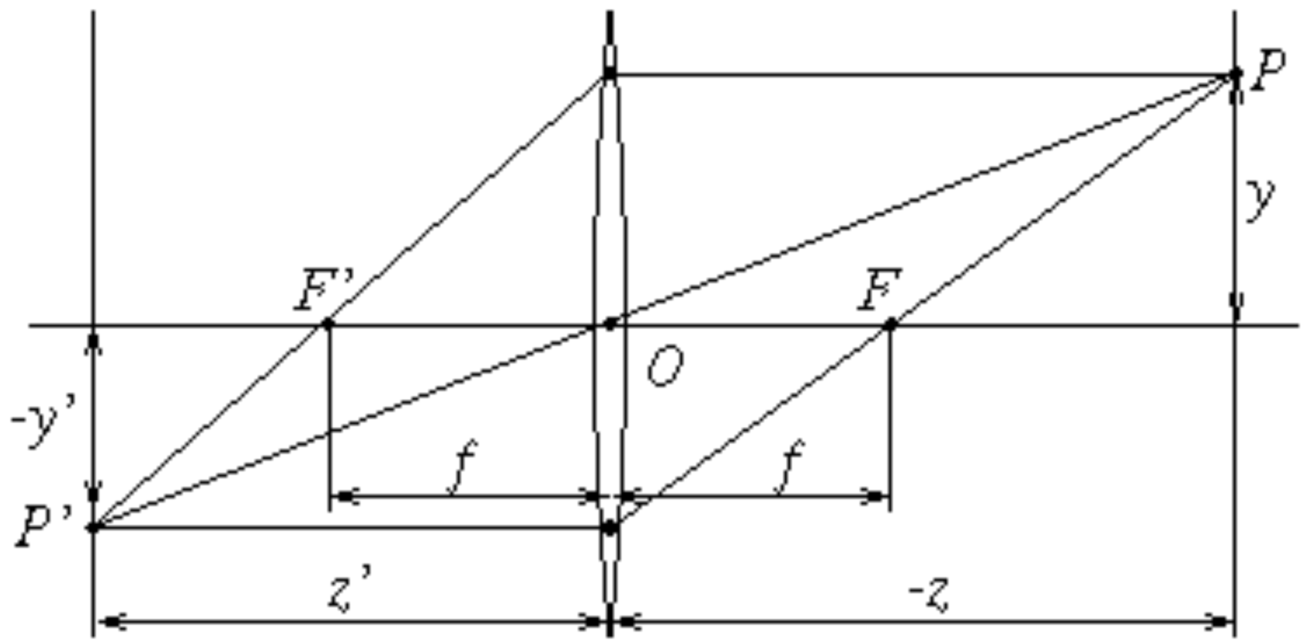


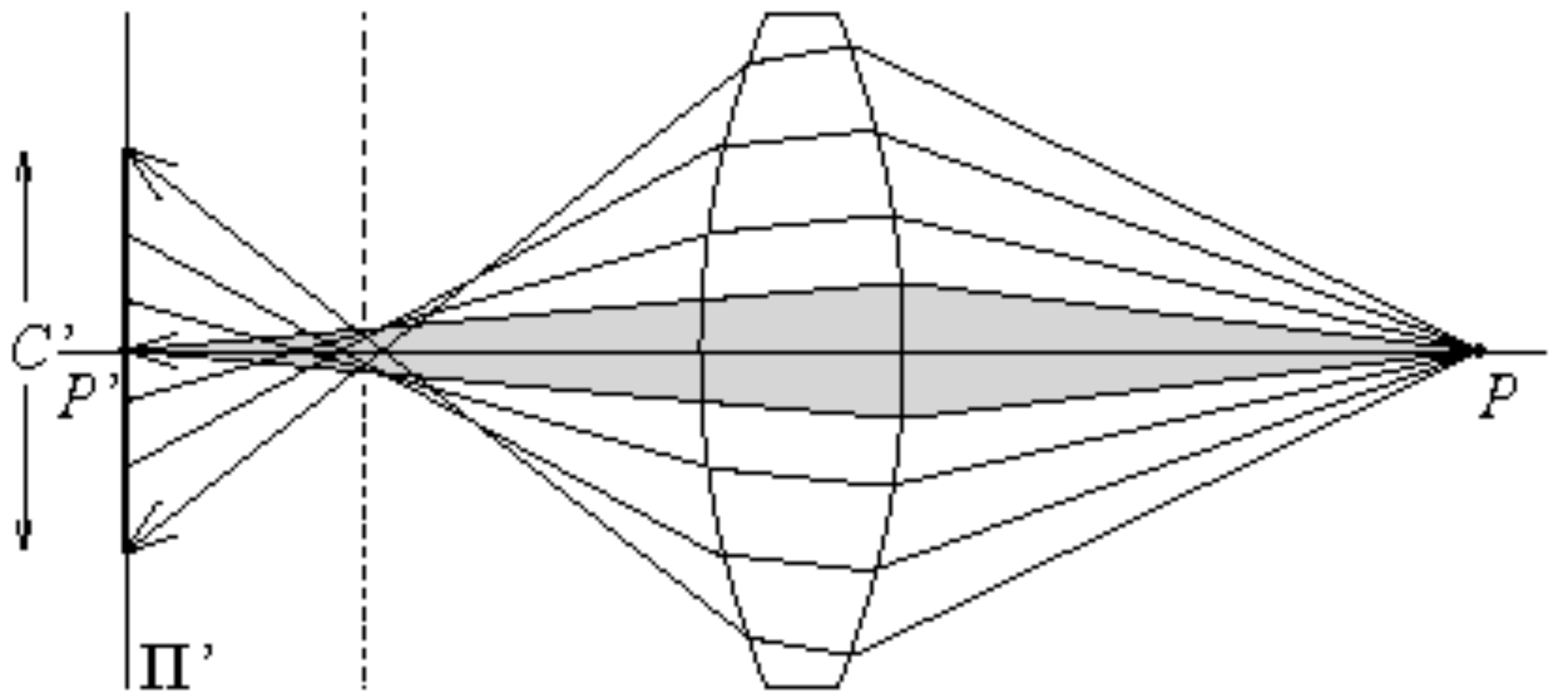
A lens model - the thin lens



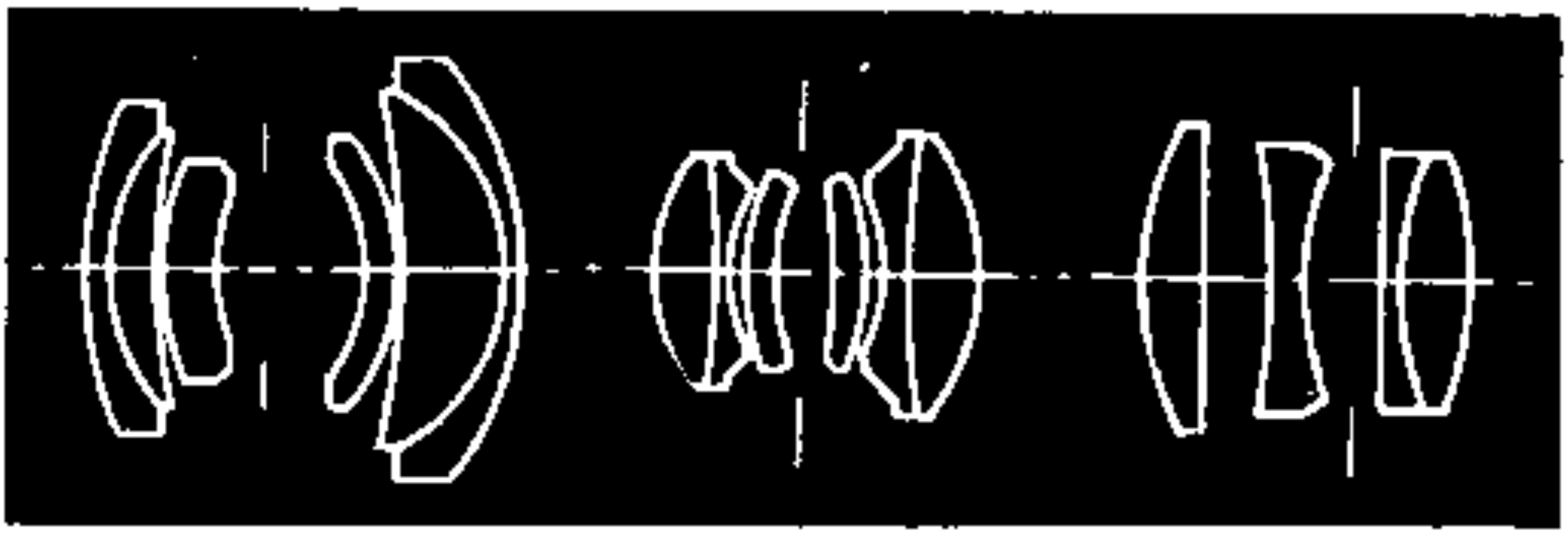
Lens Problems

- Chromatic aberration
  - Light at different wavelengths follows different paths; hence, some wavelengths are defocussed
  - Machines: coat the lens
  - Humans: live with it
- Scattering at the lens surface
  - Some light entering the lens system is reflected off each surface it encounters (Fresnel's law gives details)
  - Machines: coat the lens, interior
  - Humans: live with it (various scattering phenomena are visible in the human eye)
- Geometric phenomena (Barrel distortion, etc.)

