Announcements

- Assignment 1
  - theory (**due Wednesday**)
  - programming (**due next Friday**)
- Tutorial this week
  - Surface of revolution, normals, polygonal meshes, and polygonal approximation to surface of revolution
- **Office Hours today 1-2 pm**

Last week's review

- **Coordinate Free Geometry**

- **3D Geometric Curves**
  - **Forms:** Implicit, Parametric
  - **Primitives:** plane, bilinear patch, spherical cones, ellipsoids, surface of revolution, …
  - Normals and Tangents
  - Polygonal & Triangular Meshes

- **3D Transforms**
  - **Types:** Affine (also in Homogeneous Coordinates)
  - **Examples:** Translation, Rotation, Scaling

Big Picture

- **What can we do so far?**
  - Model a 2D/3D object (hierarchical objects)
  - Transform a 2D/3D object
  - Raster 2D object
- **What else do we need?**
  - **Camera**
  - Know interplay between light and surfaces
- **Why?**
  - **We need to project model of the 3D world to 2D film plane (or screen)** … we need to know how to convert 3D object into 2D representation we know how to raster.

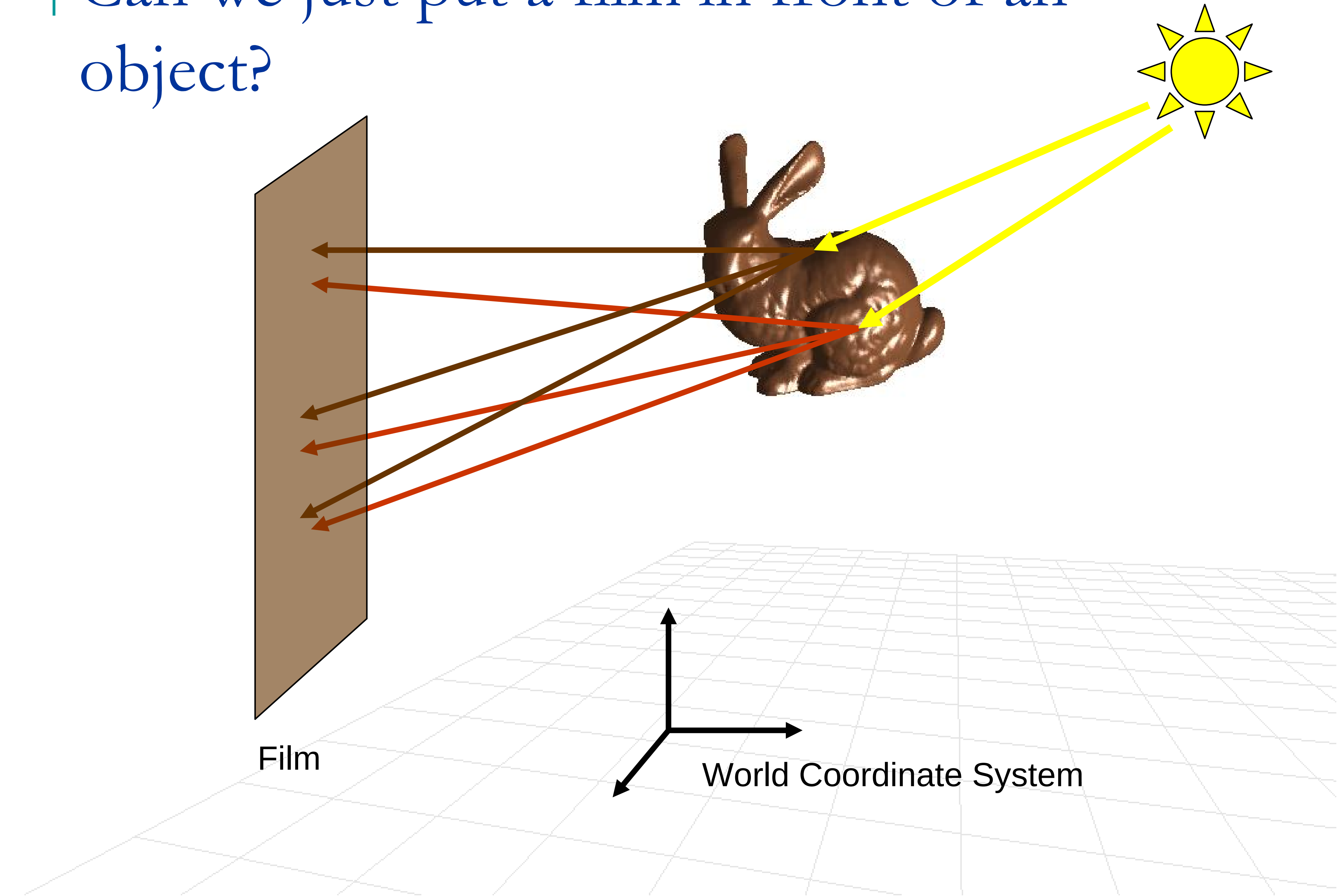
Camera Models
Part 1

Computer Graphics, CSCD18

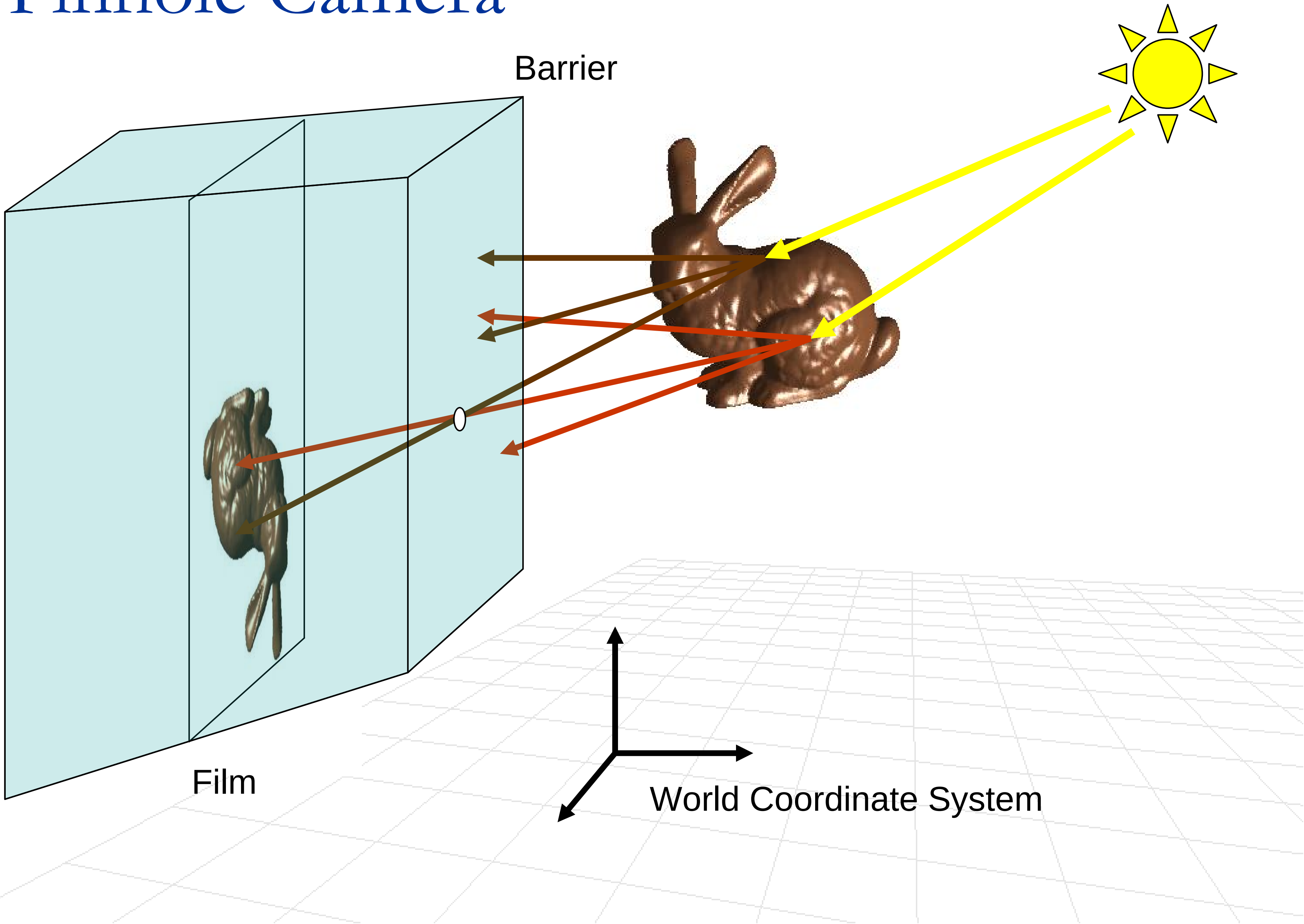
Fall 2008

Instructor: Leonid Sigal

Can we just put a film in front of an object?

