CSCI 497P/597P: Computer Vision

Lecture 18

Pinhole Camera Model

360 (Spherical) Panoramas, Part 1

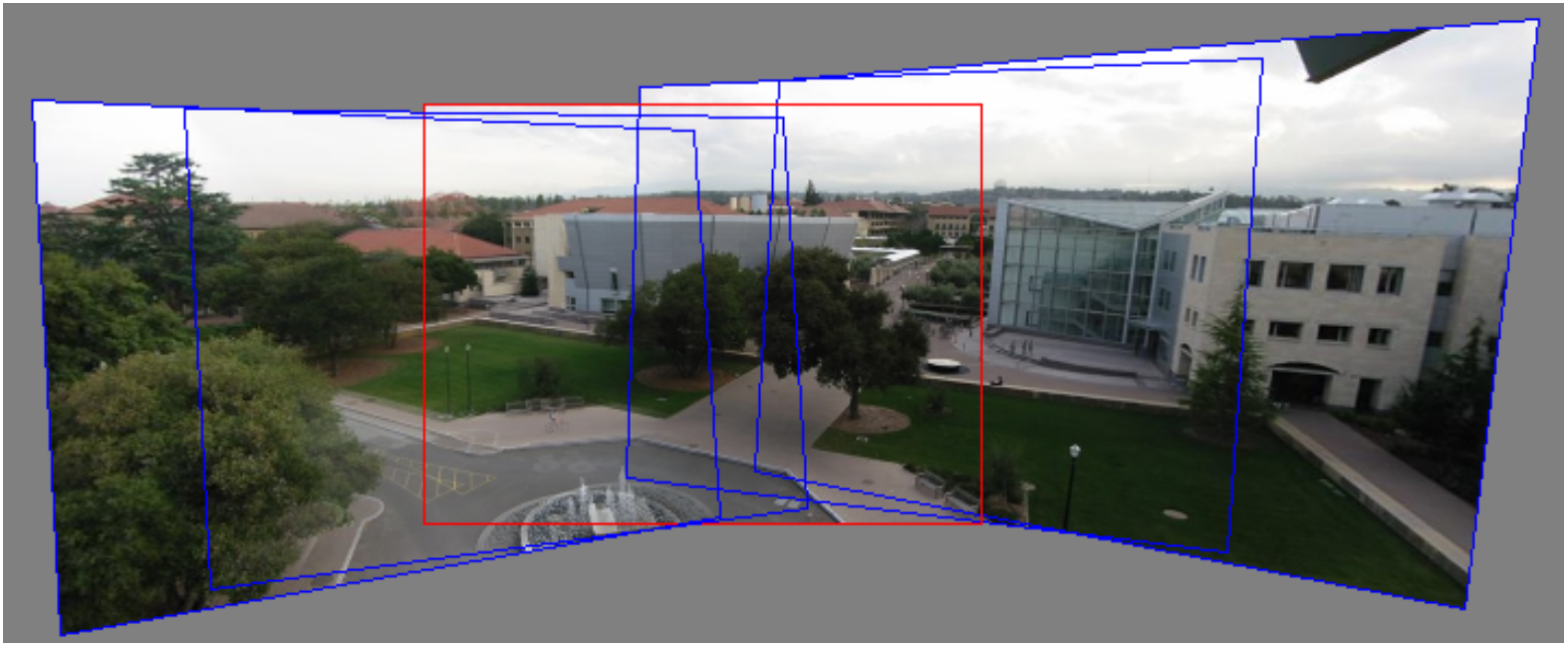
Announcements

- HW3 due Wednesday
- P2 due in a week - how's it going?

Goals

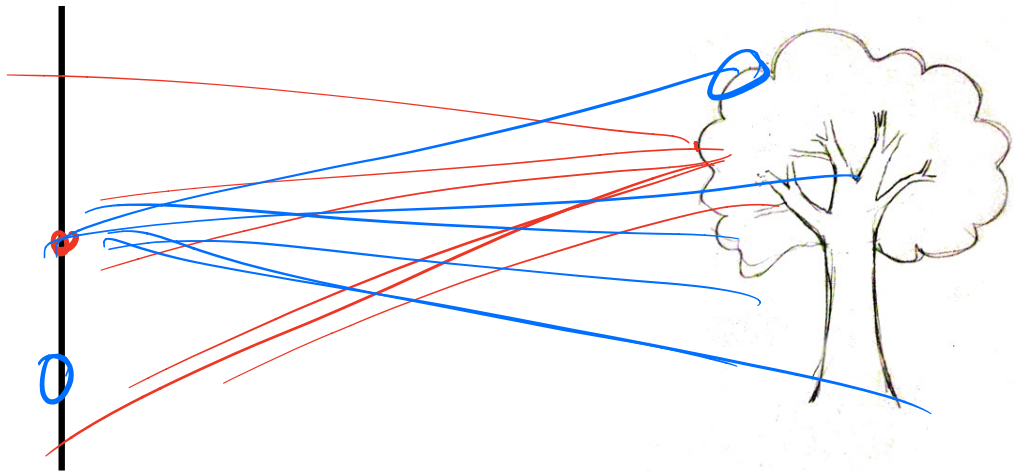
- Understand where images come from (under the pinhole camera model)
  - Be able to derive the 3x4 pinhole projection matrix
  - Understand the interpretation of planar panorama stitching in terms of using homographies to map images onto a common plane.
- Get intuition for how to create 360 degree panoramas by mapping images onto a spherical surface instead.

Can we make 360 panoramas?

