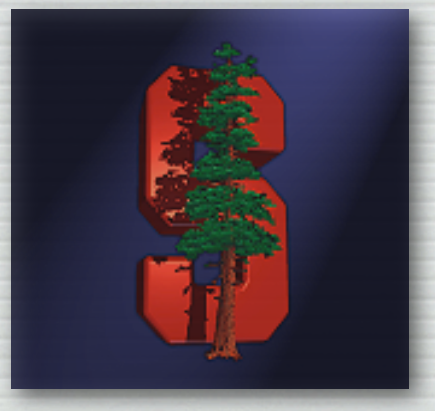
Panoramas

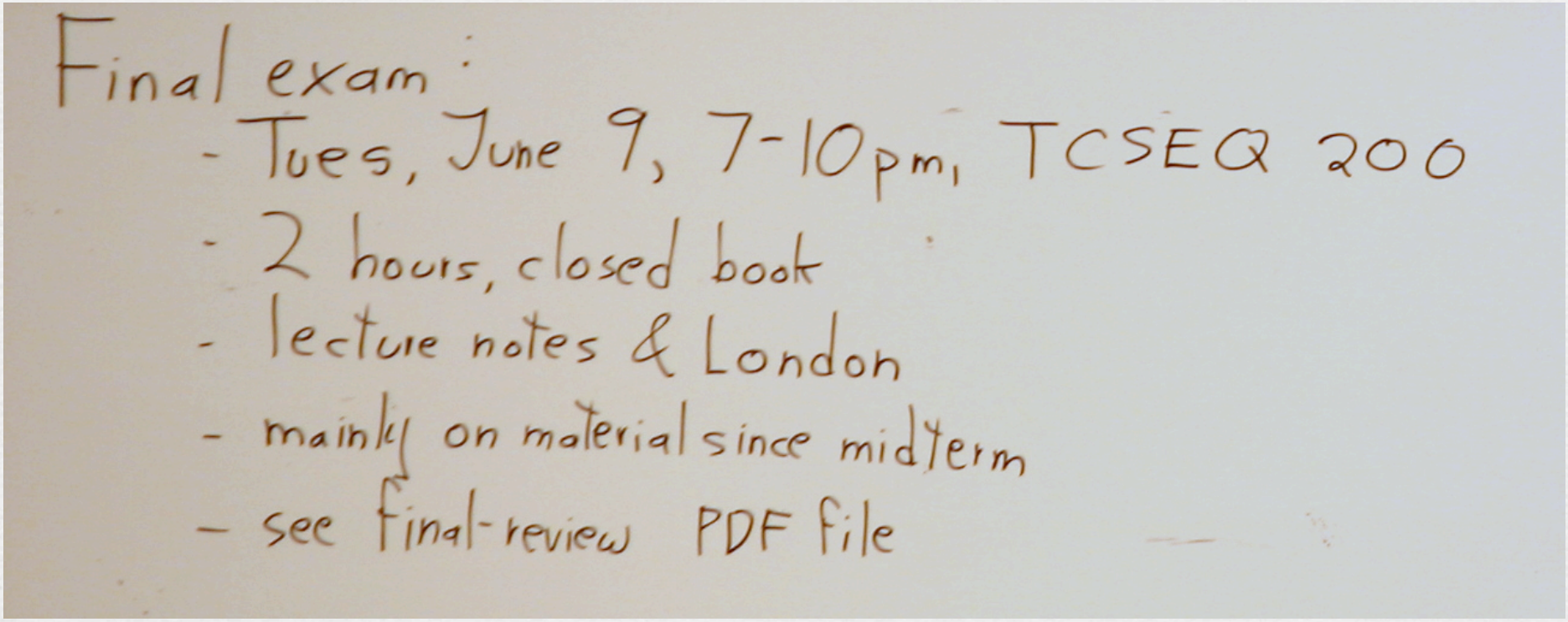
CS 178, Spring 2009



Marc Levoy
Computer Science Department
Stanford University

Announcements

- from whiteboard



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What is a panorama?

