CSCI 497P/597P: Computer Vision

Scott Wehrwein

Cameras and Panoramas

Reading

- Szeliski: Chapter 2.1.5-6, 6.3

Goals

- Understand the geometry of basic image formation under the pinhole model.
- Understand the derivation for the 3x4 pinhole perspective projection matrix.
- Know the properties and projection matrix associated with orthographic projection.
- Understand the concept of focal length and its relationship with the projection matrix.

Announcements

- RANSAC Slides and lecture notes are on course webpage.
- Aiming for P3 release early next week.

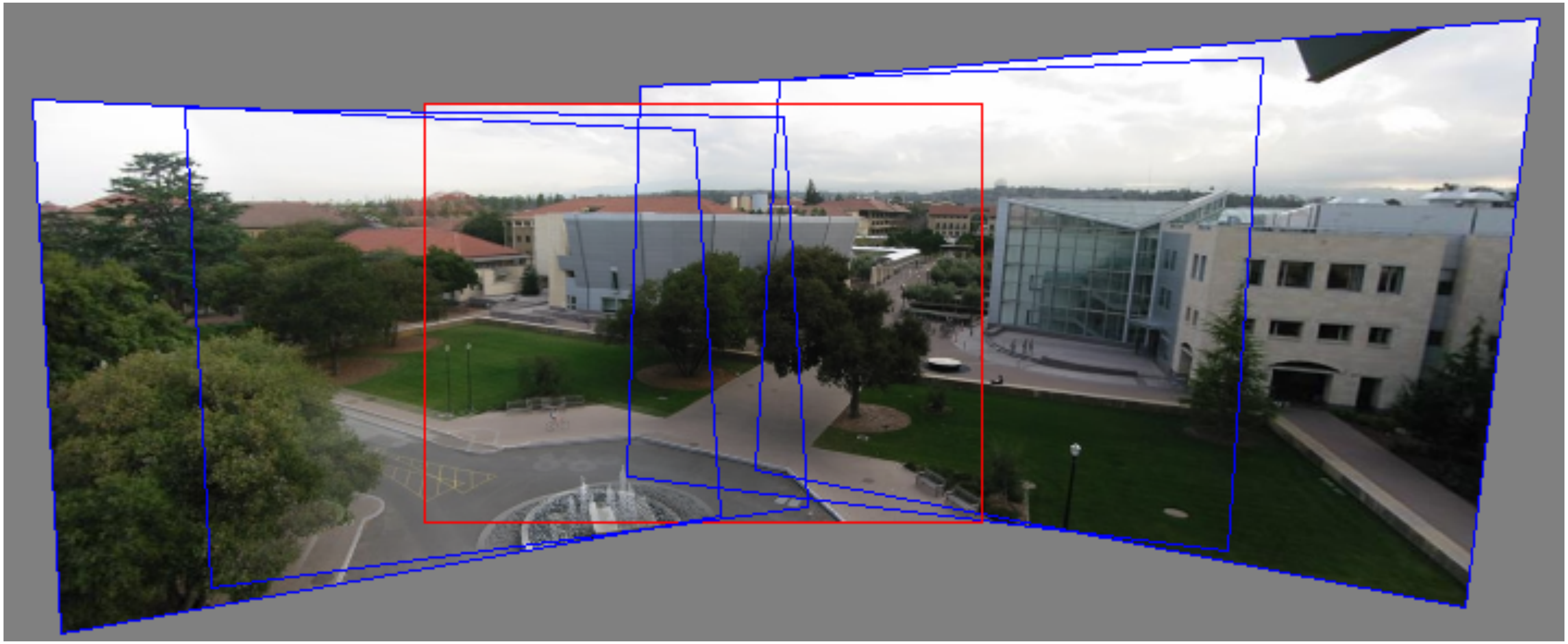
Happenings

- Monday, 2/4 – CSCI Faculty Candidate: Research Talk – 4 pm in CF 316
- Tuesday, 2/5 – CSCI Faculty Candidate: Teaching Talk – 4 pm in CF 316
- Tuesday, 2/5 – ACM Research Talk: Nick Majeske! – 5 pm in CF 316
- Wednesday, 2/6 – PNNL Info Table – 11 am – 3 pm in the CF 4th Floor Foyer
- Wednesday, 2/6 – Tech Talk: PNNL – 5 pm in CF 105
- Wednesday, 2/6 – Peer Lecture Series: Debugging Workshop – 5 pm in CF 420
- Thursday, 2/7 – Winter Career Fair w/ STEM Focus – 11 am – 3 pm in the MAC Gym

Panoramas

- Now we know how to create panoramas!
- Given two images:
  - Step 1: Detect features
  - Step 2: Match features
  - Step 3: Compute a homography using RANSAC
  - Step 4: Combine the images together (somehow)
- What if we have more than two images?