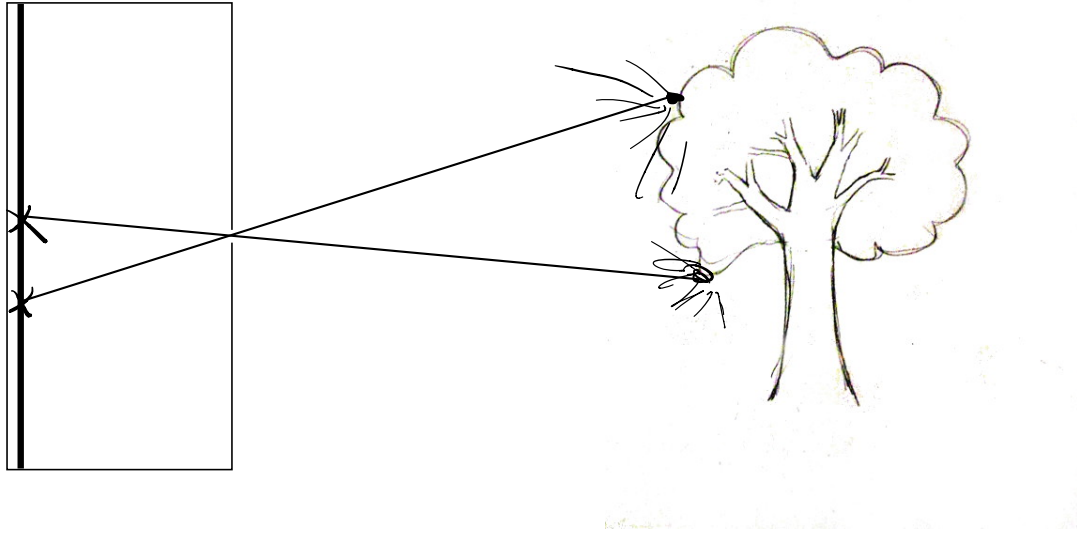


To answer this, we need to know how these images came to be.
Why can we even make **any** panoramas with homographies?

Where do images come from?



497Cam, Mk I: Not Really A Camera At All.



497Cam, Mk II: A Pinhole Camera

Camera Obscura (pinhole camera)

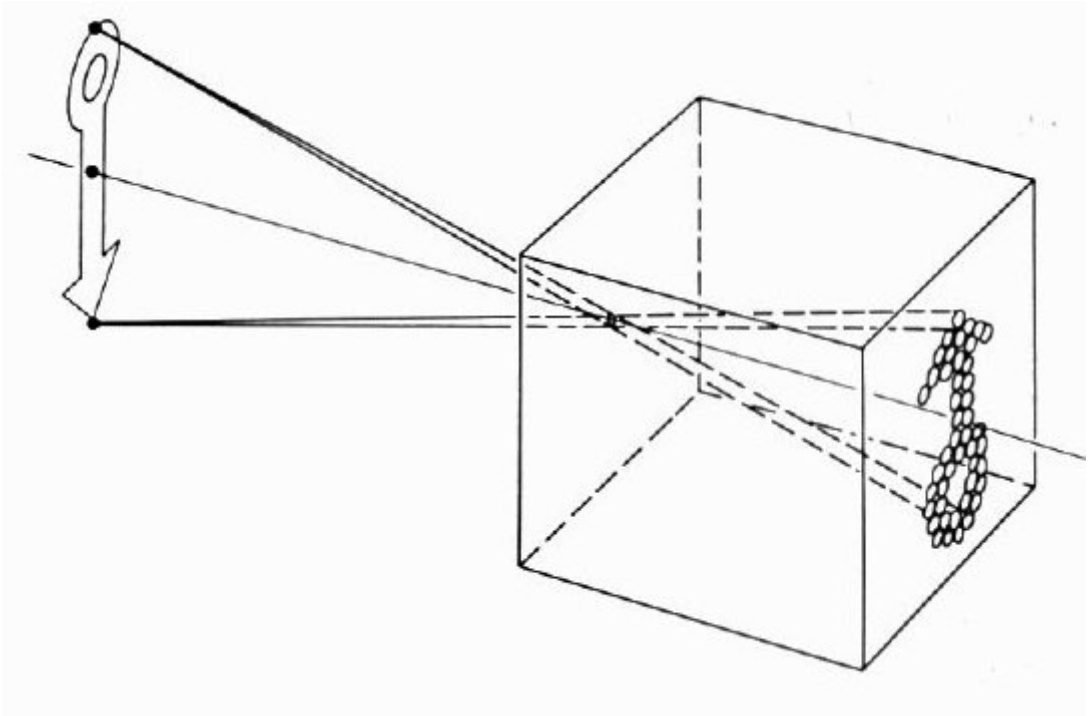
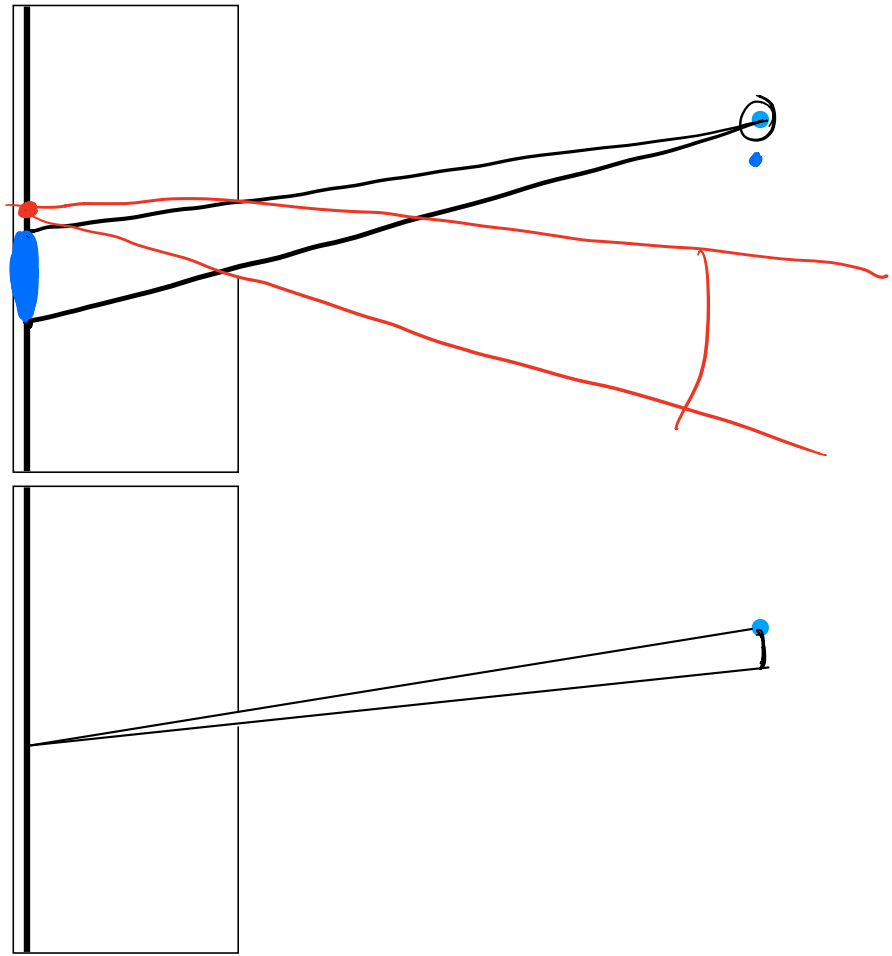
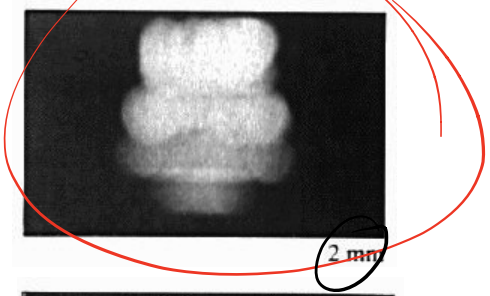
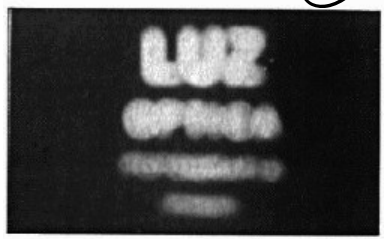