- a wider-angle image than a normal camera can capture
- any image stitched from overlapping photographs
- a cropping aspect ratio on a normal shot

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Outline

- capturing panoramas
- stitching together a panorama
- perspective versus cylindrical projection

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Panoramic cameras

flatback panoramic camera

swing-lens panoramic camera

SLR on panning clamp

motorized pan-tilt head

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Operation of swing-lens camera

- lens rotates, film is curved (blue curve at bottom), and a slit (located near the film plane?) rotates with the lens, producing a cylindrical projection of the world
  - straight lines don't remain straight in this projection
  - the in-focus surface is curved (red curve at top), unlike the (nearly) flat field of a normal photograph

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Swing-lens panoramic images

San Francisco in ruins, 1906

101 Ranch, Oklahoma, circa 1920

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Panoramic cameras

flatback panoramic camera

swing-lens panoramic camera

SLR on panning clamp

motorized pan-tilt head

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Lee Frost, Val D'Orcia, Tuscany, Italy

Lee Frost, Volubilis, Morocco

Lee Frost,
Vertical Panoramas,
Santorini

Matthew Scott, Cuernos del Paine, Chile

Stitching images together to make a mosaic

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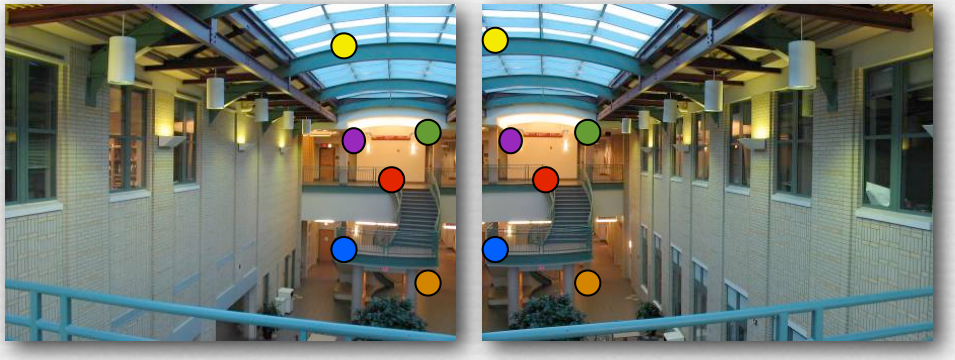
Stitching images together to make a mosaic



- given a set of images that should stitch together
  - by rotating the camera around its center of perspective
- step 1: find corresponding features in a pair of image
- step 2: compute transformation from 2nd to 1st image
- step 3: warp 2nd image so it overlays 1st image
- step 4: blend images where they overlap one another
- repeat for 3rd image and mosaic of first two, etc.

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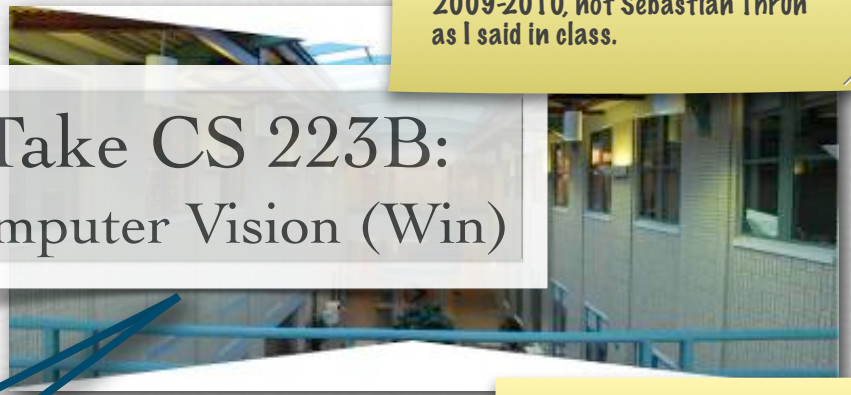
Stitching images together to make a mosaic



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Take CS 223B:
Computer Vision (Win)

May be taught by Fei-Fei Li in 2009-2010, not Sebastian Thrun as I said in class.

Take CS 448F:
Image Processing for Photography and Vision (Aut)

Will be taught by our own Andrew Adams.

Also CS 448A:
Computational Photography (Win)

I'll be teaching this course, possibly with help from Prof. Fredo Durand of MIT.

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What kind of transformation do we need?

translation?

rotation?

perspective!