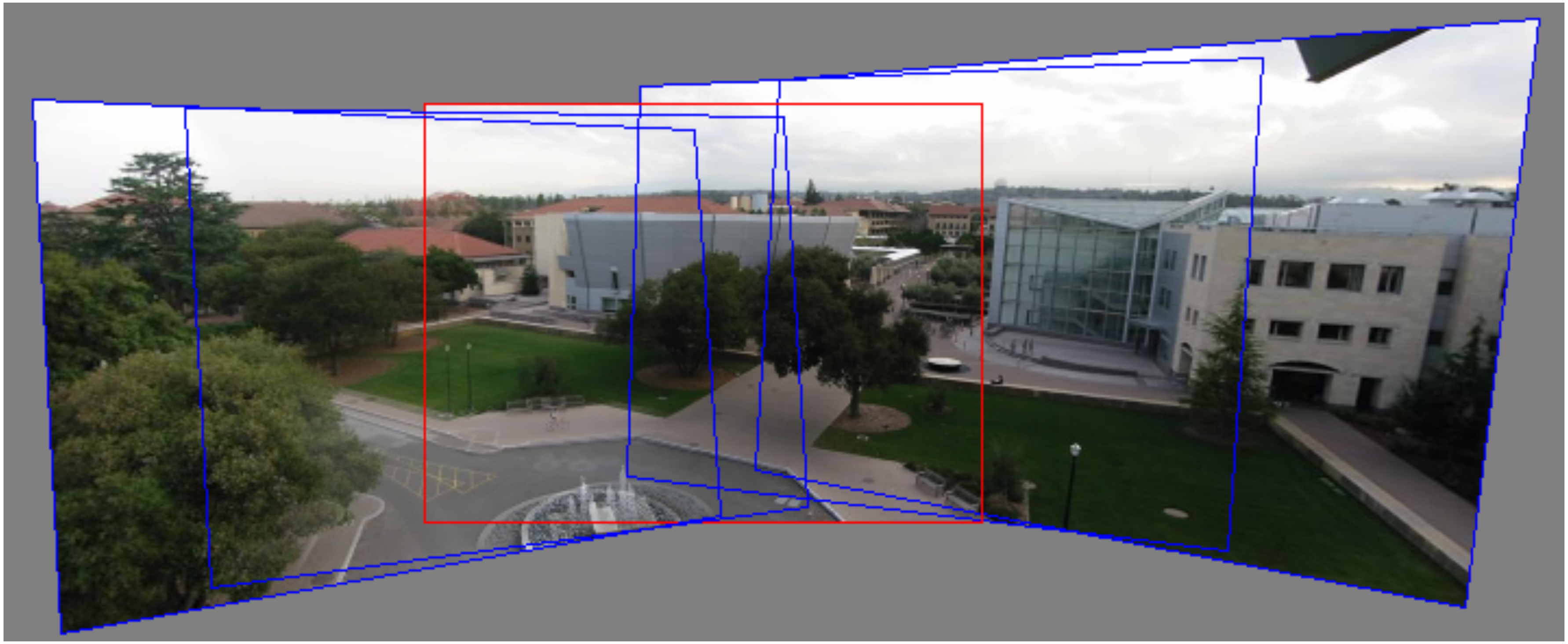
Can we use homographies to create a 360 panorama?