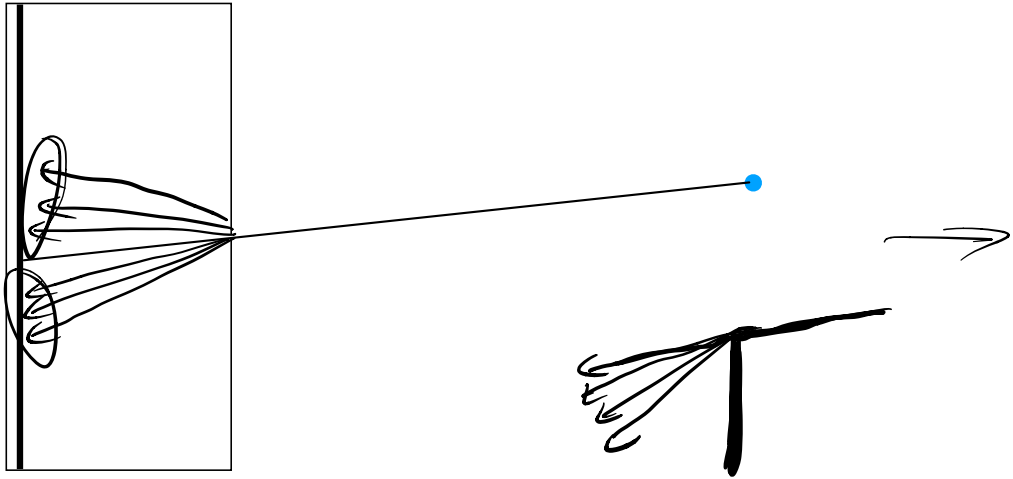
image: https://petapixel.com/2014/05/12/diy-tutorial-convert-room-camera-obscura/