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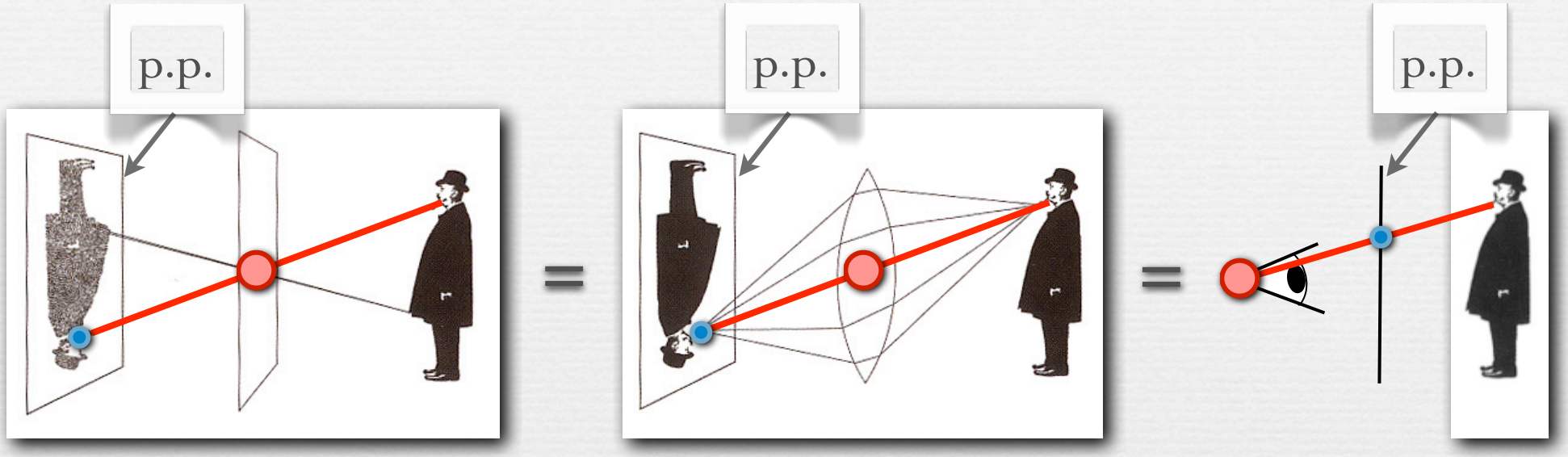
Quick review of perspective projection



pinhole camera = photographic camera = Albrecht Dürer's drawing glass

= center of perspective (c.p.)

= projection of feature in scene onto picture plane (p.p)

- these three image formation methods will produce the same perspective view on the p.p. (except for the size of the view)
  - all that matters is position of c.p. and orientation of p.p.

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Reprojecting an image onto a different picture plane

the sidewalk art of Julian Beever

- the view on any picture plane can be projected onto any other plane in 3D without changing its appearance as seen from the center of projection

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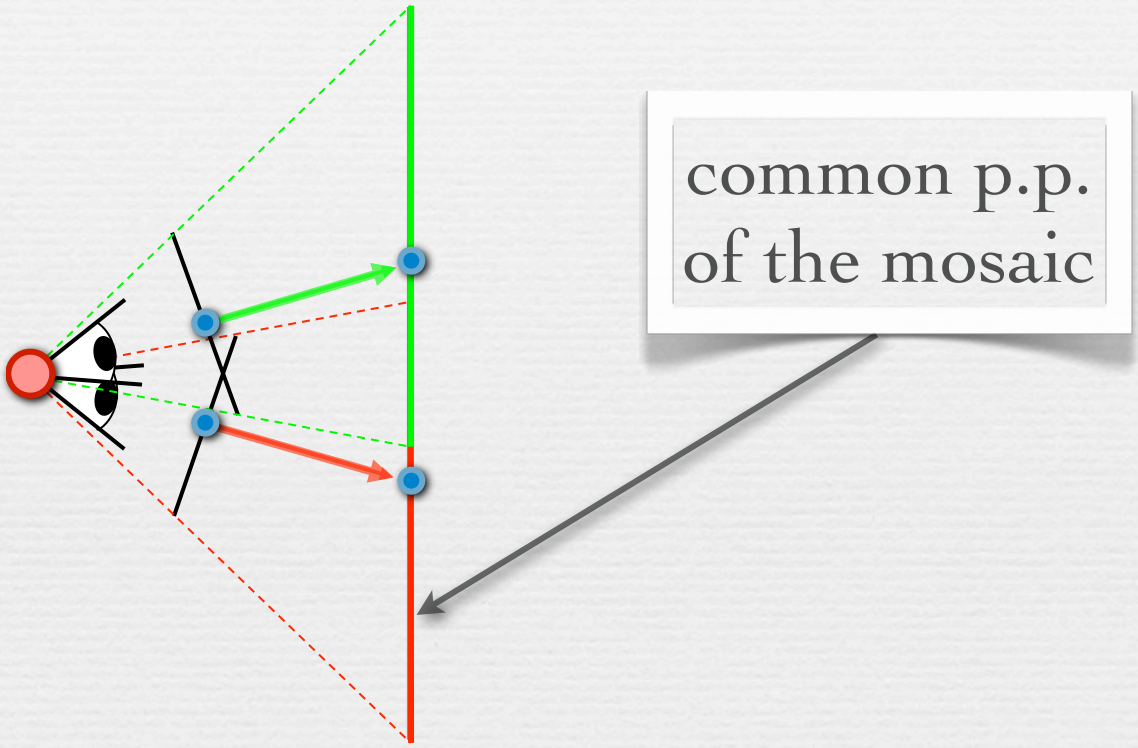
Reprojecting panoramic images to a common picture plane