- In order to figure this out, we need to learn what a **camera** is

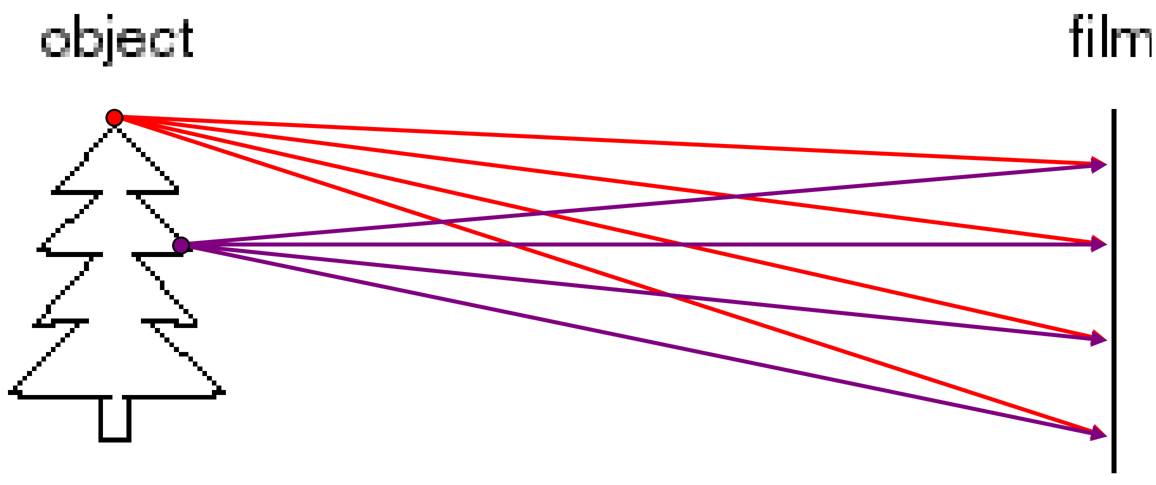
360 panorama

Can we use homographies to create a 360 panorama?



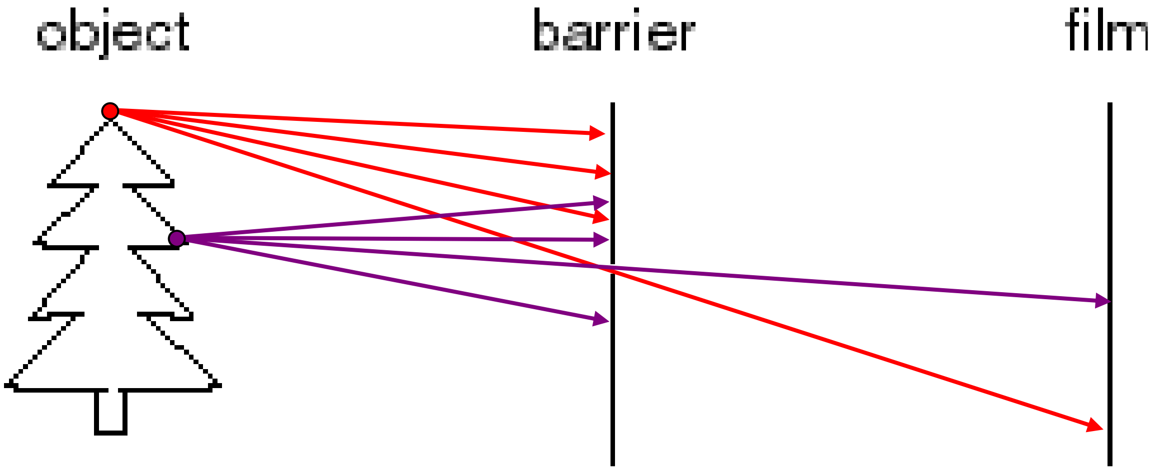
- In order to figure this out, we need to learn what a **camera** is

Image formation



- Let's design a camera
  - Idea 1: put a piece of film in front of an object
  - Do we get a reasonable image?