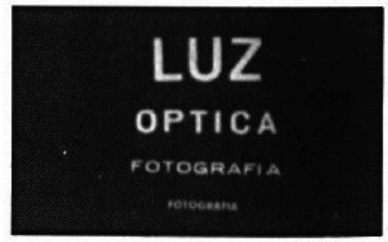
The Effect of Pinhole Size









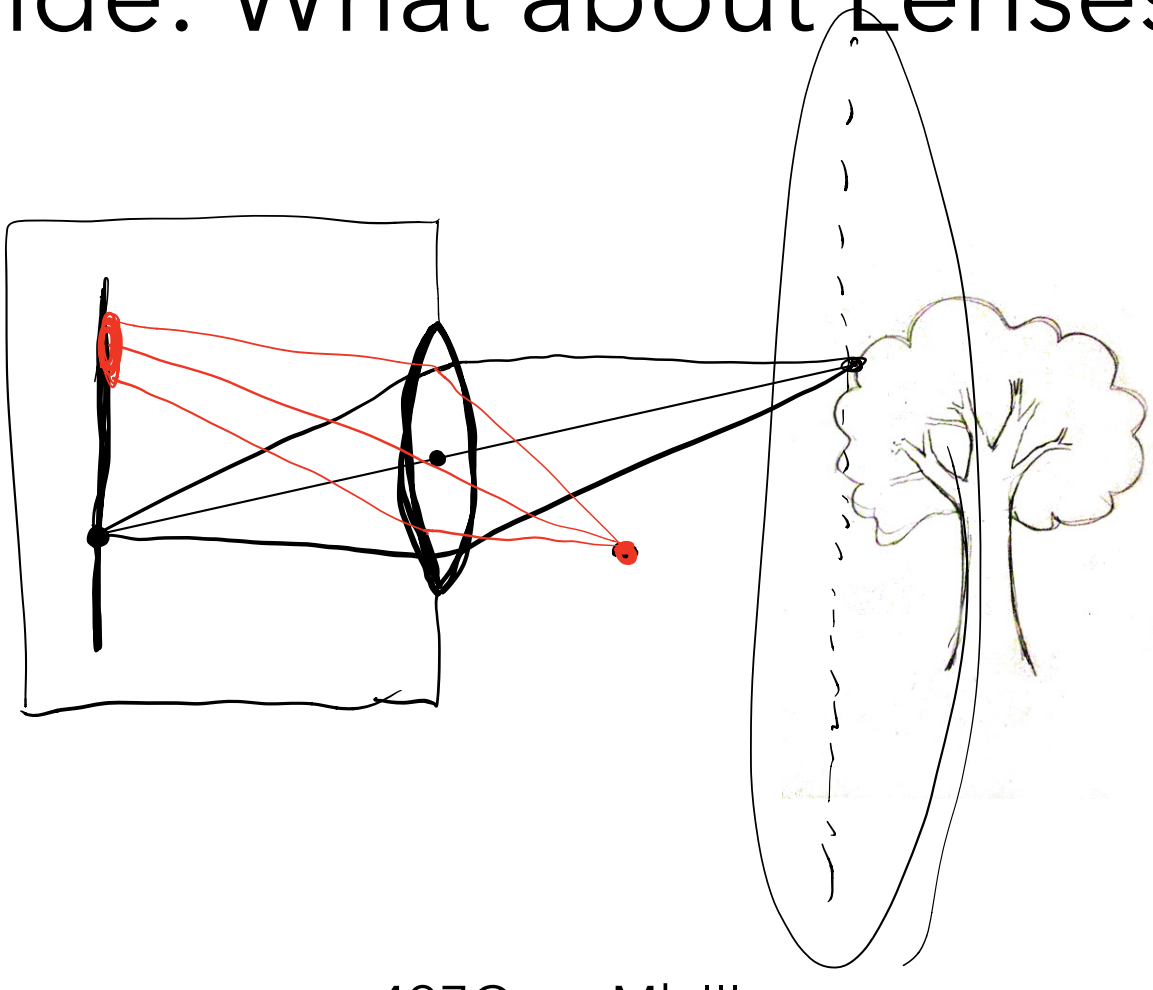


0.35 mm

0.15 mm

0.07 mm

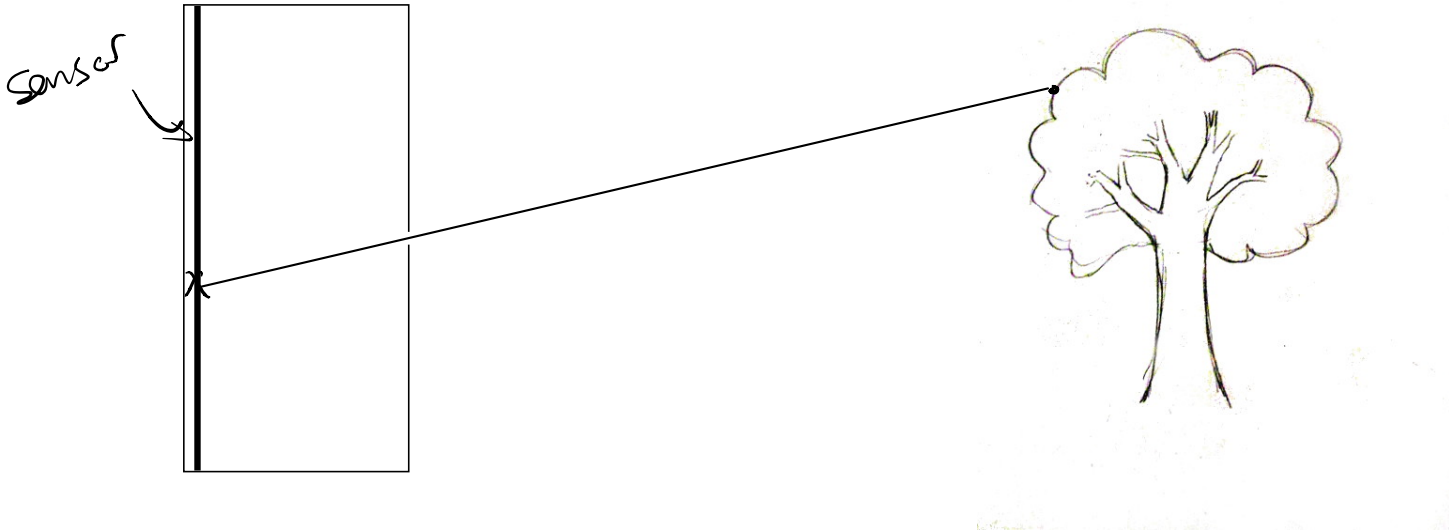
Aside: What about Lenses?