- the common picture plane of the mosaic replaces having had a wide-angle (non-fish-eye) camera in the first place

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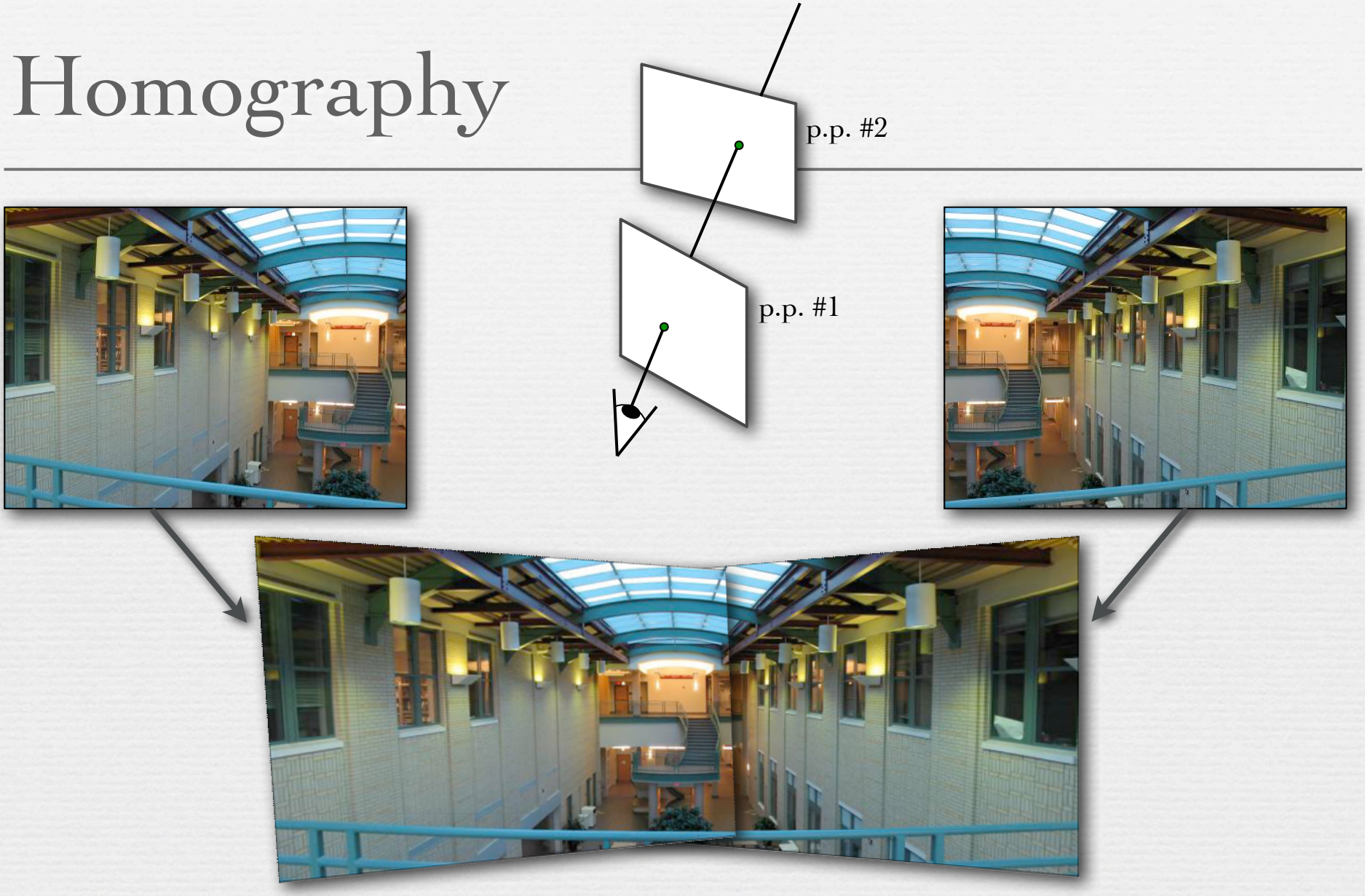
Homography



- perspective mapping between two p.p.'s using the same center of projection is called a *homography*