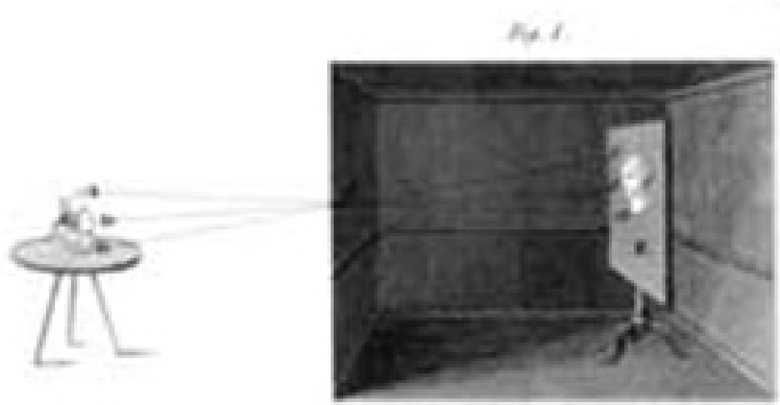


Pinhole Camera



Pinhole Camera

- Room size pinhole cameras date back to 18^{th} century



Self-made room-size pinhole camera

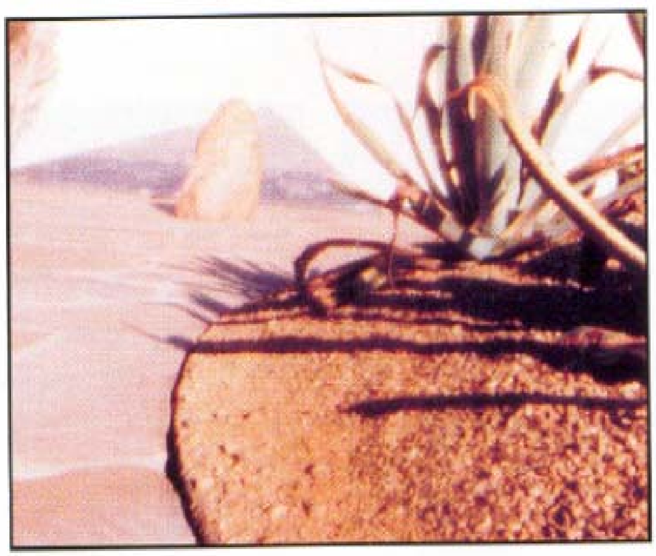
Small hole, about the size of a quarter

http://leojames.wordpress.com/2007/11/15/how-to-make-your-own-camera-obscura/

Pinhole camera

- **Problems**
  - Small pinhole -> sharp image, but little light, slow image acquisition
  - Large pinhole -> reduces sharpness, but faster acquisition

Photograph made with small pinhole



Photograph made with larger pinhole

Images from lecture notes of Matthias Zwicker

Lenses

- **Focus the light**, so that enough light can be captured in sufficiently short amount of time (i.e. allows the pinhole to be made larger)

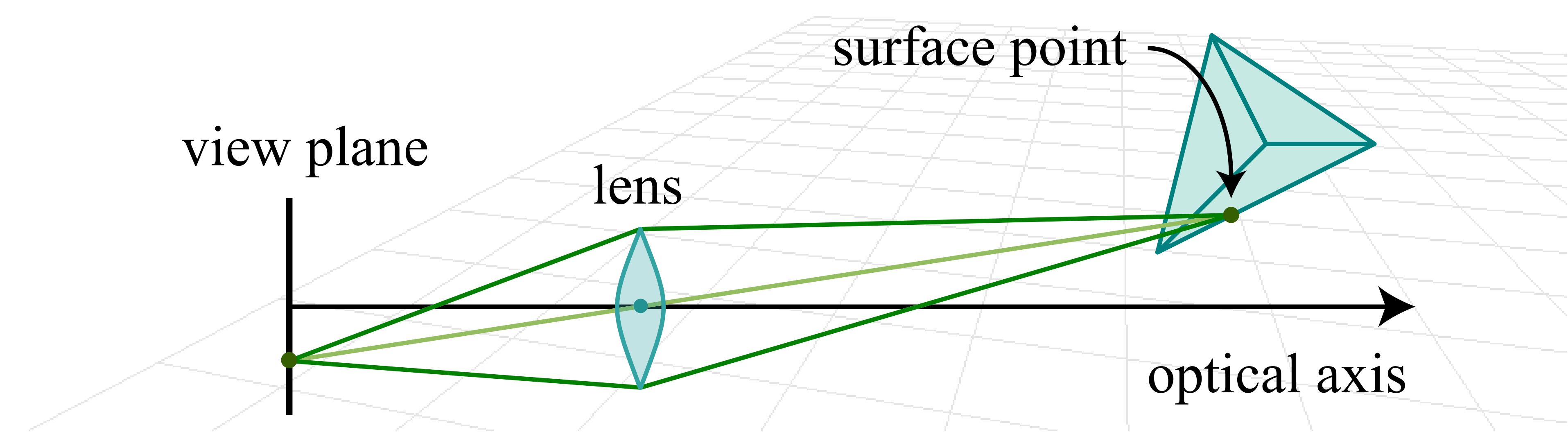
6 sec. exposure

0.01 sec exposure

Images from lecture notes of Matthias Zwicker

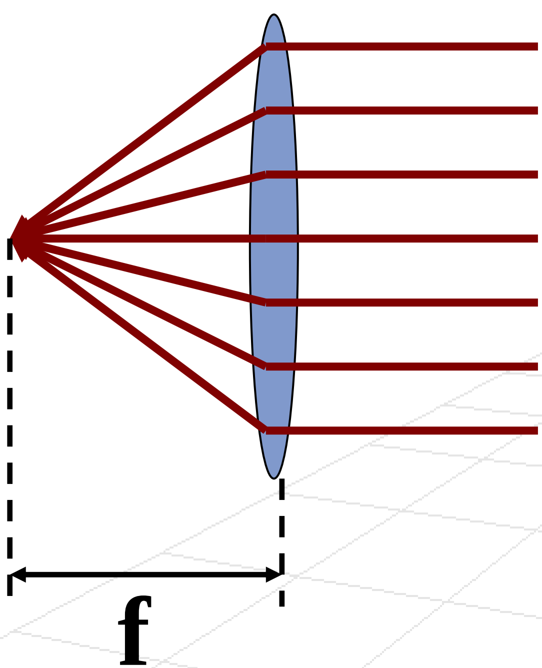
Lenses

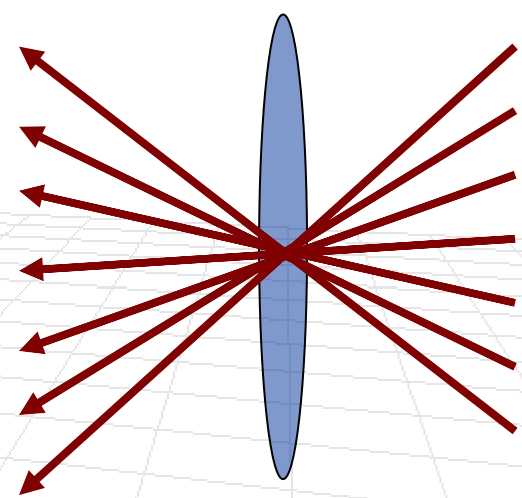
- **Lens models in real cameras can be very complex**
- **We will only consider a simple "Thin Lens" model**