497Cam, Mk III

The Pinhole Camera Model

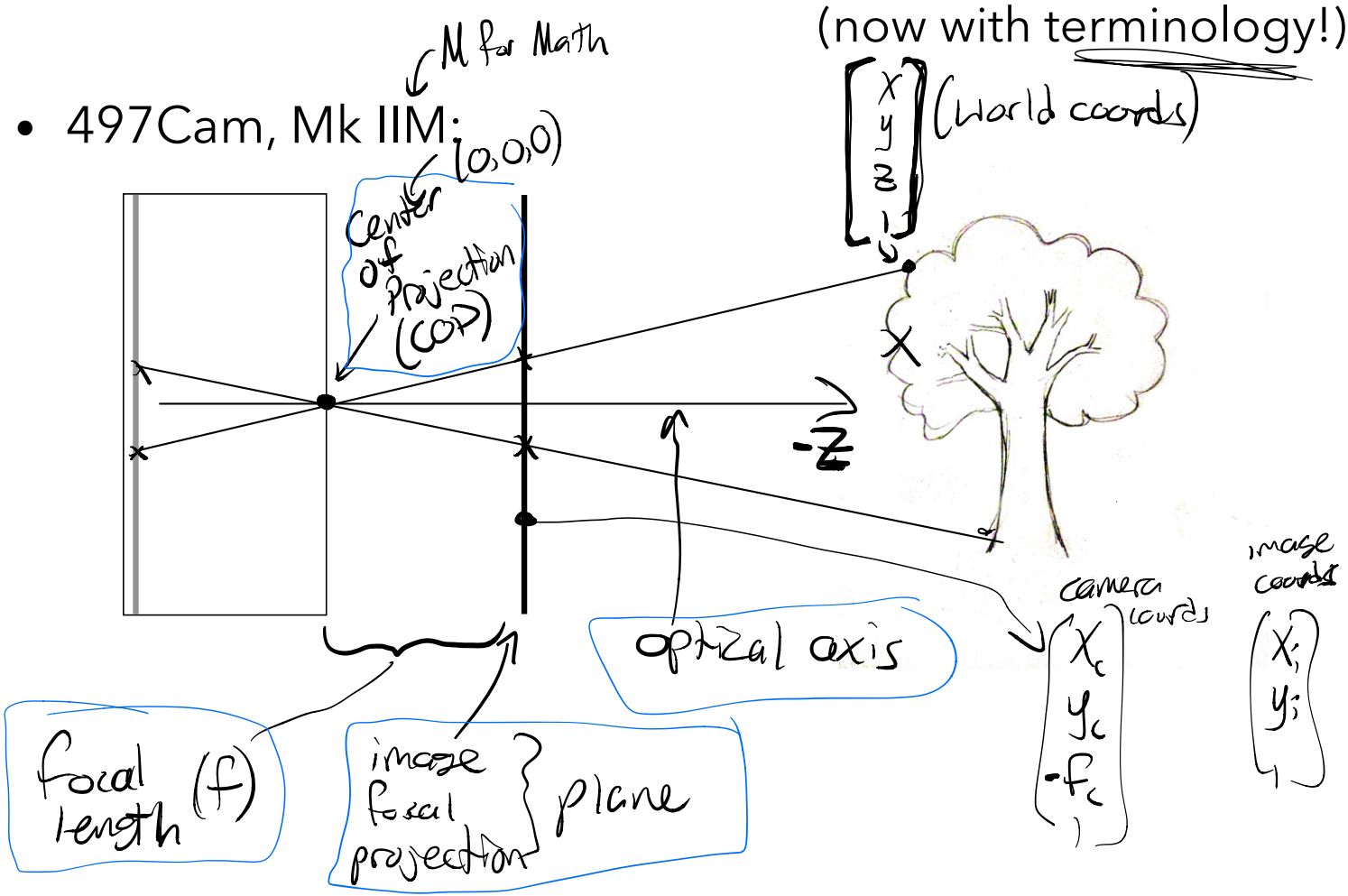
- 497Cam, Mk II:



The Pinhole Camera Model

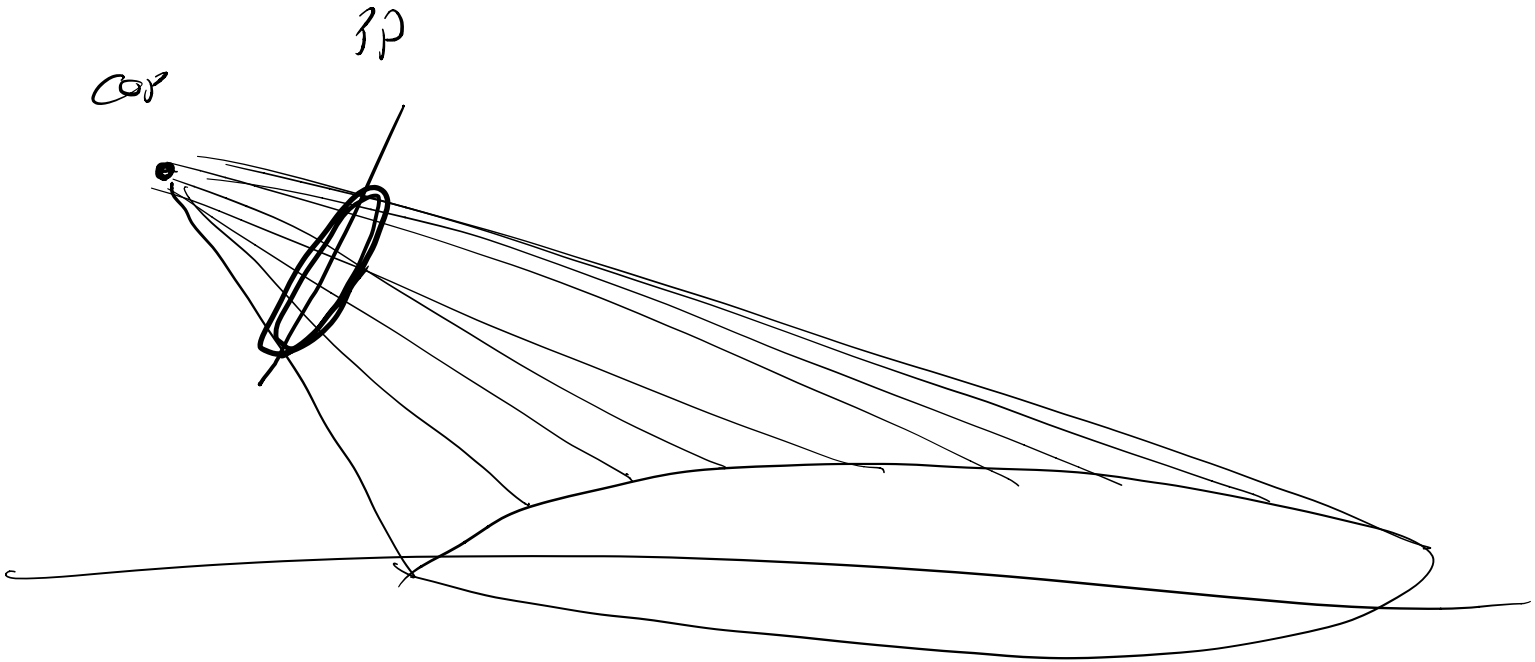
(now with terminology!)

- 497Cam, Mk IIM:




MAKE POVERTY HISTORY
JULIAN BEEVER
CoolOpticalIllusions.com

How does that work?