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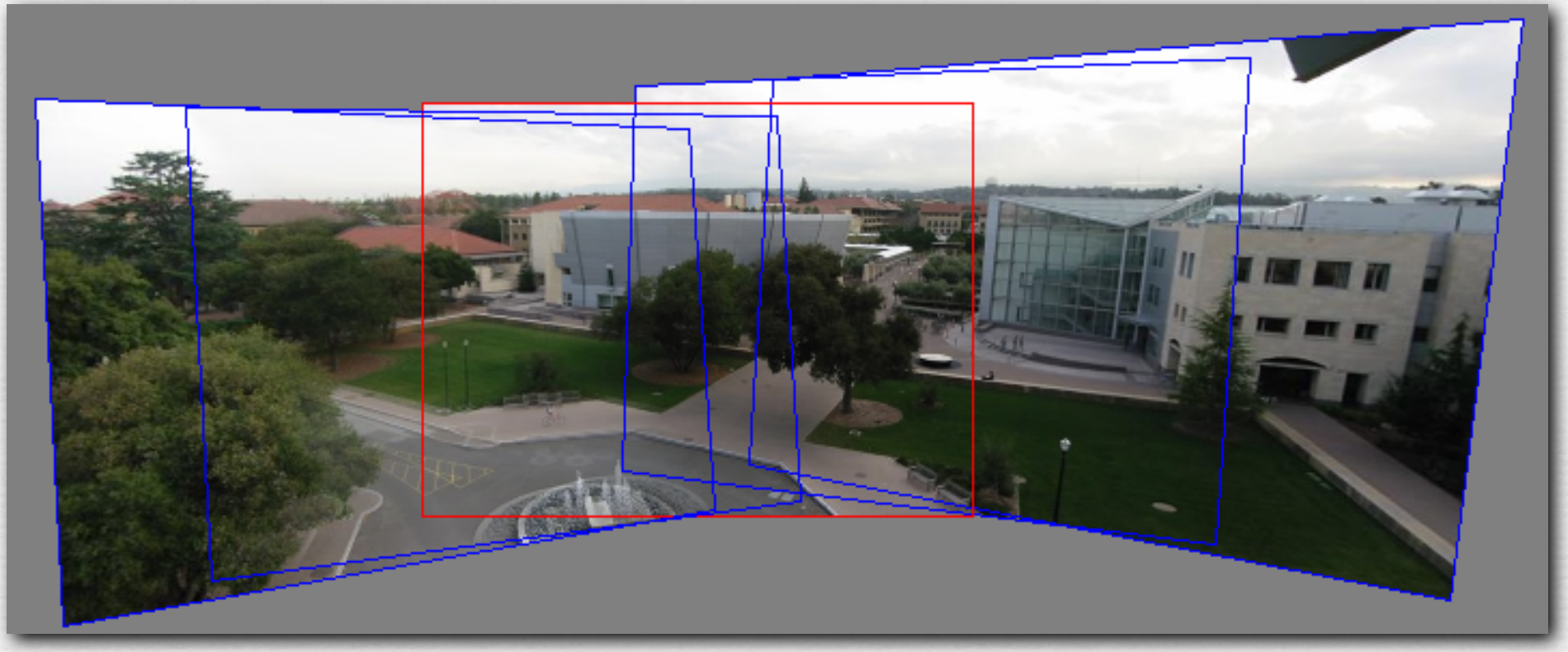
Summary of perspective stitching



- pick one image, typically the central view (red outline)
- warp the others to its plane
- blend

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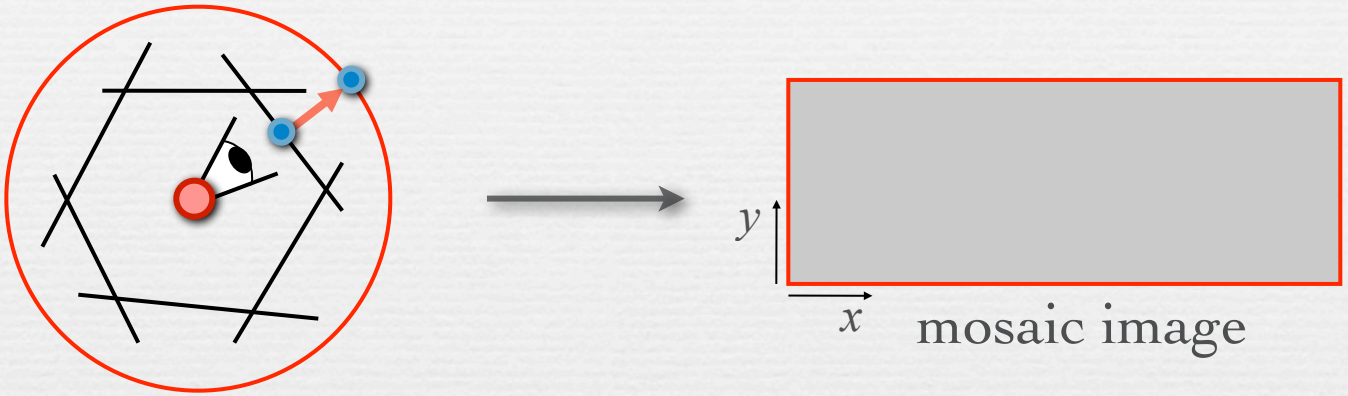
Cylindrical panoramas

- What if you want a 360° panorama?