Thin Lens Model

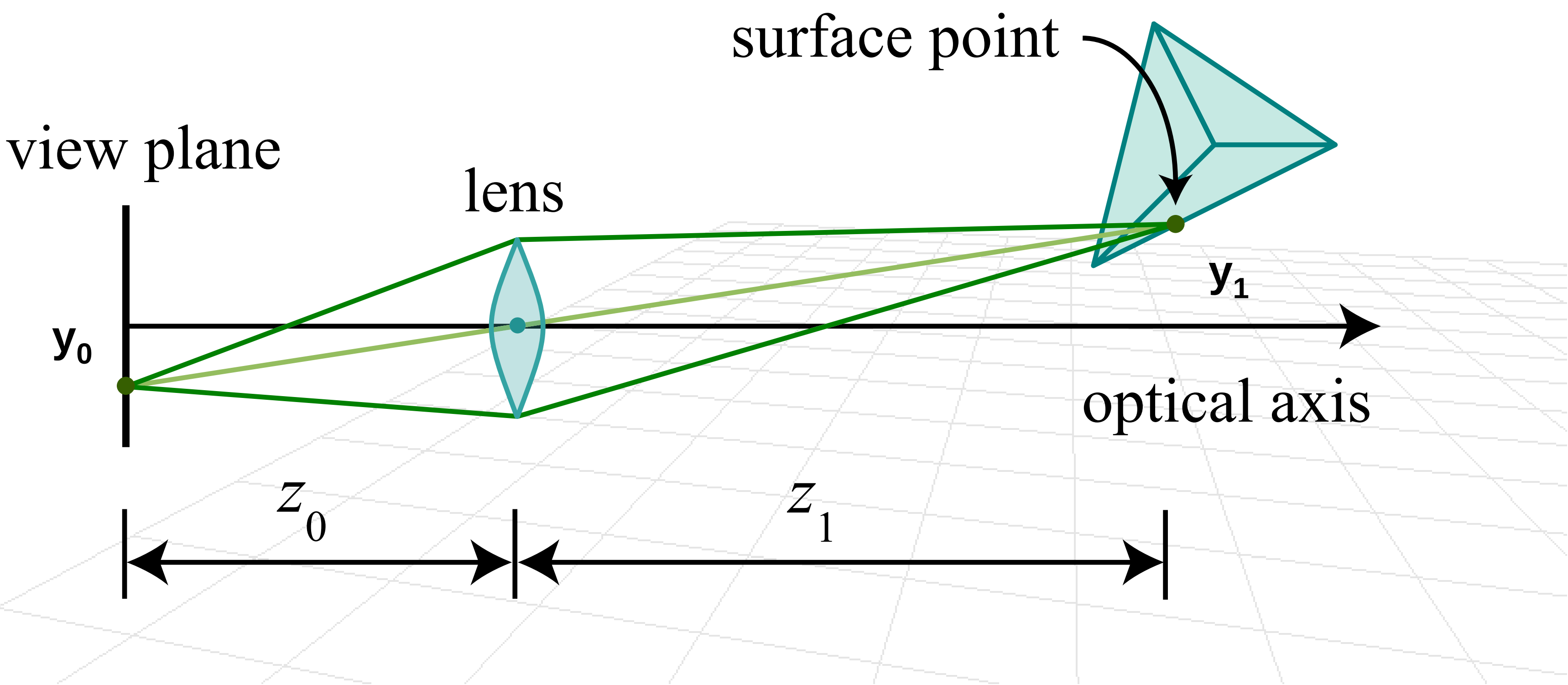
- **All parallel rays converge at focal length f**
- **Rays through the center are not deflected**





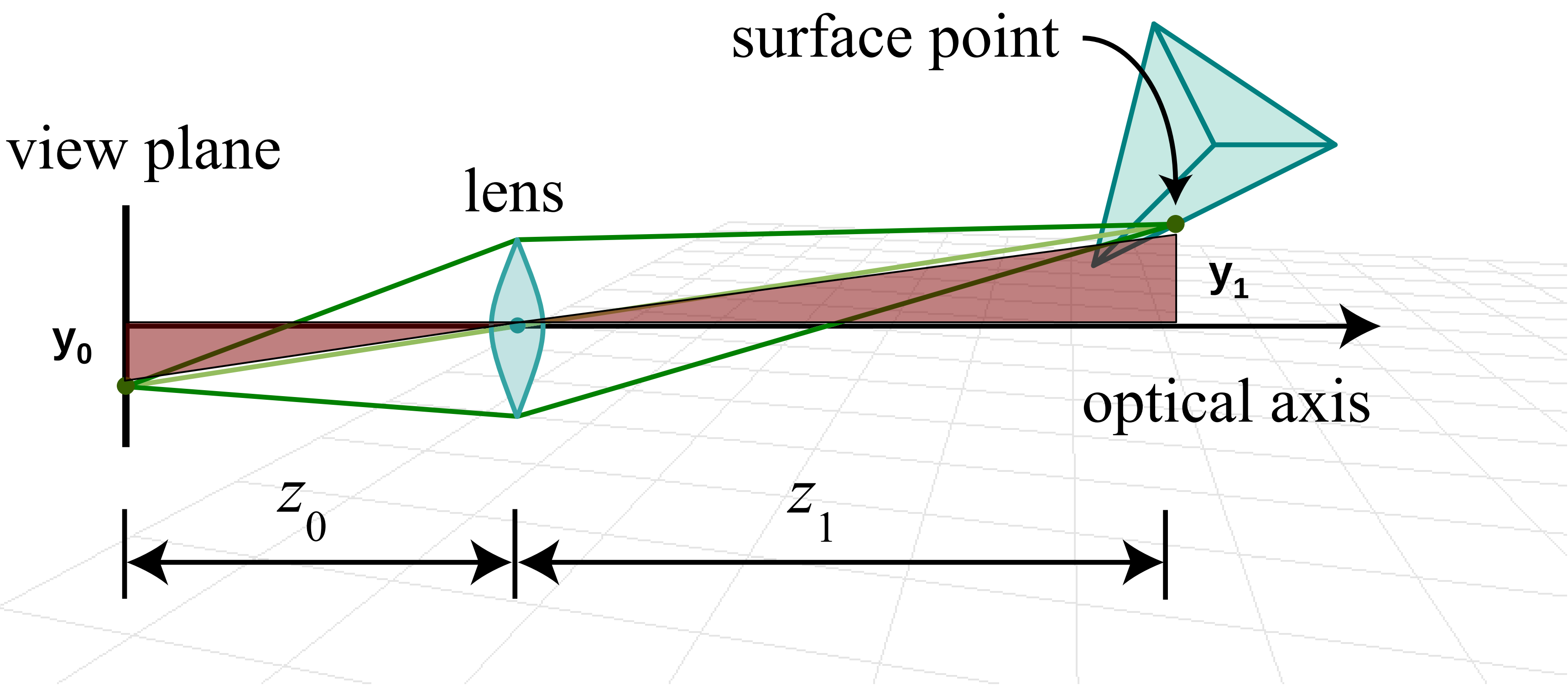
Thin Lens Model

- For rays that are not parallel, we can derive the thin lens equation



Thin Lens Model

- For rays that are not parallel, we can derive the thin lens equation
- Similar triangles: $\mathbf{y}_0 / \mathbf{y}_1 = \mathbf{z}_0 / \mathbf{z}_1$