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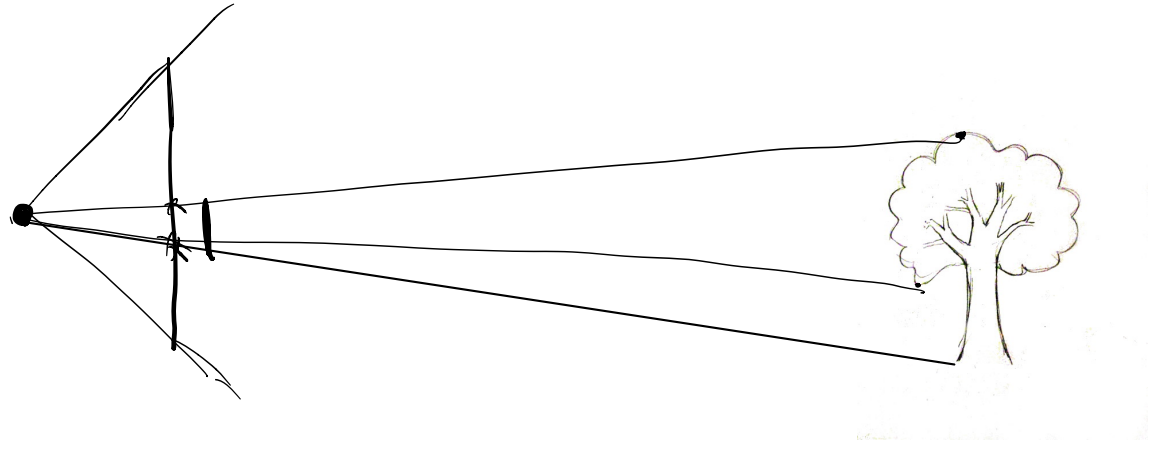
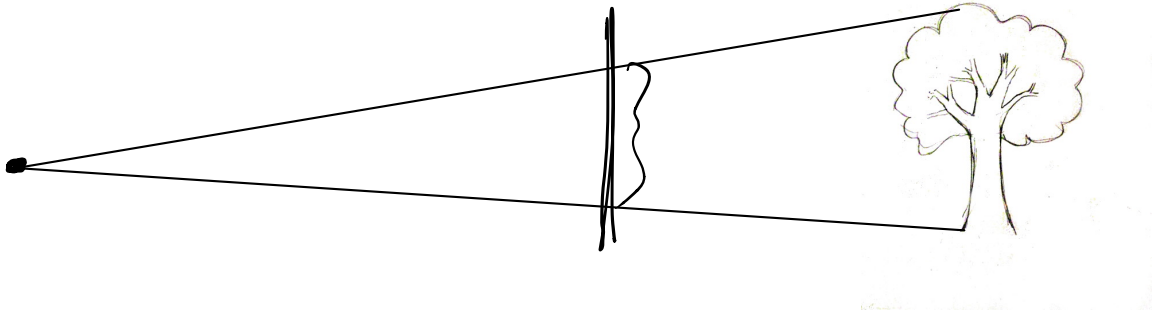
Focal Length