Pinhole camera



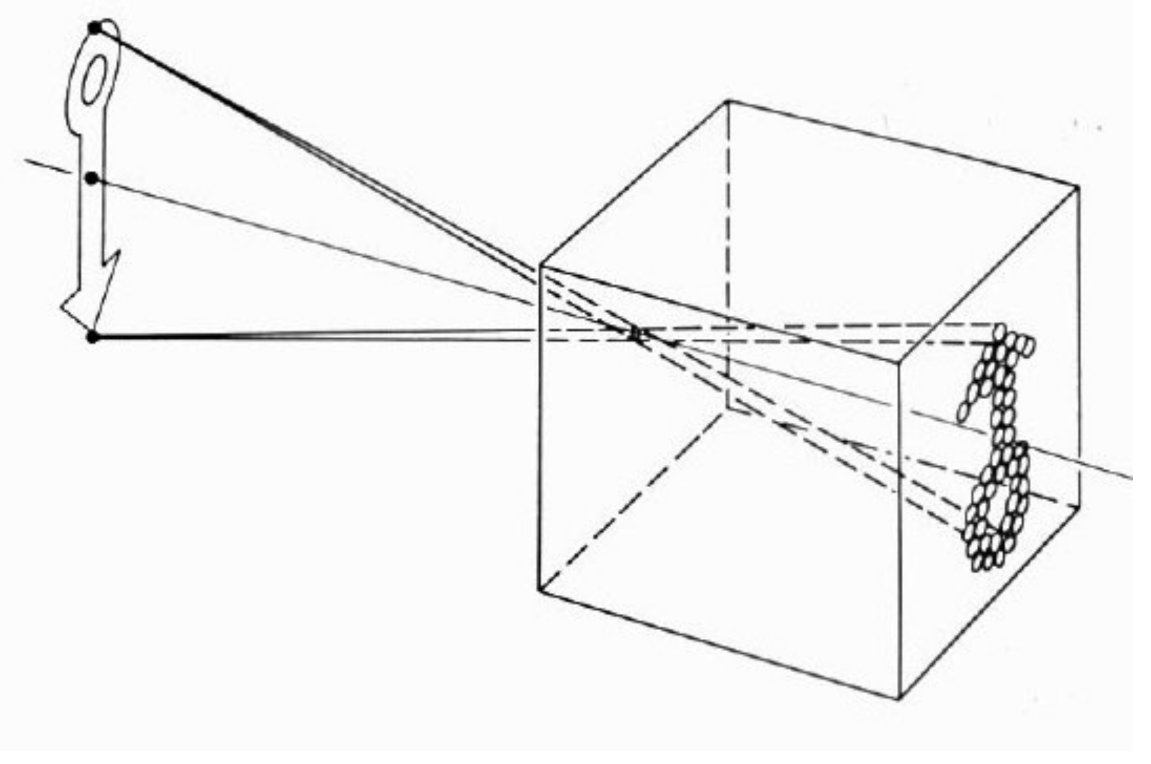
- Add a barrier to block off most of the rays
  - This reduces blurring
  - The opening known as the **aperture**
  - How does the image relate to the scene?

Camera Obscura

- Basic principle known to Mozi (470-390 BC), Aristotle (384-322 BC)
- Drawing aid for artists: described by Leonardo da Vinci (1452-1519)