- project each image onto a cylinder
- a cylindrical image is a rectangular array

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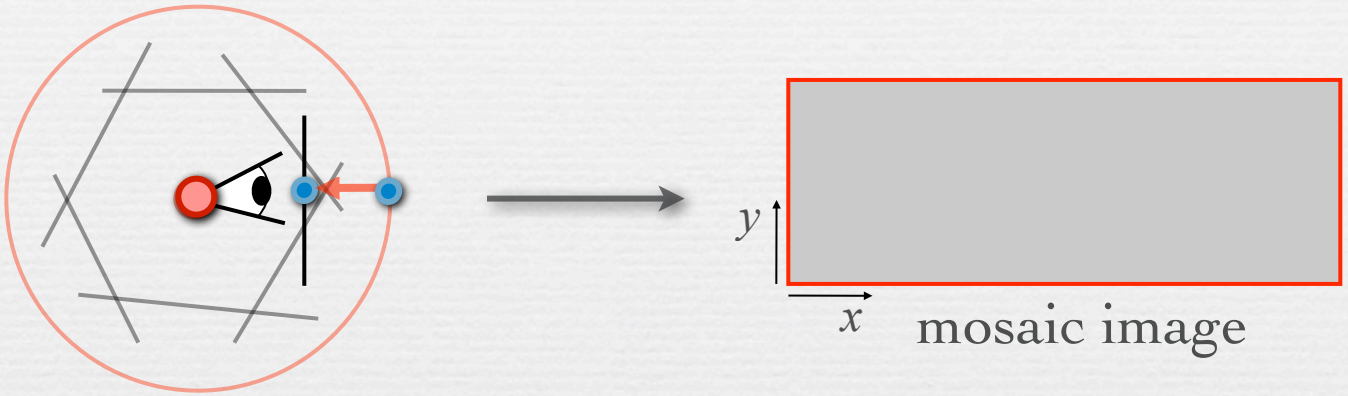
Cylindrical panoramas

- What if you want a 360° panorama?



- project each image onto a cylinder
- a cylindrical image is a rectangular array
- to view without distortion, reproject a portion of the cylinder onto a picture plane representing the display screen

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Example

common picture plane of mosaic image

perspective reprojection

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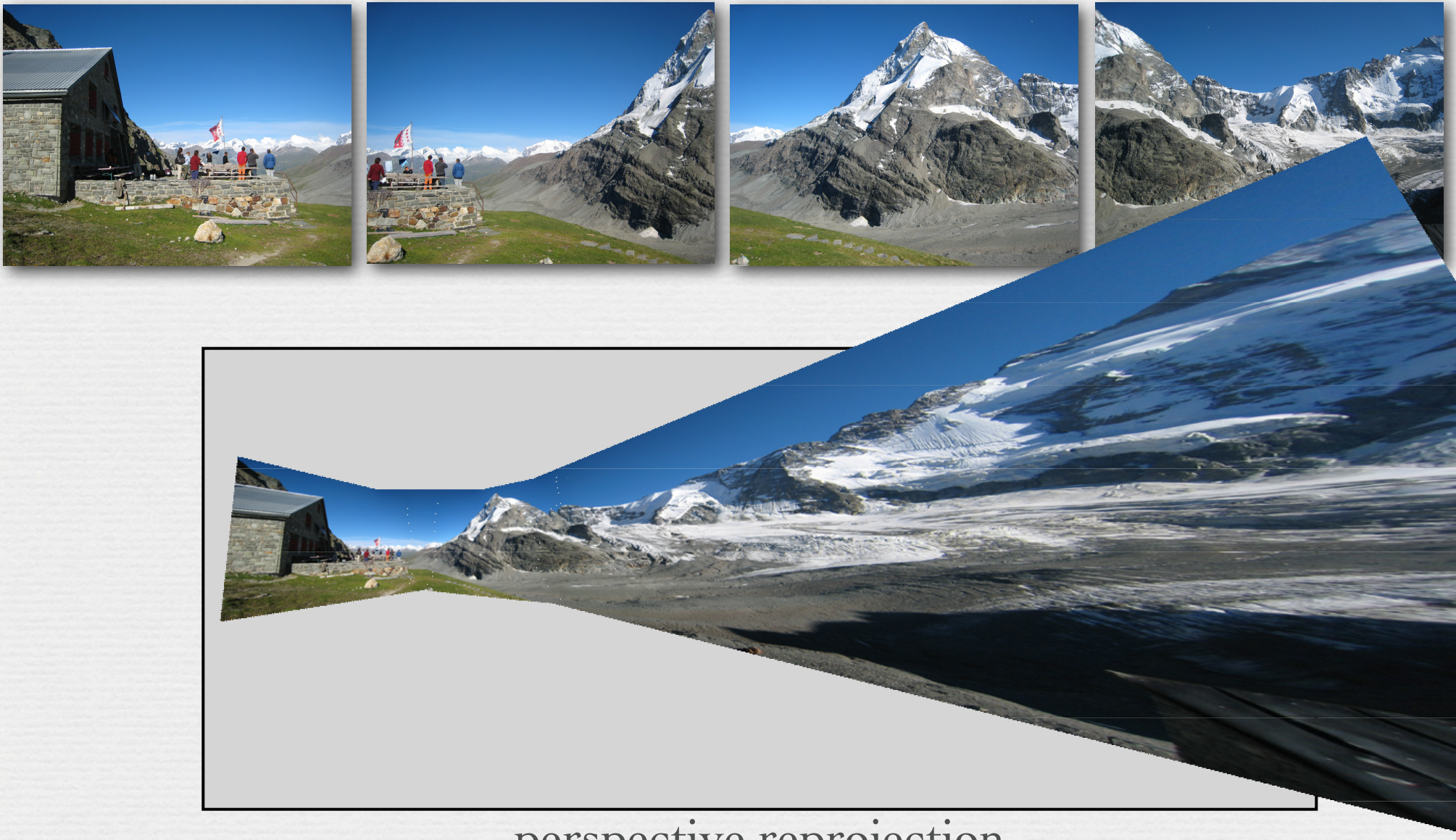
Using 4 shots instead of 3