The effect of Focal Length

$ ← Cheap → $

24mm

70m

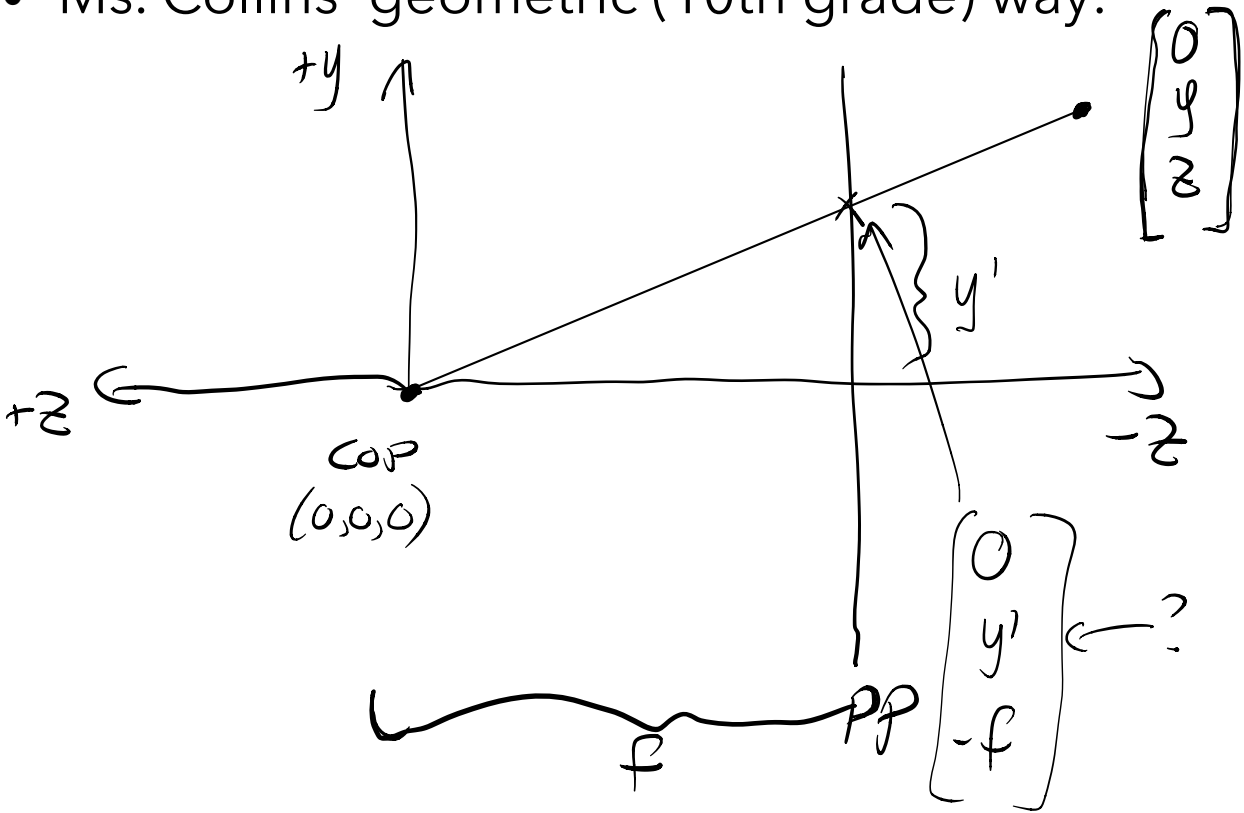
105mm

300mm

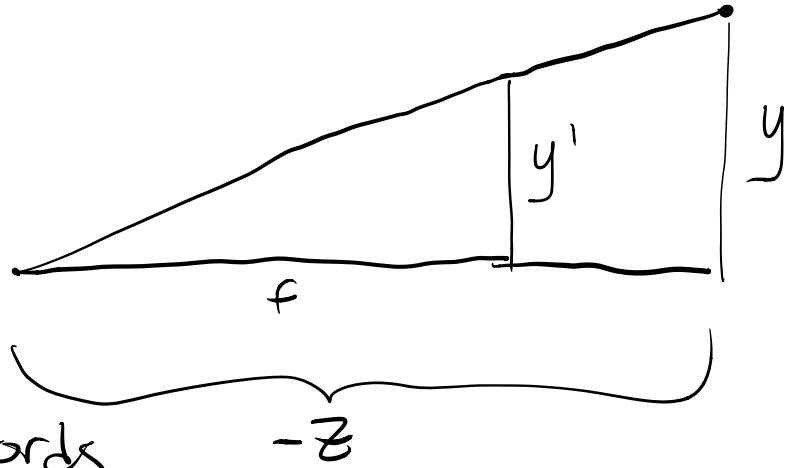
Projection in a Pinhole Camera

For a given 3D pt, where does it land in the image?

- Ms. Collins' geometric (10th grade) way:



$$\frac{y'}{y} = \frac{f}{-z}$$



Camera coords

$$y' = \frac{-fy}{z}$$

$$x' = \frac{-fx}{z}$$

$$z = -f$$

$\longrightarrow$

image coords

$$x' = \frac{-fx}{z}$$

$$y' = \frac{-fy}{z}$$

$$w = 1$$

Projection in a Pinhole Camera

- Dr. Swenton's (15th grade) way:

3D coords

$$\begin{bmatrix} \frac{-fx}{z} \\ \frac{-fy}{z} \\ 1 \end{bmatrix} \approx \begin{bmatrix} -fx \\ -fy \\ z \end{bmatrix} \approx \begin{bmatrix} x \\ y \\ \frac{-z}{f} \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & \frac{-1}{f} & 0 \end{bmatrix} \begin{bmatrix} x \\ y \\ z \\ 1 \end{bmatrix}$$

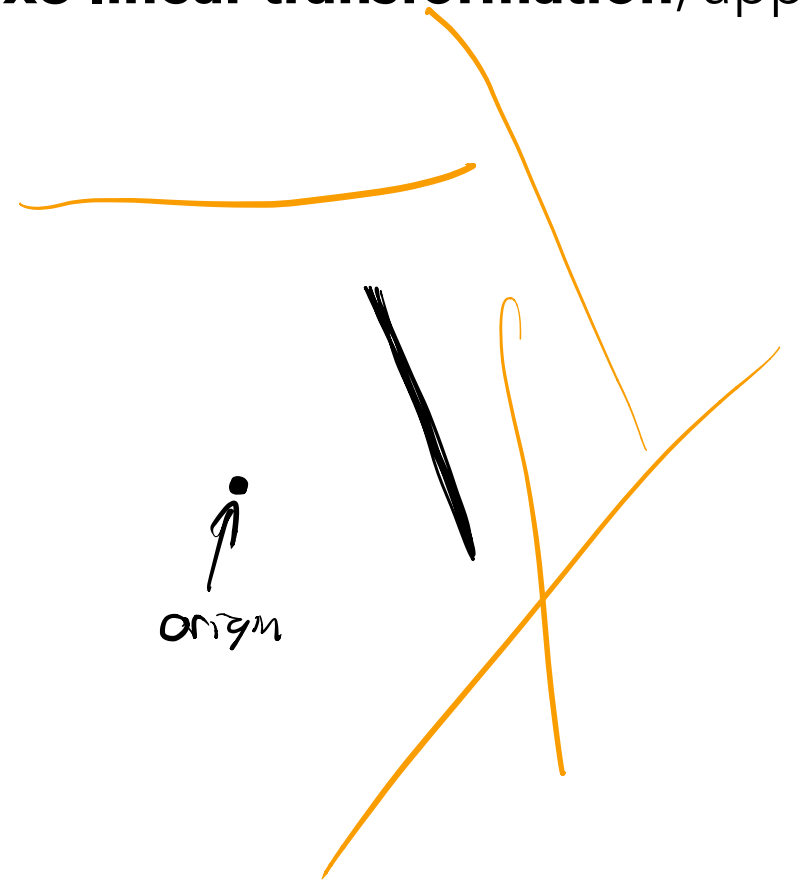
no division!