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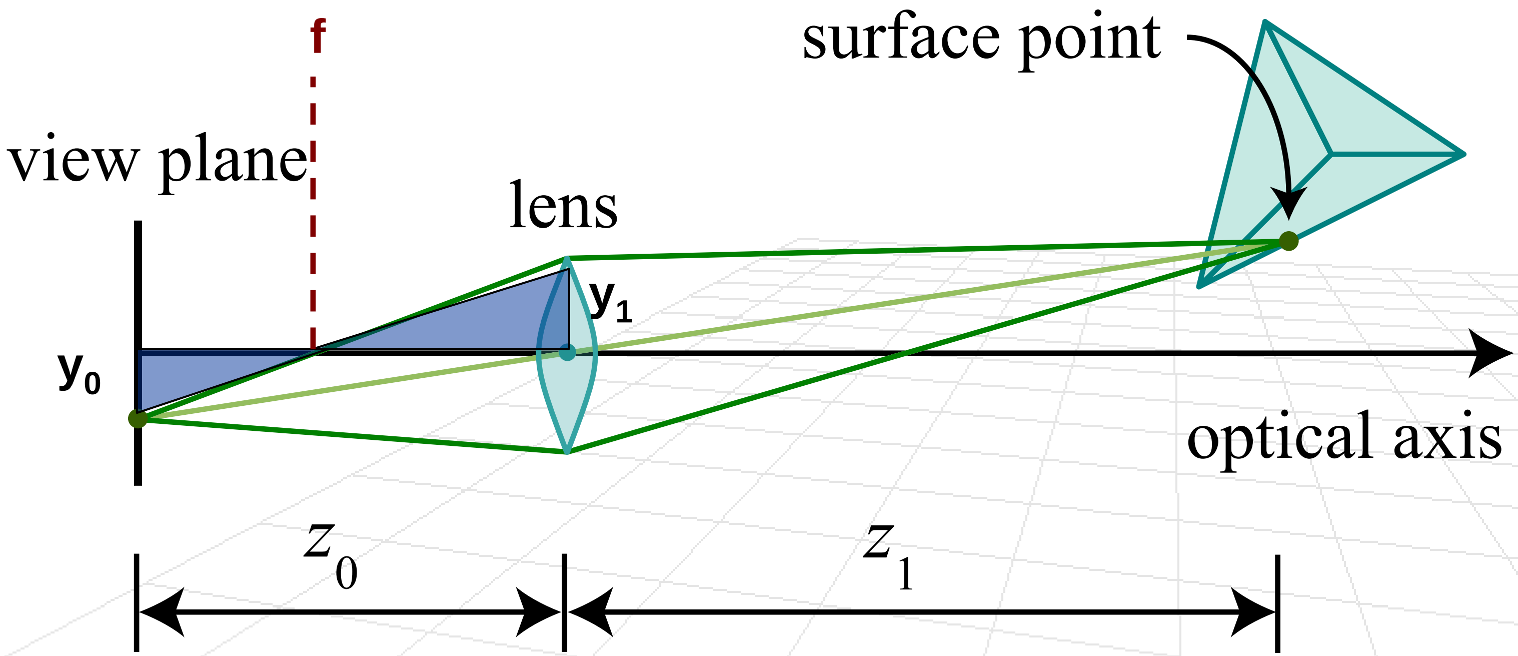
- Similar triangles: $\mathbf{y}_0 / \mathbf{y}_1 = (\mathbf{z}_0 - \mathbf{f}) / \mathbf{f}$



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$$\frac{\mathbf{z}_0}{\mathbf{z}_1} = \frac{\mathbf{z}_0 - \mathbf{f}}{\mathbf{f}}$$

$$\boxed{\frac{1}{\mathbf{z}_0} + \frac{1}{\mathbf{z}_1} = \frac{1}{\mathbf{f}}}$$

Thin Lens Model Derivation

$$\frac{z_0}{z_1} = \frac{z_0 - f}{f}$$

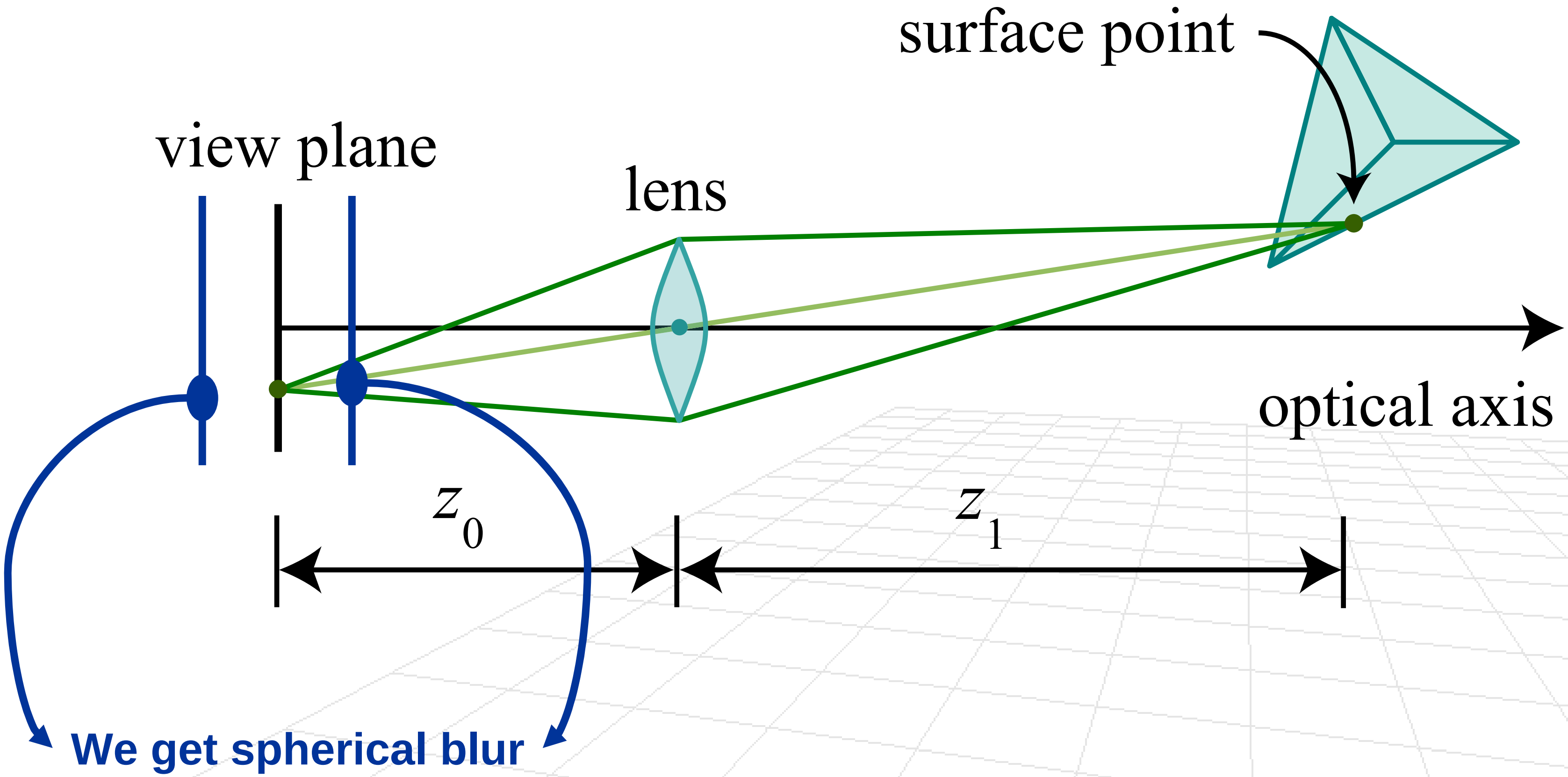
$$z_0 f = z_1 z_0 - z_1 f$$

$$f(z_0 + z_1) = z_1 z_0$$

$$\frac{z_0 + z_1}{z_1 z_0} = \frac{1}{f}$$

$$\frac{1}{z_0} + \frac{1}{z_1} = \frac{1}{f}$$

What if we put view plane elsewhere?