Source: A. Efros

Camera Obscura



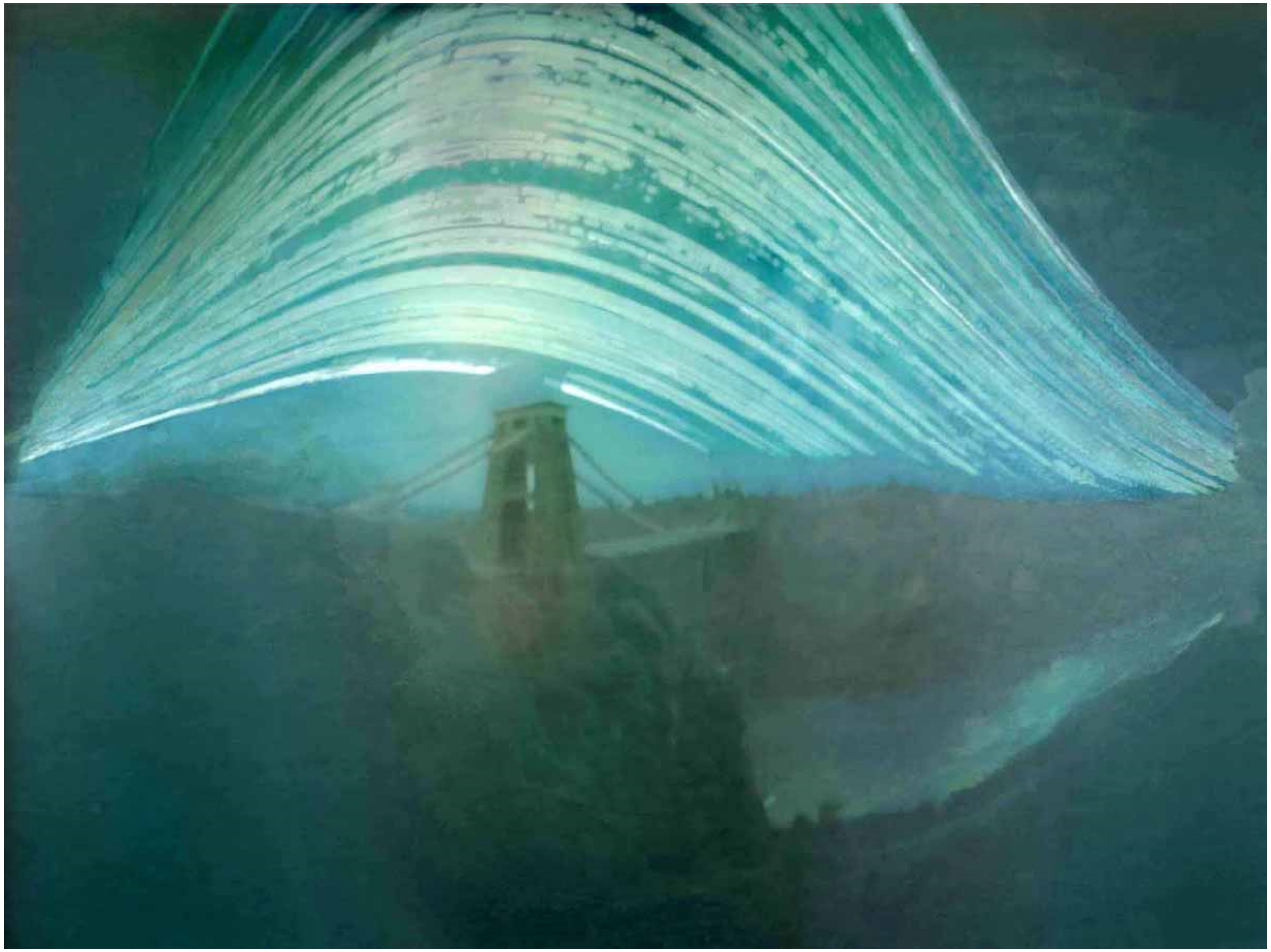
Home-made pinhole camera

Why so blurry?