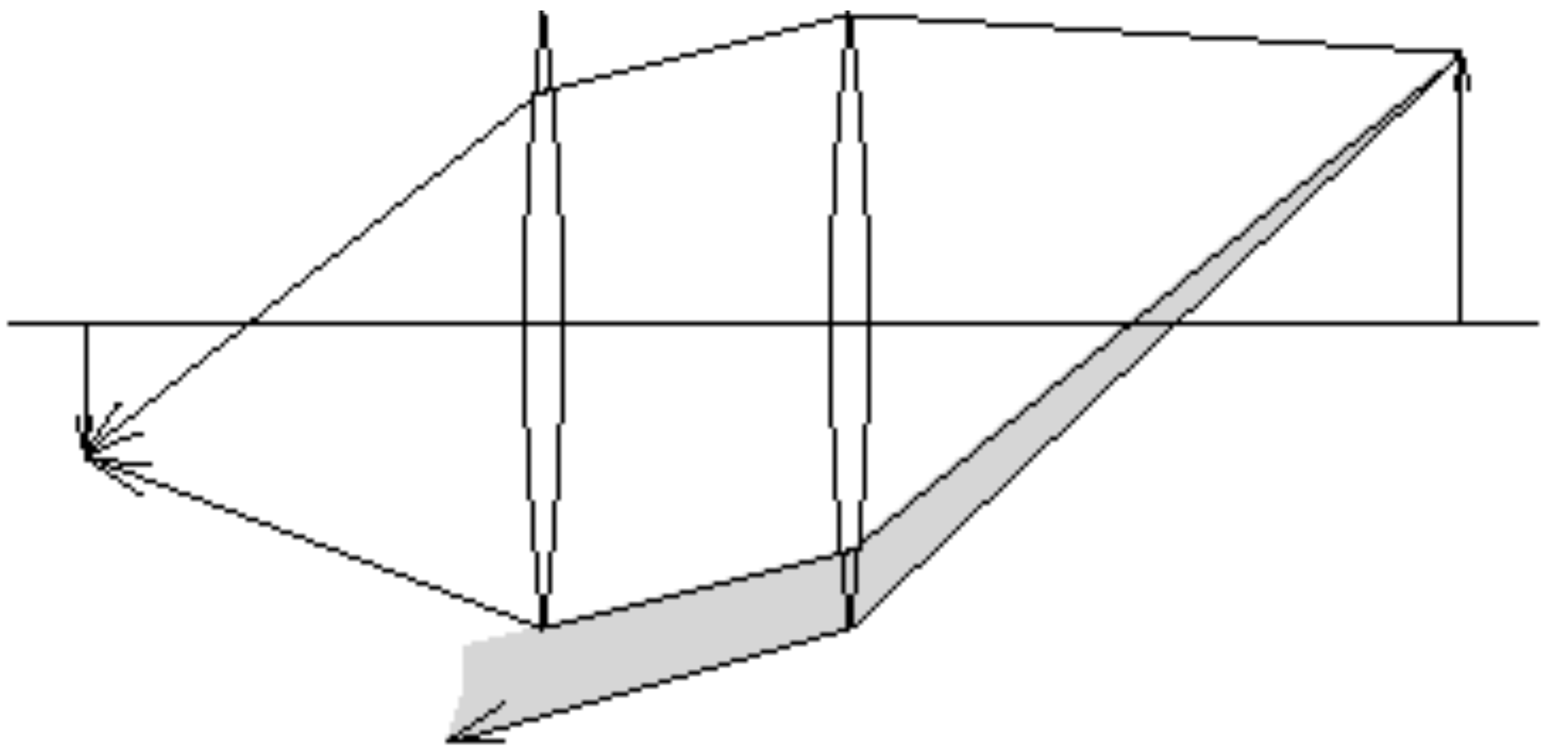
Lens Problems - Spherical Aberration



Lens Systems



Vignetting



Camera Parameters

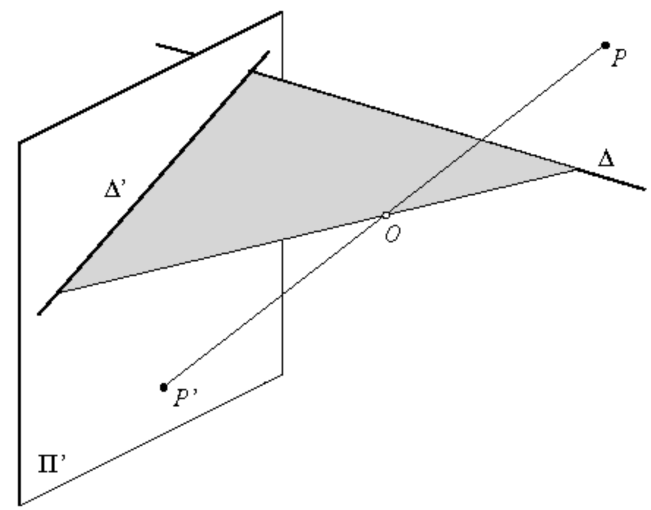
- Issue
  - camera may not be at the origin, looking down the z-axis
    - extrinsic parameters describe position and orientation of camera
  - one unit in camera coordinates may not be the same as one unit in world coordinates
    - intrinsic parameters of camera
      - focal length, principal point, aspect ratio, angle between axes, etc.

Camera Calibration

- Issues:
  - what are intrinsic parameters of the camera?
  - what is the camera matrix? (intrinsic+extrinsic)
- General strategy:
  - view calibration object
  - identify image points
  - obtain camera matrix by minimizing error
  - obtain intrinsic parameters from camera matrix
- Error minimization:
  - Linear least squares
    - easy problem numerically, solution can be rather bad
  - Minimize image distance
  - more difficult numerical problem, solution is better