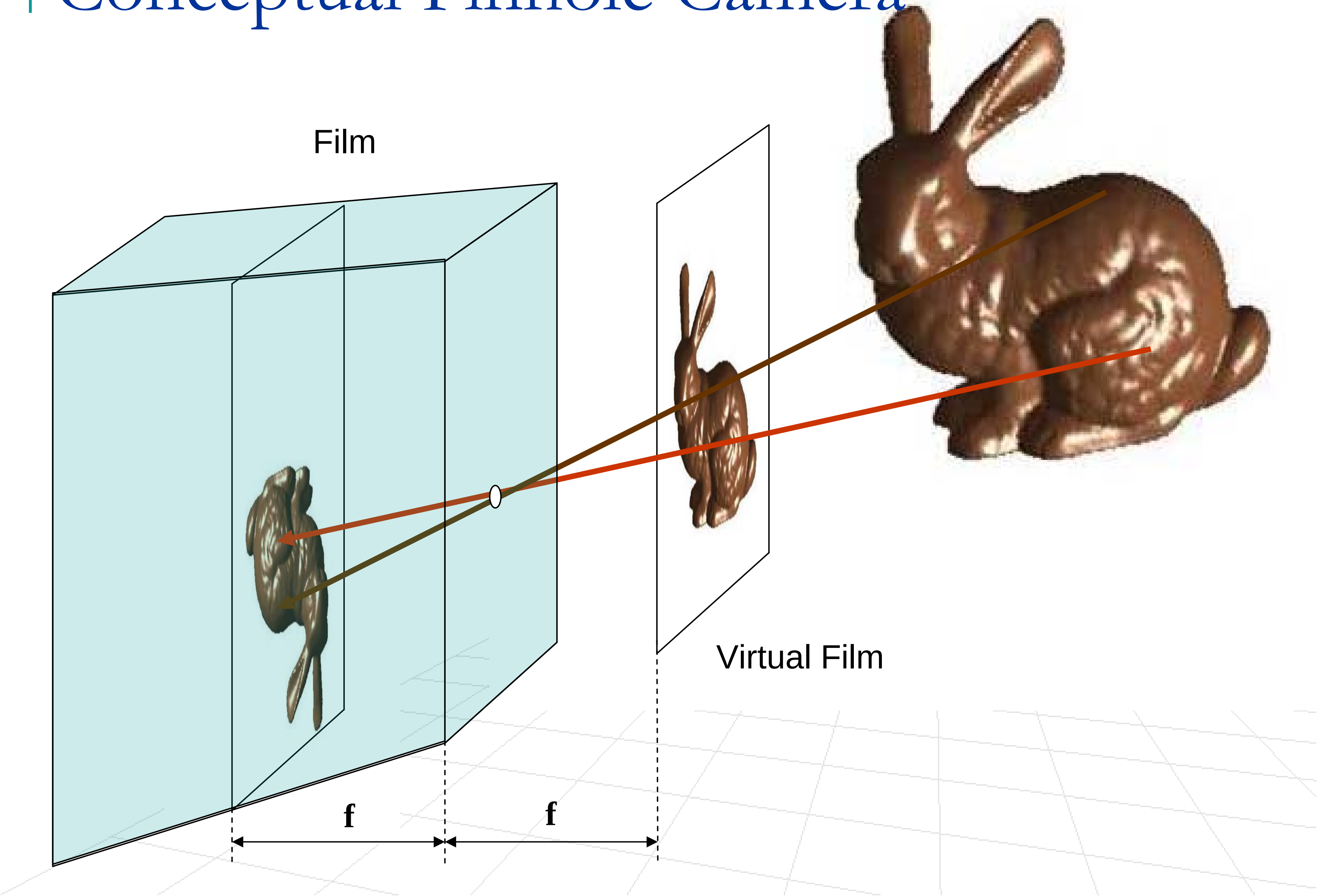


Relationship of Thin Lens Camera and Pinhole Camera

- Pinhole camera is the idealization of the thin lens camera model, where the aperture shrinks to a tiny hole

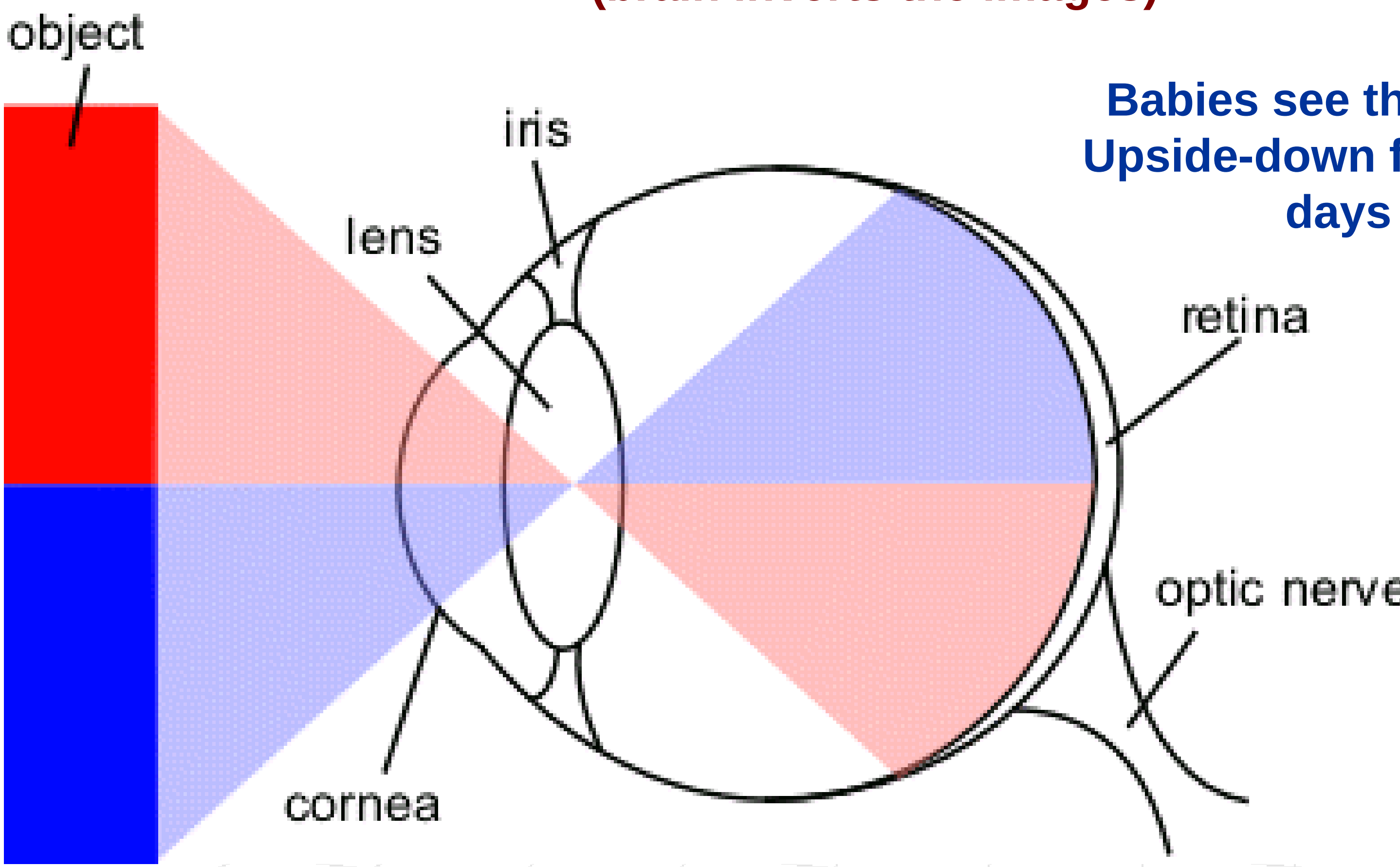
- Let’s go back to the pin hole camera, it is simpler to deal with

Conceptual Pinhole Camera



Our eye is also a camera

Except the image plane is curved (brain inverts the images)