http://www.debevec.org/Pinhole/

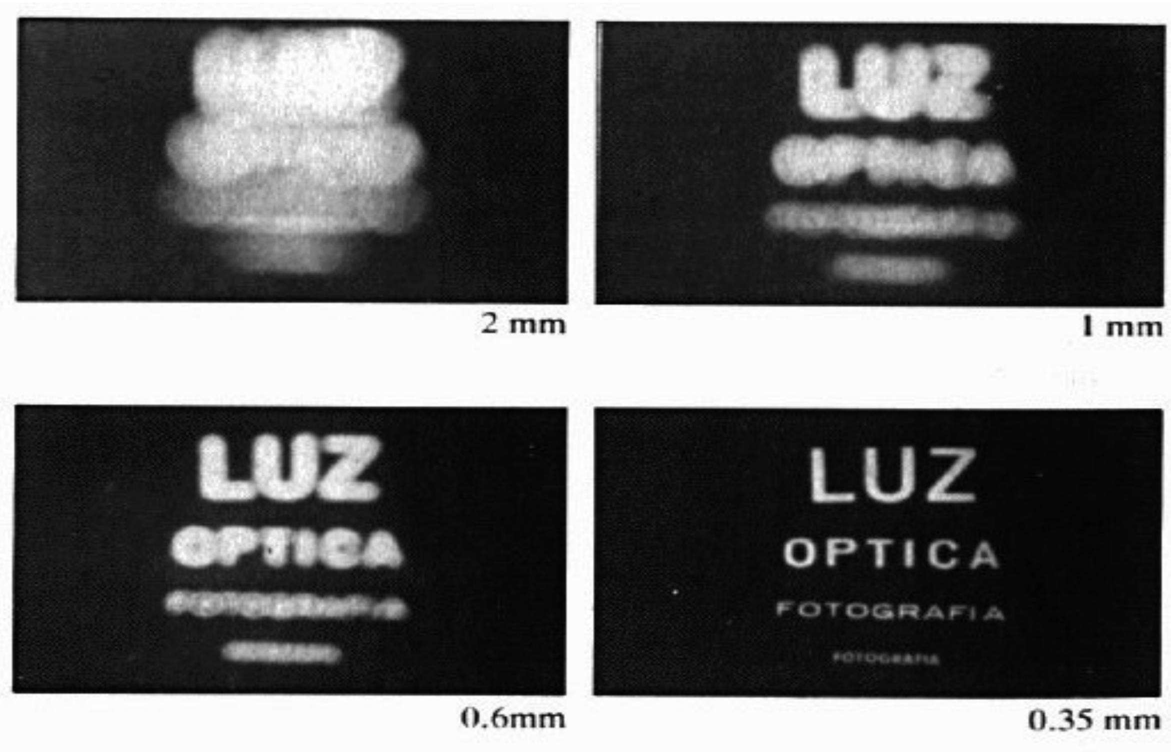
Slide by A. Efros

Pinhole photography



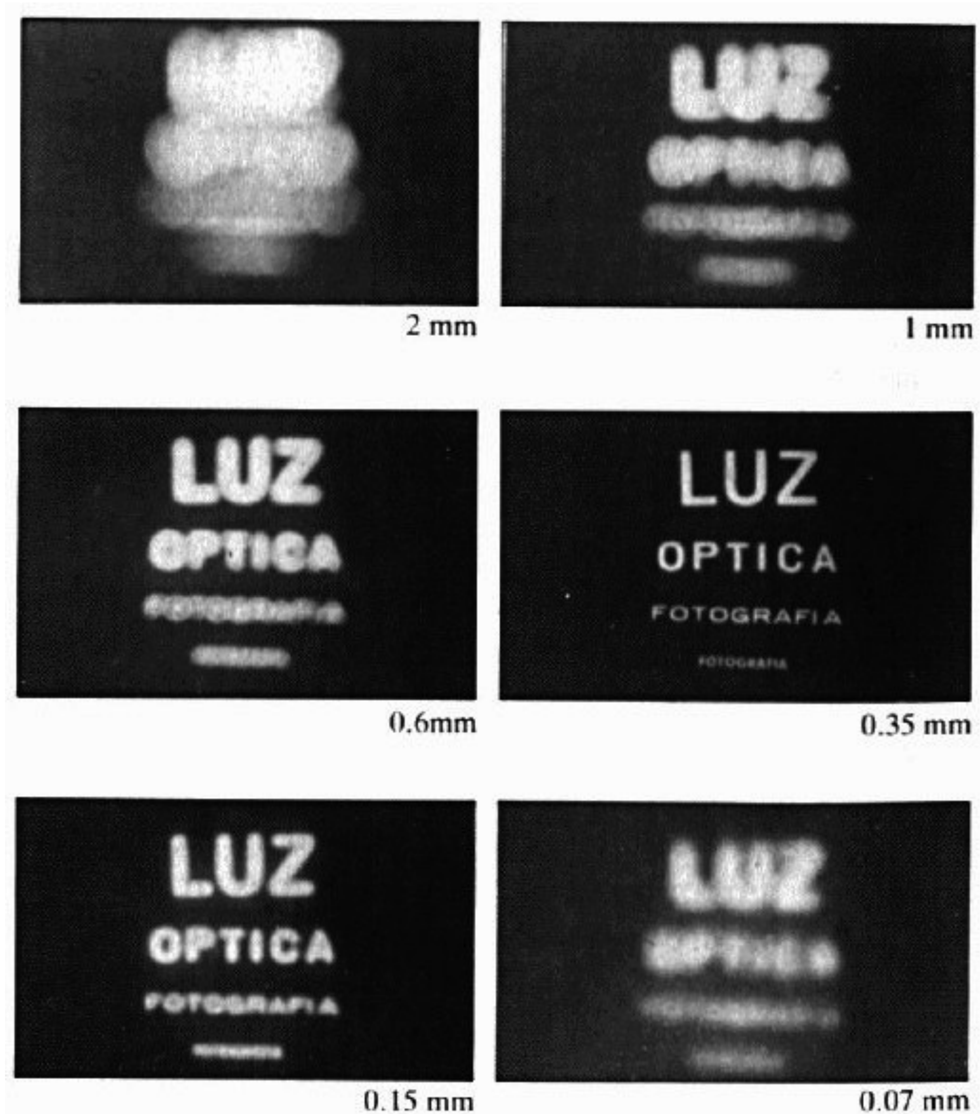
Justin Quinnell, The Clifton Suspension Bridge. December 17th 2007 - June 21st 2008
***6-month* exposure**