weirdness all in w

Pinhole Projection Matrix

Reinterpreting Homographies

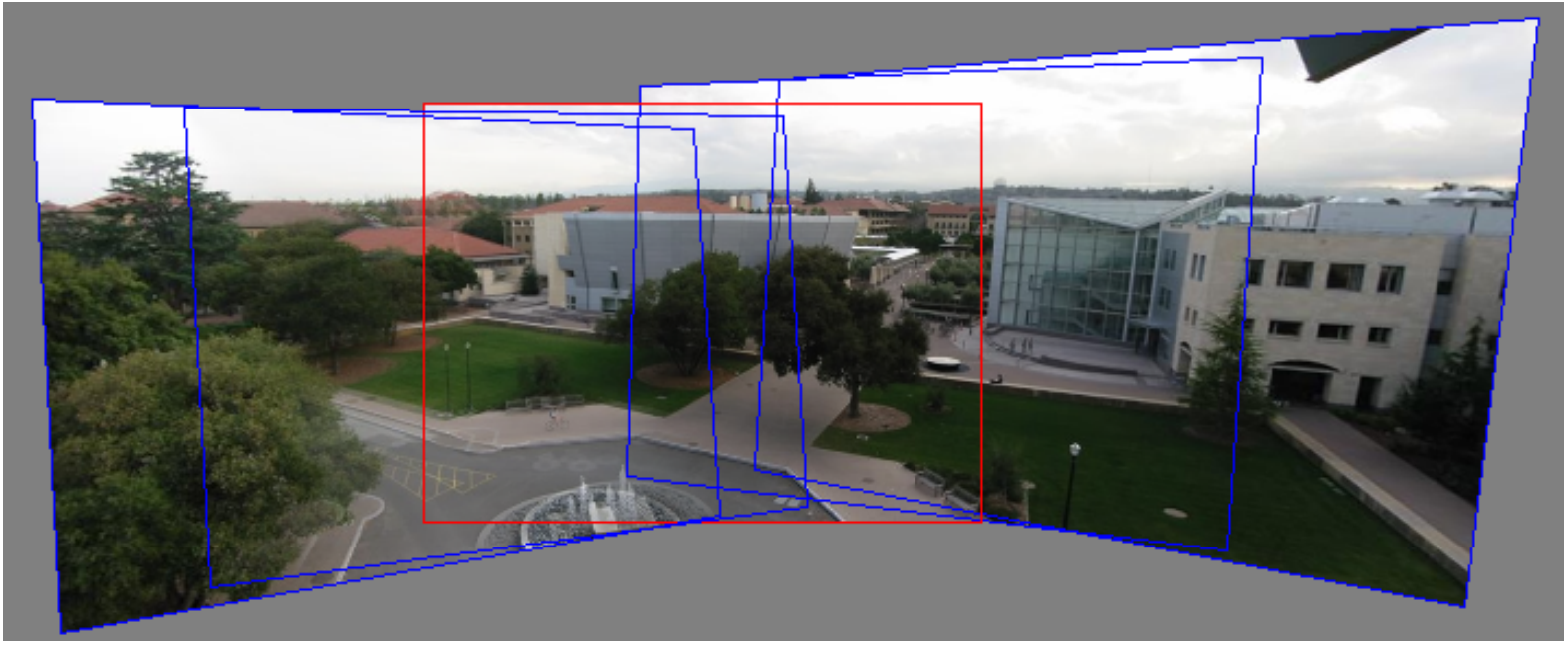
A **3x3 linear transformation**, applied to a projection **plane**.



Reinterpreting Homography-aligned Panoramas

- Several image planes are warped (projected) onto a common image plane.

I'll ask it again:
Can we make 360 panoramas?



Planar Panoramas

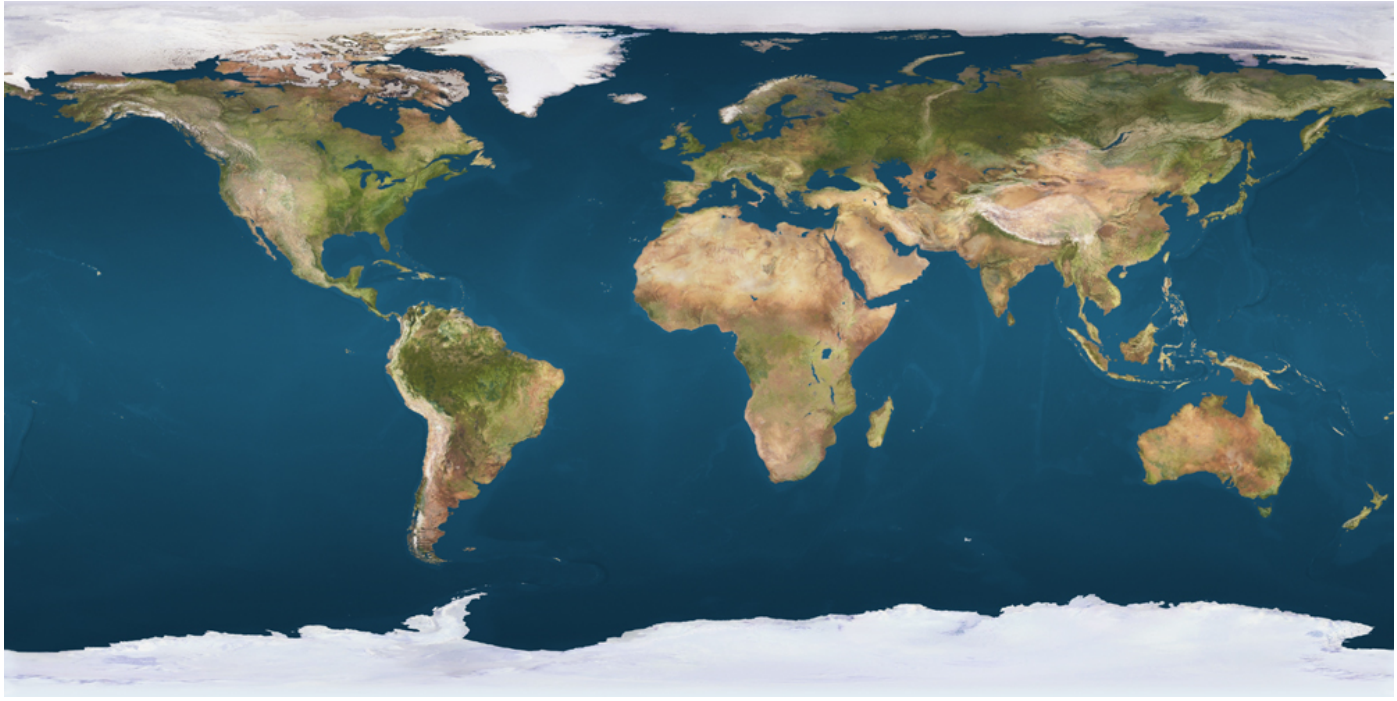
We can't make 360 panoramas with homographies.

Spherical Panoramas

Idea: project images onto a **sphere** instead of a plane.

Example: Google Street View

Unwrapping a Sphere



Spherical Panoramas

What motion model should we use?

Spherical Panoramas

1. Warp planar images onto the surface of a sphere

2. Align with **translational** (!) motion model.

3. Stitch and blend as usual.