perspective reprojection

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Back to 3 shots

surface of cylinder

cylindrical reprojection

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Back to 3 shots

surface of cylinder

cylindrical reprojection

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Back to 3 shots

perspective reprojection

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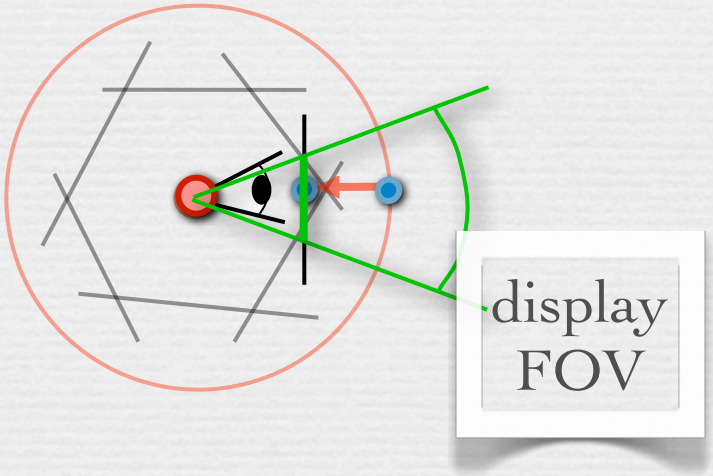
2nd reprojection to a plane for display



- imagine photographing the inside of a cylinder that is wallpapered with this panorama
  - if your FOV is narrow, your photo won't be too distorted

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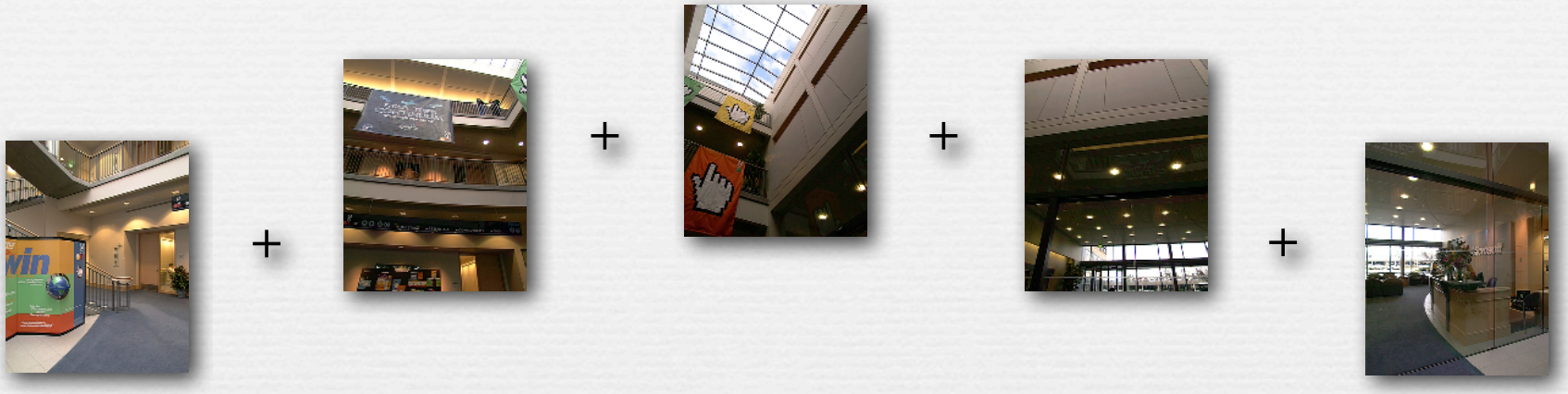
Spherical panoramas