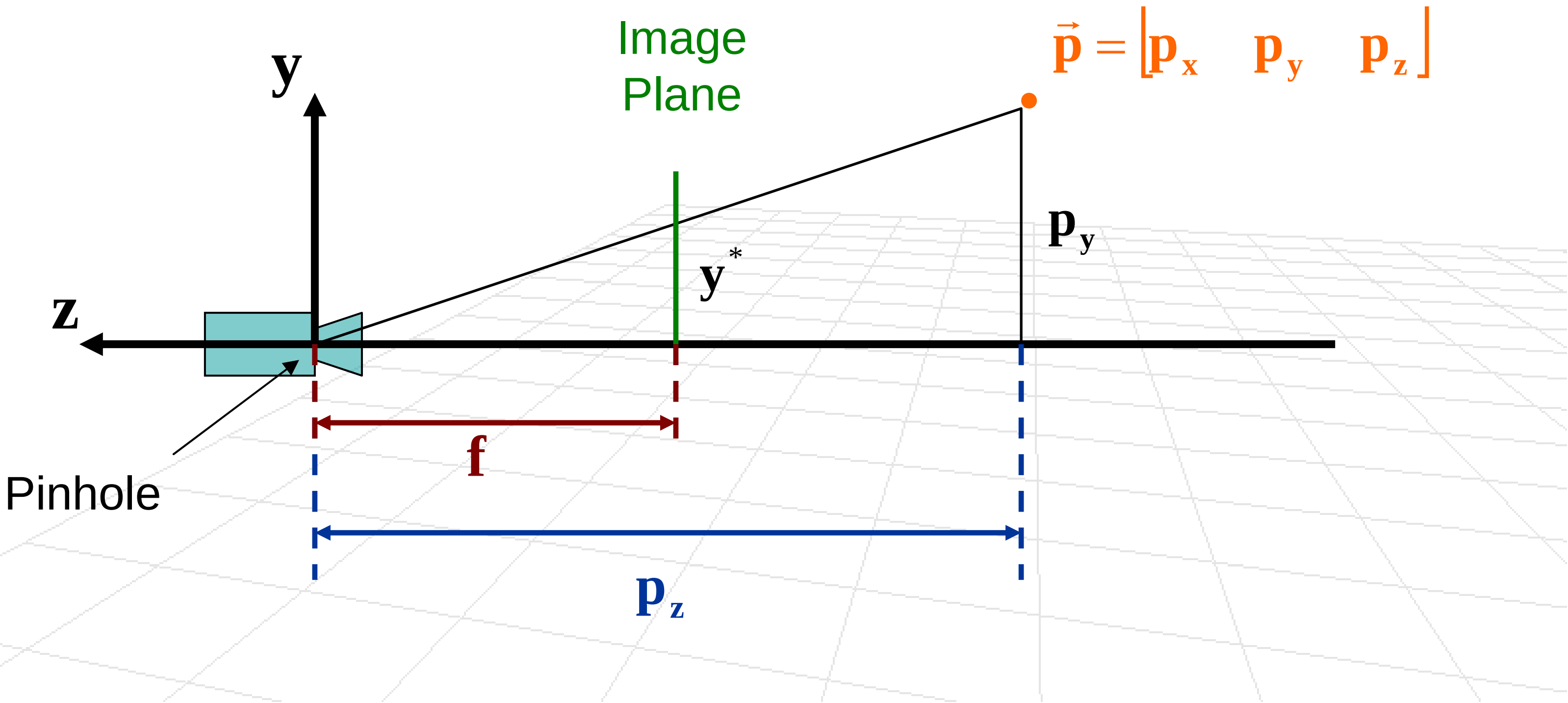
Babies see the world Upside-down for a few days

http://www.societyofrobots.com/

Brain is very smart

Perspective Projection

- Using similar triangles:



Perspective Projection

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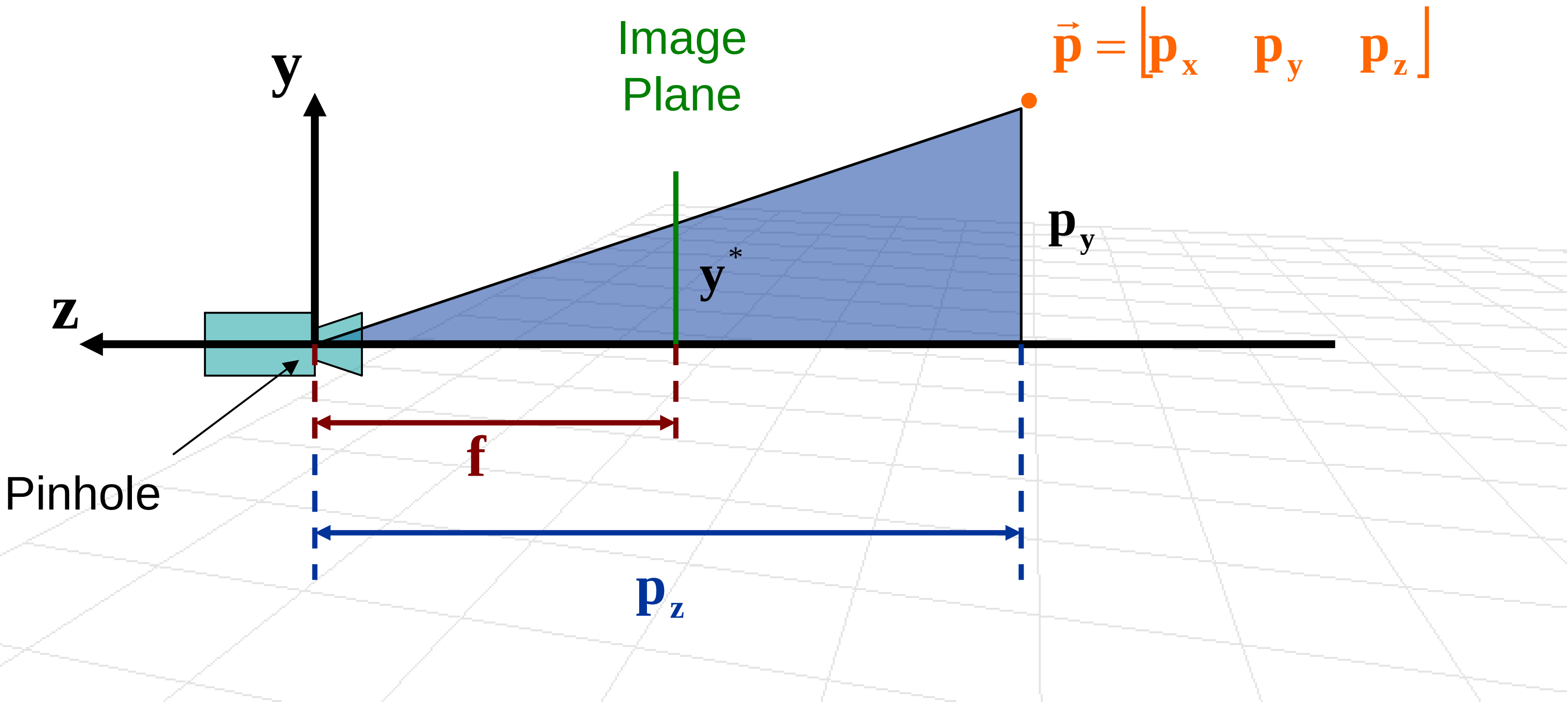