Shrinking the aperture

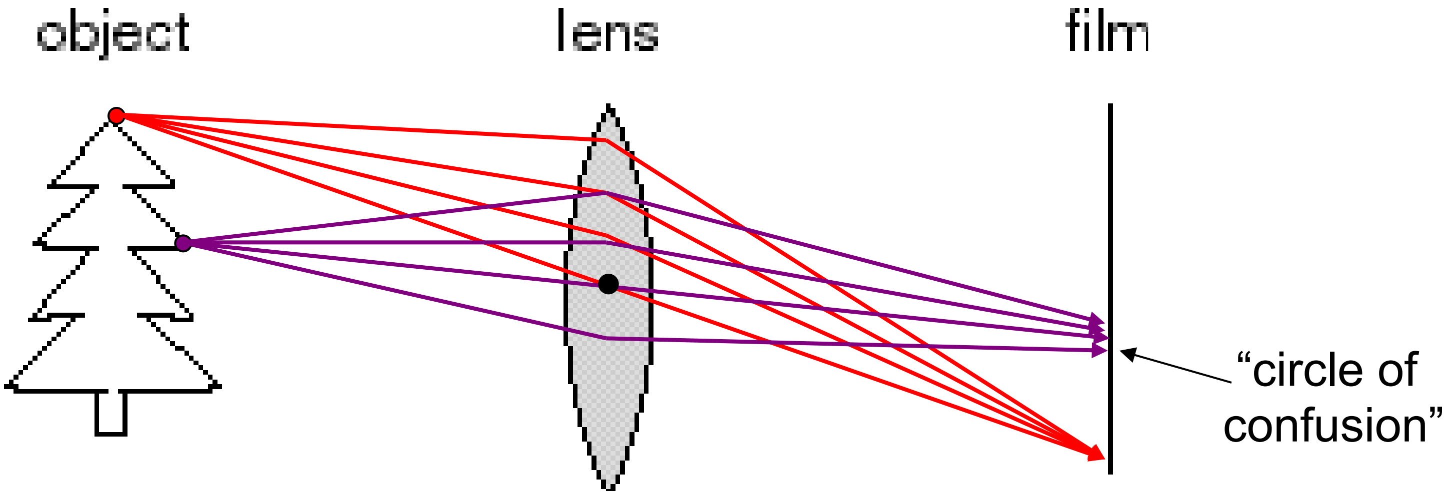


- Why not make the aperture as small as possible?
  - Less light gets through
  - *Diffraction* effects...

Shrinking the aperture



Adding a lens



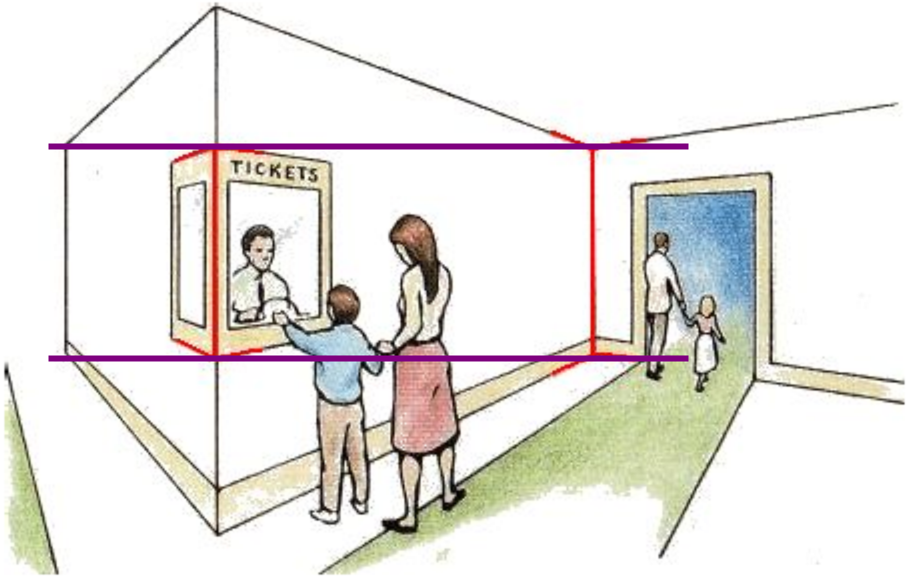
- A lens focuses light onto the film
  - There is a specific distance at which objects are "in focus"
    - other points project to a "circle of confusion" in the image
  - Changing the shape of the lens changes this distance