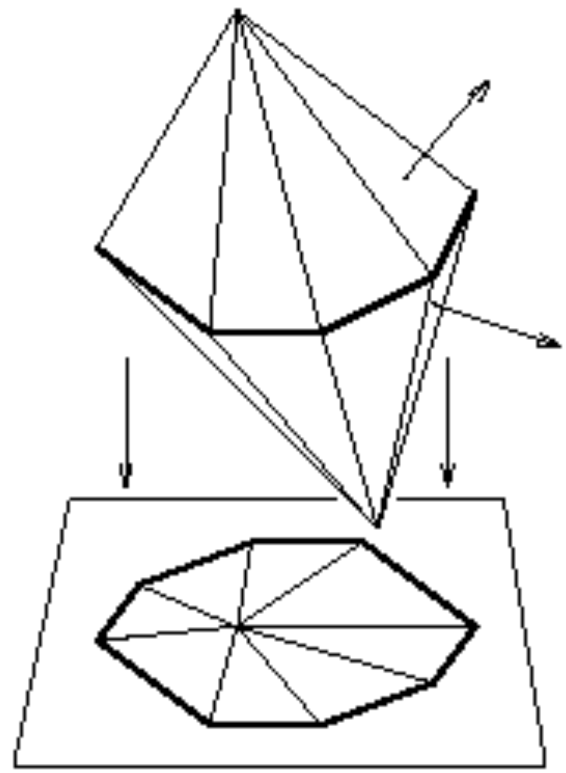
Geometric properties of projection

- Points -> points
- Lines -> lines
- Polyhedra -> polyhedra
- Degeneracies
  - line through focal point (pinhole) -> point
  - plane through focal point (pinhole) -> line
- Curved surfaces are complicated



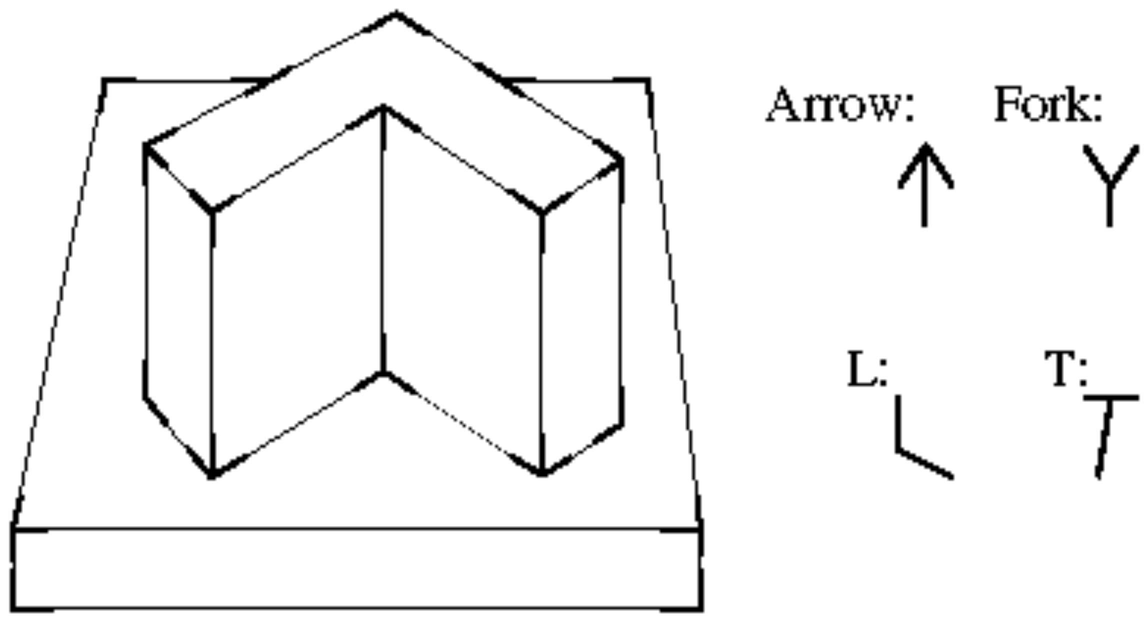
Polyhedra project to polygons

- because lines project to lines, etc



Junctions are constrained

- Which leads to a process called line labelling
  - look for consistent junction, edge labels
    - BUT can’t get real lines, junctions from real images



Curved surfaces are more interesting

- Outline
  - set of points where view direction is tangent to surface
  - projection of a space curve which varies from view to view of a surface