Perspective Projection

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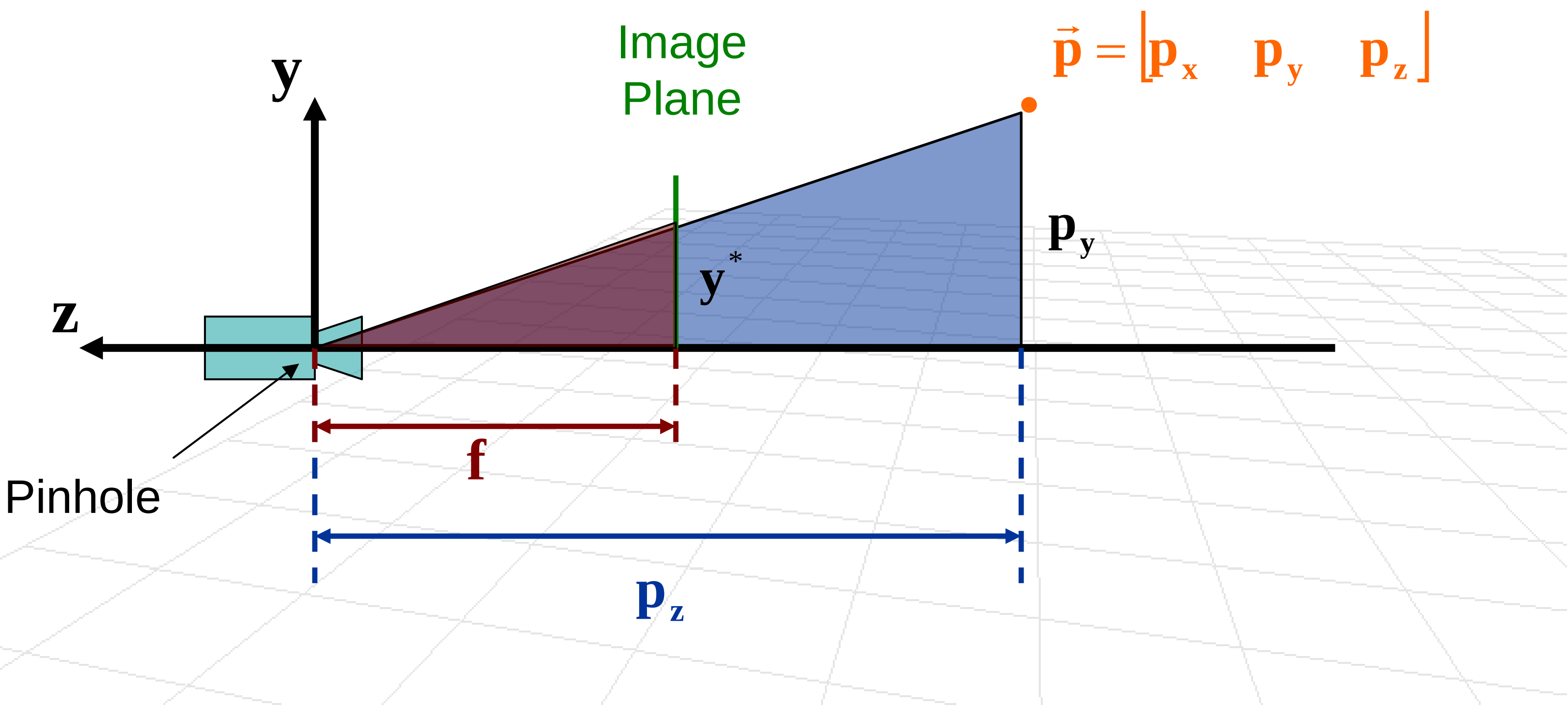
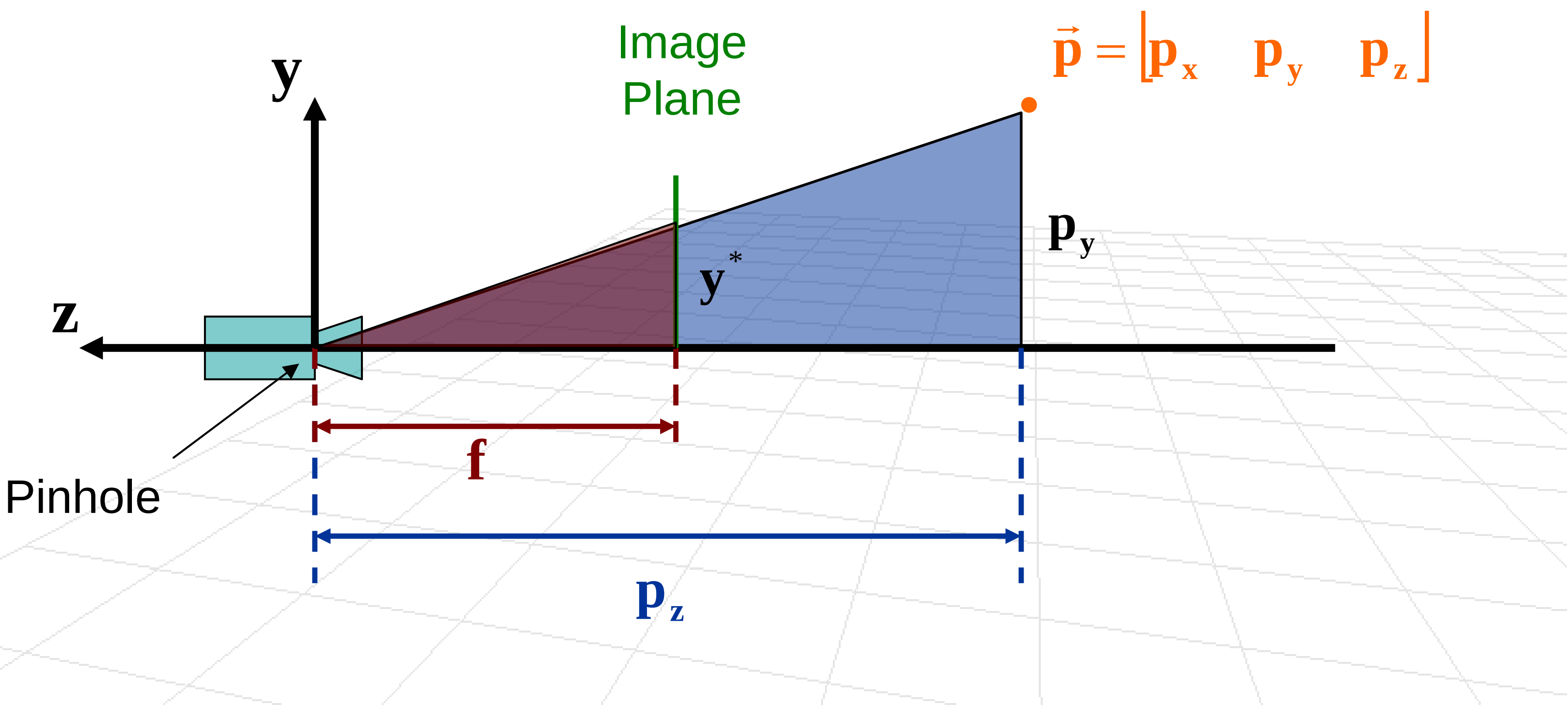


Perspective Projection

- Using similar triangles: $\frac{y^*}{p_y} = \frac{f}{p_z}$

$$y^* = \frac{f}{p_z} p_y$$



Perspective Projection

- Using similar triangles: $\frac{y^*}{p_y} = \frac{f}{p_z}$ $\frac{x^*}{p_x} = \frac{f}{p_z}$

$$y^* = \frac{f}{p_z} p_y$$

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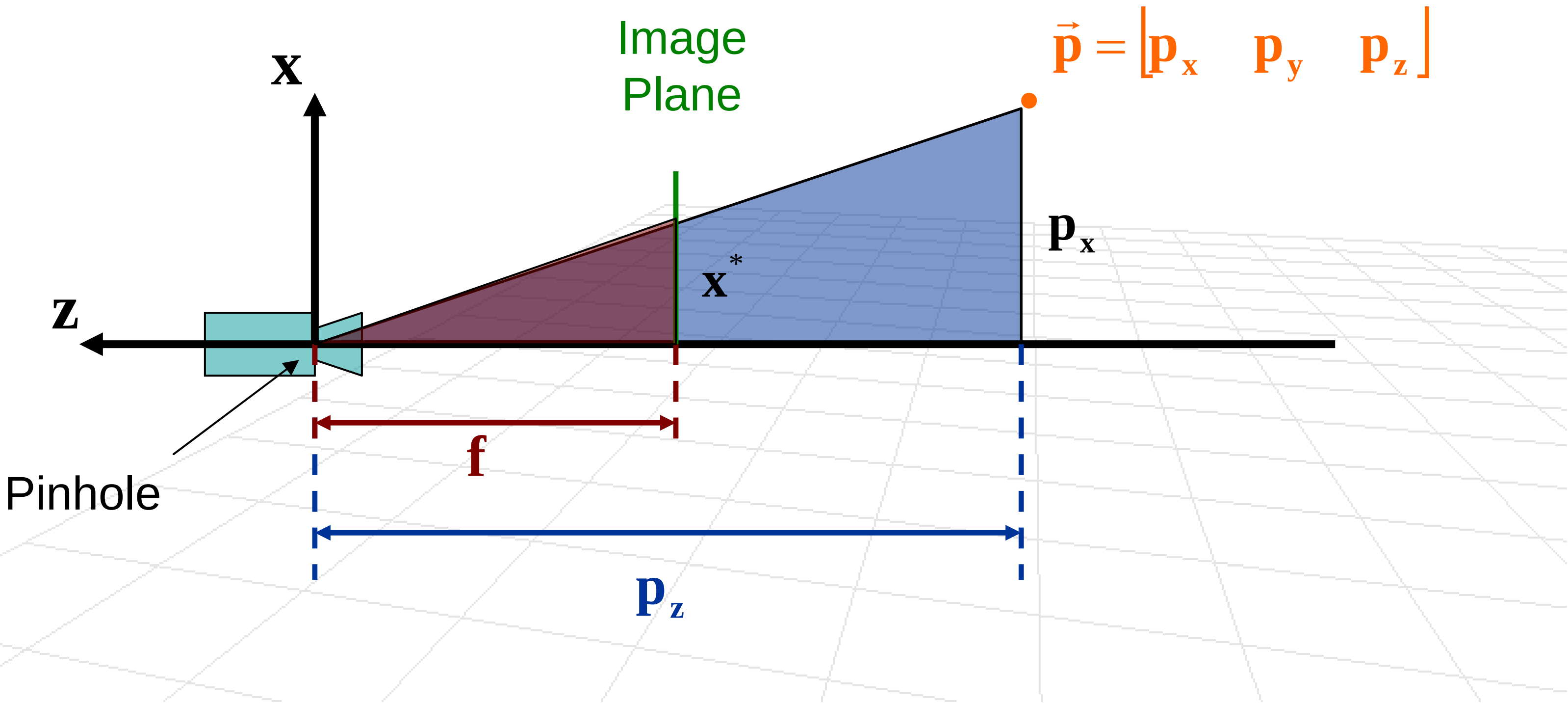
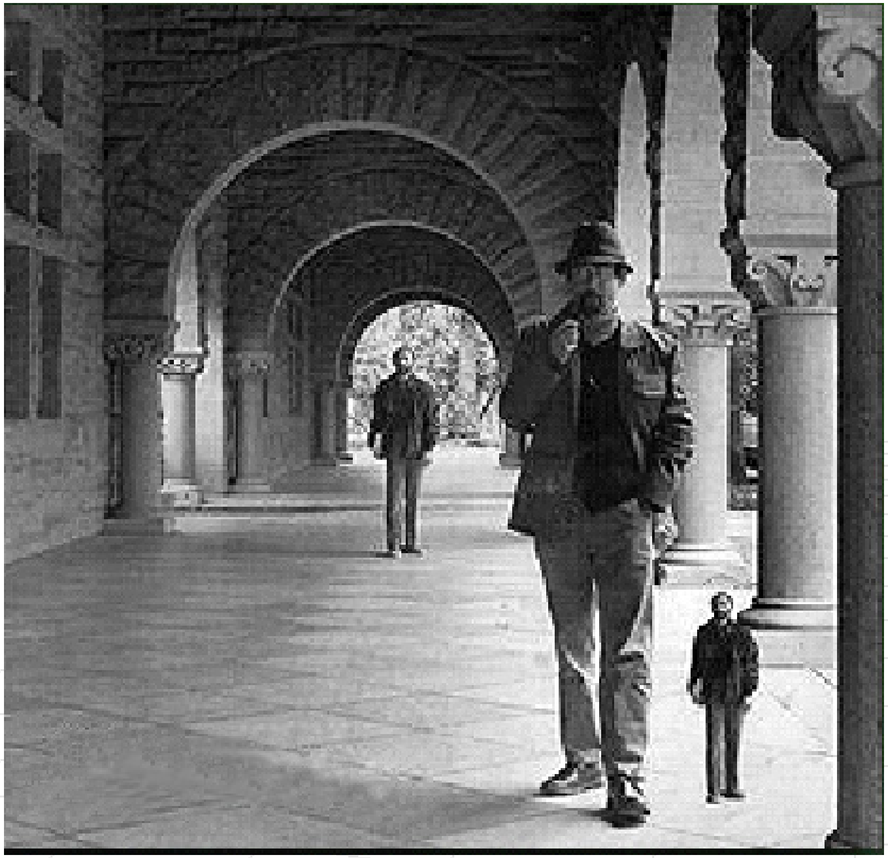