Projection


MAKE POVERTY HISTORY
JULIAN BEEVER
CoolOpticalIllusions.com

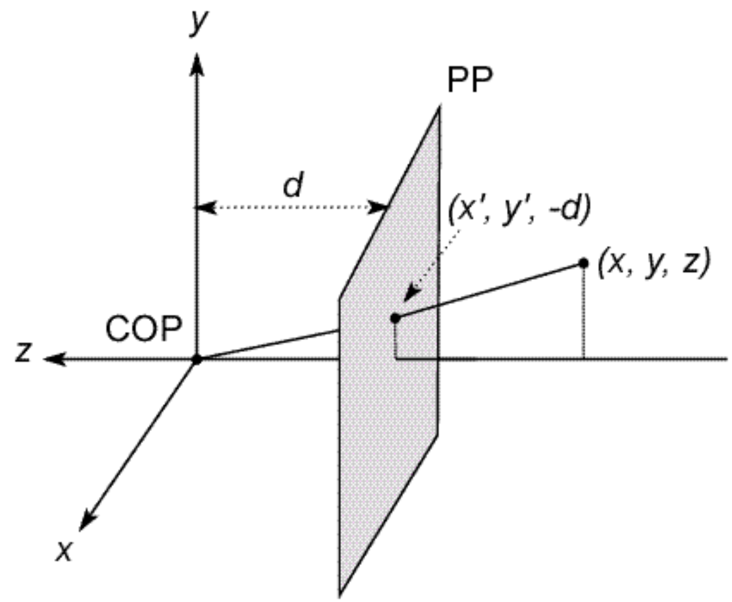
Projection

Müller-Lyer Illusion



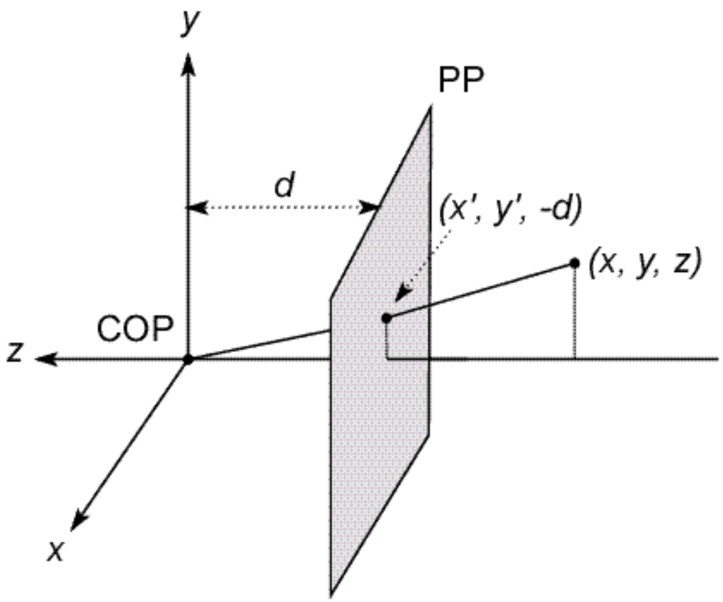
http://www.michaelbach.de/ot/sze_muelue/index.html

Modeling projection



- The coordinate system
  - We will use the pinhole model as an approximation
  - Put the optical center (**C**enter **O**f **P**rojection) at the origin
  - Put the image plane (**P**rojection **P**lane) *in front* of the COP
    - Why?
  - The camera looks down the *negative* z axis
    - we like this if we want right-handed-coordinates

Modeling projection



- Projection equations
  - Compute intersection with PP of ray from (x,y,z) to COP
  - Derived using similar triangles (on board)

$$(x, y, z) \rightarrow (-d\frac{x}{z},\ -d\frac{y}{z},\ -d)$$

- We get the projection by throwing out the last coordinate:

$$(x, y, z) \rightarrow (-d\frac{x}{z},\ -d\frac{y}{z})$$

Modeling projection

- Is this a linear transformation?
  - no—division by z is nonlinear

Homogeneous coordinates to the rescue—again!

$$(x, y) \Rightarrow \begin{bmatrix} x \\ y \\ 1 \end{bmatrix}$$

homogeneous image coordinates

$$(x, y, z) \Rightarrow \begin{bmatrix} x \\ y \\ z \\ 1 \end{bmatrix}$$

homogeneous scene coordinates

Converting *from* homogeneous coordinates

$$\begin{bmatrix} x \\ y \\ w \end{bmatrix} \Rightarrow (x/w, y/w)$$

$$\begin{bmatrix} x \\ y \\ z \\ w \end{bmatrix} \Rightarrow (x/w, y/w, z/w)$$

Perspective Projection

Projection is a matrix multiply using homogeneous coordinates:

$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & -1/d & 0 \end{bmatrix} \begin{bmatrix} x \\ y \\ z \\ 1 \end{bmatrix} = \begin{bmatrix} x \\ y \\ -z/d \end{bmatrix} \Rightarrow (-d\frac{x}{z}, \ \ -d\frac{y}{z})$$

divide by third coordinate

This is known as **perspective projection**

- The matrix is the **projection matrix**

- (Can also represent as a 4x4 matrix – OpenGL does something like this)

Perspective Projection

- How does scaling the projection matrix change the transformation?

$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & -1/d & 0 \end{bmatrix} \begin{bmatrix} x \\ y \\ z \\ 1 \end{bmatrix} = \begin{bmatrix} x \\ y \\ -z/d \end{bmatrix} \Rightarrow (-d\frac{x}{z}, \quad -d\frac{y}{z})$$

$$\begin{bmatrix} -d & 0 & 0 & 0 \\ 0 & -d & 0 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} x \\ y \\ z \\ 1 \end{bmatrix} = \begin{bmatrix} -dx \\ -dy \\ z \end{bmatrix} \Rightarrow (-d\frac{x}{z}, \quad -d\frac{y}{z})$$