- 1st reprojection is to a sphere instead of a cylinder
- can't store as rectangular array without distortion

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Slide credits

- Fredo Durand
- Alyosha Efros
- Steve Seitz
- Rick Szeliski

- Frost, Lee, *Panoramic Photography,* F+W Publications, 2005.

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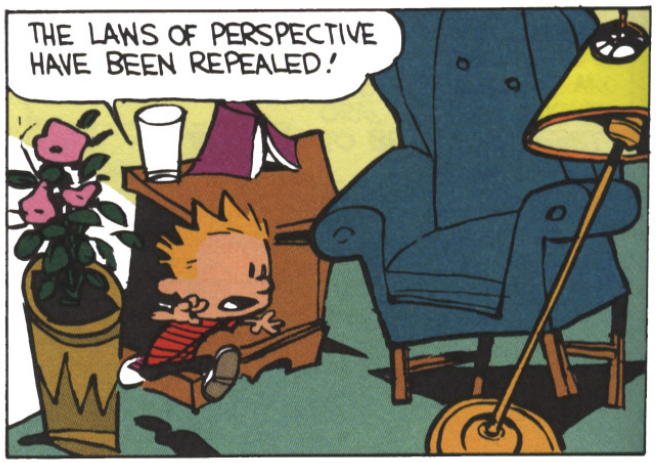
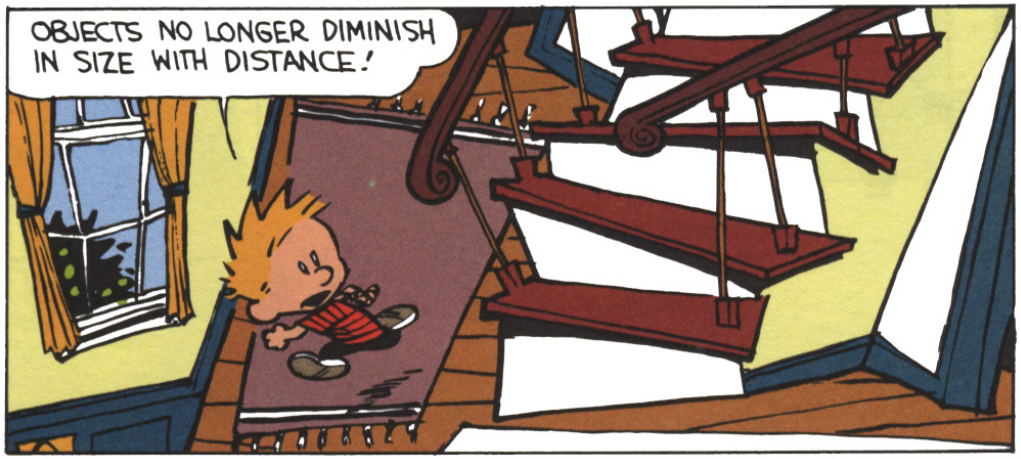
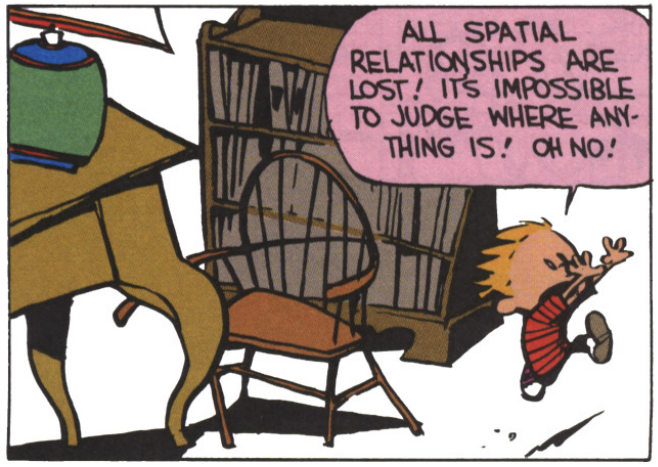
calvin and hobbes

by WATTERSON