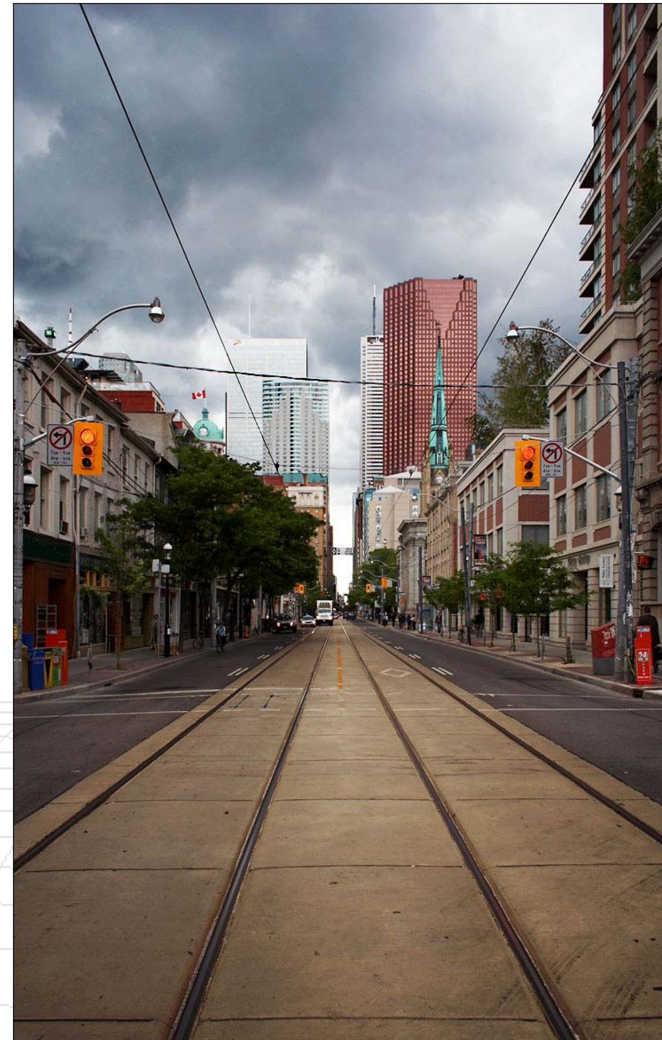
Perspective Projection

- What does prospective projection gives us?
  - Depth perception - objects that are far away appear smaller



Perspective Projection Properties

- Not a linear transform
- Important properties
  - Lines are preserved
  - Distances along the lines are not
  - Parallel lines are not preserved (vanishing point)



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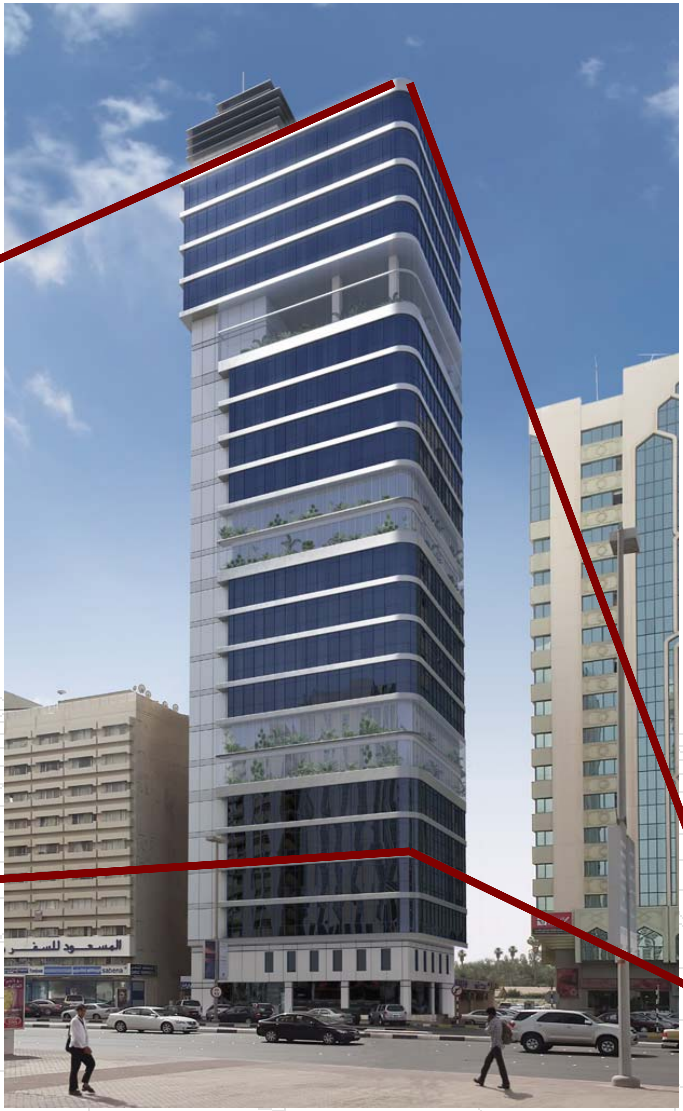

Orthographic Projection

- What if objects are sufficiently far away?
  - Rays almost perpendicular
  - Variation in $\mathbf{p}_z$ is insignificant
  - For both points $\mathbf{y}^* \approx \alpha\, \mathbf{p}_y$